Airbus Sees Greener Future in Hydrogen

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What Led to USAF's NGAD Demonstrator

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September 28-October 11, 2020 · Volume 182 · Number 19




**16** | *Airbus presented three hydrogen-powered aircraft concepts on Sept. 21: a turbofan, a turboprop and a blended wing body. The manufacturer aims to turn at least one of them into a real aircraft program by 2035.*

AIRBUS CONCEPT

## DEPARTMENTS



## FEATURES



## ON THE COVER

*Seeing—and hearing—is believing when it comes to the emerging world of eVTOLs and the claims of its many early developers. Senior Editor Guy Norris got to do both when secretive Joby Aviation gave Aviation Week unprecedented access to review the technology behind its advanced air mobility concept and an update on progress toward certification as an electric-powered air taxi. His report begins on page 30. Joby Aviation photo.*

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# FEEDBACK

## FAIR PAYMENT TERMS

Kevin Michaels' "Rebooting Boeing" *(July 27-Aug. 16, p. 10)* highlights the lows to which Boeing directors sank the company, not to mention this year's stock buyback and the $62 million award to their former CEO, Dennis Muilenburg, under whose leadership the 737 MAX debacle took place.

Many professionals belong to organizations with a code of conduct, which stipulates that members adhere to respect for others and honesty. Federal Acquisition Regulation 52.232-25 and the Prompt Payment Act guide timely payment of employees to include subcontractors. We need to hold Boeing directors to the same payment terms they impose on their subcontractors. To characterize their egregious financial practices only as "financial engineering" is a disservice to America.

Thank you for your excellent reporting.

*JP Villedrouin, Reston, Virginia*

## BALANCED APPROACH

While I agree with Vaughn Askue's letter *(Aug. 31-Sept. 13, p. 6)* that a "direct law" button in the cockpit is an idea worth a trial, I vividly remember the difficulties teaching, checking and getting compliance in digital flight guidance system (DFGS) use when Pacific Southwest Airlines (PSA) was transitioning from Boeing 727s to MD-80s. I was PSA director of flight operations at LAX at the time. Complicating the process was the change from a three-man to a two-man crew.

We found it necessary to demand that much line flying be accomplished with the DFGS. There was considerable resistance to these "new" procedures, partly because many had difficulty transitioning to mostly automated flying and partly because of pilot egos: "I can certainly fly the aircraft better than that auto flight guidance system." Of course, at the end of a 14-hr. duty period, operating in heavy weather conditions, can one really? With one fewer crewmember, a coupled approach to minimums was deemed far safer. Did we expect that one could still safely fly a manual approach under those same conditions? Of course!

Safety concerns today have been reversed; too few pilots are real aviators any longer. It is extraordinarily clear that there needs to be a balanced approach to safe piloting. I can just hear flight-standards people demanding fixed amounts of "hand-flying" to offset the updated automated cockpits.

Truly, one needs pilots with the judgment AND flying skills, so that each individual knows himself well enough to make the best auto/manual flying decision.

The "direct law" button is a great idea as long as the aviator can fly the aircraft manually when "direct law" is activated!

*Roger D. Crim, San Diego*

## SHELL GAME

With regard to Steve Grundman's viewpoint "Can the Pentagon Spend More Smartly" *(Aug. 31-Sept. 13, p. 58)*, the underlying issue is not whether the Pentagon can develop the requisite "strategic focus" in order to increase the productivity of our nation's defense dollars—the issue is much deeper, darker and more malignant.

For example, on July 26, 2016, the Office of the Inspector General issued a report indicating that for fiscal 2015, the Army failed to provide adequate support for $6.5 trillion in journal voucher budget adjustments. Given that the entire Army budget in 2015 was $120 billion, unsupported adjustments were 54 times the level of spending authorized by Congress. Additionally, the Army's Fund Balance increased by $794 billion—an adjustment representing more than six times appropriated spending.

Reports like this point to a very clear and present danger to American taxpayers: the failure to comply with basic Constitutional and legislative requirements for spending and disclosure.

In addition, the Pentagon is quietly asking Congress to rescind the requirement to produce an unclassified version of the Future Years Defense Program (FYDP) database. Preparation of the unclassified FYDP, which provides estimates of defense spending for the next five years, has been required by law since 1989 and has become an integral part of the defense budget process.

Our military budgeting and funding practices, which are more akin to an elaborate shell game, have been finely honed over the past 70 years. What's been created is an absolute masterpiece of public deception and fiscal unaccountability. Under the ineffectual watch of a paralyzed Congress, our nation tears itself apart fighting over racial equality, quality of life, health care and climate change—all while vast fortunes materialize and vanish from one budgetary line item to another.

*John J. Curcio, Eastchester, New York*

## CORRECTION

"Fiddling While Rome Burns" *(Sept. 14-17, p. 5)* should have identified Rep. Michael Turner as ranking member of the House Armed Services Committee strategic forces subcommittee.

## BEHIND THE SCENES

Senior Editor **Guy Norris** flew to two California locations to report on Joby Aviation's eVTOL air taxi project (see page 30). The first attempt to visit the company's flight-test facility was thwarted by ferocious wildfires; the resulting smoke caused these apocalyptic-looking skies over the Bay Area. This photo was captured on Sept. 9 in the early afternoon.

GUY NORRIS/AW&ST

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.

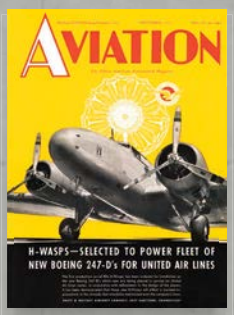
1918


1959


1982


# 104 YEARS
# COUNTLESS MILESTONES

1934




1967


1995


2019


1944


1968


2007


2020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BOEING

# WHO'S WHERE

**Ed Dandridge** has been named *Boeing* senior vice president and chief communications officer. Dandridge succeeds Greg Smith, who served as interim chief communications officer since July in addition to his role as executive vice president of enterprise operations and chief financial officer. Dandridge joins Boeing from AIG, where he was global chief marketing and communications officer, AIG General Insurance, since April 2018. He previously held executive roles at Marsh & McLennan Cos., Nielsen and the ABC television network.

*Singapore Technologies Engineering* has promoted **Jeffrey Lam** to president of the aerospace sector from deputy president. He succeeds **Lim Serh Ghee**, who becomes chief operating officer, a new position that will include some functions previously overseen by Chief Corporate Officer Eleana Tan, who will retire.

**Walid Abukhaled** has been appointed CEO of *Saudi Arabian Military Industries*. Abukhaled was CEO for the Middle East at Northrop Grumman, deputy minister of industrial affairs at the Saudi Ministry of Commerce and Industry, president and CEO of General Electric in Saudi Arabia and Bahrain, and held executive positions at BAE Systems.

*Onboard Systems*, a helicopter cargo hook equipment provider, has hired **Cory VanBuskirk** as president. VanBuskirk was with Collins Aerospace, where he served as general manager of the Goodrich Hoist and Winch division. He succeeds Jason Lemmon, who will retire but remain as an advisor and board member.

*Leidos* has appointed U.S. Army Lt. Gen. (ret.) **Darrell K. Williams** vice president of defense group logistics. Williams was director of the Defense Logistics Agency, overseeing the National Defense Stockpile and a global workforce of more than 25,000 military personnel and civilians.

*Sanad Group* has appointed **Troy Lambeth** group CEO, in addition to his role as CEO of Sanad Capital, an aviation leasing entity for spare engines and aircraft components, and **Mansoor Janahi** deputy group CEO in addition to his roles as CEO of the Sanad Aerotech and Sanad Powertech engine maintenance, repair and overhaul divisions. Sanad is a wholly owned subsidiary of Mubadala Investment Co.

*Embraer Commercial Aviation* has promoted **Martyn Holmes** to chief commercial officer from vice president for Europe, Russia and Central Asia. Embraer regional sales teams were restructured to combine the European sales function with those for the Middle East and Africa after the scrubbed takeover by Boeing.



## HONORS AND ELECTIONS

Women in Defense, a subsidiary nonprofit organization under the National Defense Industrial Association, Greater Los Angeles Chapter, has named its *Service to the Flag Award* winners for 2020: in the Government category, U.S. Air Force Maj. Gen. **Donna Shipton**, director of strategic plans, programs, requirements and analyses at Air Force Materiel Command headquarters; in the Industry category, **Joanna Speed**, managing director of aerospace and defense SpeedNews conferences for the Aviation Week Network; and in the Community category, **Antoinette Balta**, executive director and co-founder of the Veterans Legal Institute.

The Aero Club of Washington is presenting the *Donald D. Engen Aero Club Trophy for Aviation Excellence 2020* to **Michael J. Quiello**, vice president of safety at United Airlines, the industry co-chair for the Aviation Safety Information Analysis and Sharing program and, from 2016 to 2020, the industry co-chair of the Commercial Aviation Safety Team.

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

# FIRST TAKE

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ATR

## COMMERCIAL AVIATION

**The purpose-built freighter** variant of the ATR 72-600 made its first flight on Sept. 16 in Toulouse, with the initial delivery to FedEx Express planned by year-end.

**An onboard hydrogen** storage and distribution demonstration in 2021 is one of the first in a series planned by Airbus as it pursues technologies to deliver a zero-emissions airliner by 2035 (page 16).

**IATA is calling for COVID-19** testing of all international passengers before departure as a key part of efforts to restart aviation during the coronavirus pandemic.

**At least 220,000 U.S. aerospace** jobs could be lost as global civil aircraft production is potentially halved in the wake of COVID-19, says the Aerospace Industries Association.

**American Airlines has issued** a tentative Boeing 737 MAX pilot training schedule, with simulator sessions starting in November and all 4,200 737 pilots to be trained by February 2021.

**The European Commission** plans to upgrade the Single European Sky regulatory framework in a bid to modernize the region's airspace management and reduce emissions up to 10%.

**MagniX will provide** the electric propulsion system for Universal Hydrogen's conversion of the de Havilland Canada Dash 8-300 regional turboprop to fuel-cell power.

**Hong Kong's air navigation** service provider will introduce Aerion's satellite-based surveillance service in its flight information region beginning in early 2021.

## DEFENSE

**Greece will purchase** six new-build Dassault Rafales and receive 12 second-hand aircraft from French Air Force stocks, aiming for first deliveries in mid-2021 (page 50).

**Austria is to buy 18 AW169M military** versions of Leonardo's light-intermediate twin-turbine helicopter to replace its fleet of 1960s-era Aerospatiale Alouette IIIs.

**Hungary is the first country** to commit to the Multinational Air Transport Unit being established by Germany to better use its 50 Airbus A400M airlifters.

**A full-scale flight demonstrator** for the U.S. Air Force's Next-Generation Air Dominance program has flown in secret and "broken records," the service says (page 46).

**A U.S. Air Force Boeing C-17** airdropped a palletized Joint Air-to-Surface Standoff Missile in August as a prelude to a future test of a C-17-fired palletized missile.

**Lockheed Martin's Skunk Works** is developing a UAV called Speed Racer to validate that a digital engineering process called StarDrive can produce sophisticated aircraft faster and more cheaply.

**The U.S. Army has conducted** the first flight of a Boeing CH-47 Chinook fitted with the GE Aviation T408 engine, the turboshaft that powers the Sikorsky CH-53K.

## VIEW FROM WASHINGTON

# Weighing in on the 737 MAX

Many of the substantive comments on the FAA's draft requirements for getting the Boeing 737 MAX back in the air focused not on the revamped flight control computer software unique to the model, but rather on broader pilot workload issues.

Boeing—prodded by regulators for more than 18 months—says it has revamped the Maneuvering Characteristics Augmentation System control law implicated in two fatal accidents that led to the model's March 2019 grounding. But the deep dive into the MAX's certification uncovered more widespread problems, such as whether pilots are sufficiently prepared to manage emergencies (page 20).

Pilots for American Airlines are concerned that the shift away from so-called "memory items" to quick reference cards should not apply to two procedures that could happen close to the ground—runaway stabilizer and airspeed unreliable.

The American pilots are among several groups that want more focus on a manual process used to move the 737 horizontal stabilizer, or trim the airplane, in an emergency. Certain flight conditions can place aerodynamic forces on the stabilizer that make it very difficult for pilots to move the manually linked, cockpit-mounted wheel. Analysis following the MAX accidents revealed this was not well understood by pilots, Boeing or even regulators.

"The manual wheel trim forces were certified by analysis and not by flight testing," the United Arab Emirates General Civil Aviation Authority tells the FAA in comments addressing the draft requirements. "Heaviness on the manual wheel trim following a failure, like runaway stabilizer, must be fully understood and experienced by crew during training and test."

The FAA plans to review the comments and could incorporate suggestions into revamped MAX training currently being reviewed.

# FIRST TAKE

## TECHNOLOGY

**Turkey's Baykar Makina** has flown its Cezeri single-seat electric vertical-take-off-and-landing vehicle, with untethered flights conducted on Sept. 14 and 15.

**With backing from KLM and Airbus,** the Delta Technical University in the Netherlands has flown a subscale model of its Flying-V concept for an ultra-efficient airliner.

IAI

**Israel Aerospace Industries** claimed the world's first landing of a UAV at a major airport on Sept. 16, with its Heron flying into Tel Aviv's Ben Gurion International Airport alongside commercial flights.

**Walmart has launched three** different drone delivery trials, with Flytrex in North Carolina, Zipline in Arkansas, and in Nevada with DroneUp transporting COVID-19 test kits to homes.

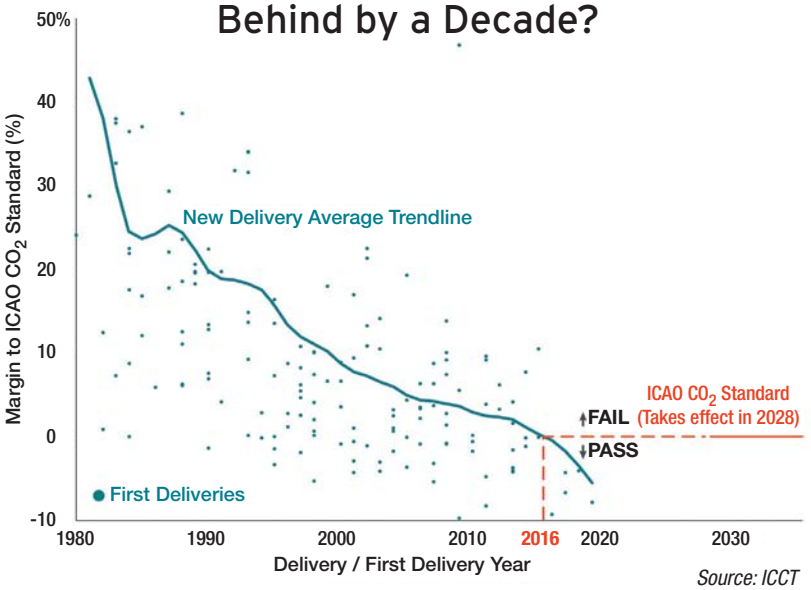
## SPACE

**Development of the** Mitsubishi Heavy Industries H3 launch vehicle has slipped at least three months, following discovery of faults in the LE-9 main engine.

**Germany's OHB has won a** €129.4 million ($151 million) contract for the Hera probe, for launch in 2024 as the European Space Agency's contribution to an international asteroid deflection effort.

**The first flight by small-satellite** launch startup Astra ended prematurely on Sept. 11 when its Rocket 3.1 booster started to head off course due to a guidance system problem.

## ICAO's $CO_2$ Standard Behind by a Decade?




*Source: ICCT*

The International Civil Aviation Organization's (ICAO) $CO_2$ standard does not take full effect until 2028, but all aircraft delivered since it was first agreed to in 2016 already beat the benchmark by a growing margin, shows a study by the International Council on Clean Transportation (ICCT). The environmental group is urging ICAO to review and tighten the measure "as quickly as possible."

## 60 YEARS AGO IN AVIATION WEEK

**The early days of the commercial jet age** are remembered nostalgically for well-dressed travelers, spacious seats, strong cocktails and meals served on chinaware. But the travel experience off the airplane was anything but glamorous, according to an editorial in our Oct. 3, 1960, edition. "London Airport and Idlewild [later JFK International] are apparently still vying to see who can maintain a woodshed terminal for transatlantic passengers for the longest, with even an experienced commuter now unable to distinguish which transatlantic terminal is the least fit for human habitation," wrote Editor-in-Chief Robert Hotz after an international swing through five countries. He lamented chronic ticket counter bottlenecks, poor baggage tagging, a lack of porters and laborious ticketing procedures that "still haven't progressed much beyond the goose quill pen." There was one bright spot. "The air terminal bars all worked well," he reported. "And this is indeed a blessing, because after being ground through the airline passenger handling system medication is urgently required." Hotz retired in 1979 and died in 2006. One imagines he would be pleased that passengers can now board planes using their mobile phones.


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

**Finland-based Iceye** has closed an $87 million financing round to complete its planned 18-satellite constellation of synthetic aperture radar microsatellites.

**NASA estimates it will cost** $27.9 billion over the next five years to complete the first phase of its Artemis program, culminating with a 2024 Moon landing.

**The European Space Agency** has awarded a €300 million contract to Airbus for development of the Copernicus polar ice and snow topography (Cristal) mission.

UP FRONT

# BYRON CALLAN

# What's in a Cut?

## A defense budget reduction can have **vastly different meanings**

**FORMER VICE PRESIDENT AND** Democratic presidential candidate Joe Biden commented in a Sept. 10 *Stars and Stripes* interview that he does "not see major reductions in the U.S. defense budget" if he is elected this November. In certain areas, spending "is going to have to be increased," he said, citing unmanned, cyber and IT.

This sounds positive and could be greeted favorably by analysts, planners and contractor managements. However, it raises a time-honored question in Washington: What exactly does a "reduction" or cut mean?

Government and elected officials are not always clear about what the cut is from, and analysts and media do not often attempt to pin down the parameters of a cut.

Let's start with a positive: It would appear to dash some views expressed this summer that a Biden administration would lead to annual defense spending dropping to $600-550 billion by the end of its first term, although some may still hold that belief because of partisan views. A cut of this magnitude would certainly be "major," and the percentage decline from fiscal 2021 would amount to a three-year decrease like that seen only in the aftermath of the Korean War.

ROBERT ALEXANDER/GETTY IMAGES

It is worth reiterating that Trump administration plans show relatively tepid defense spending growth, far below the 3-5% inflation-adjusted annual spending growth senior Pentagon leadership has testified is necessary to resource the National Defense Strategy.

The Trump administration's discretionary defense budget request and plan made public last February showed a defense request of $741 billion in discretionary budget authority for fiscal 2021, rising to $808 billion by 2025 and flatlining thereafter at $808 billion annually through 2030. The fiscal 2021 figure is likely to change, depending on what Congress could pass to reimburse contractors for pandemic-related expenses that the CARES Act deemed would be paid by the Pentagon.

But the question remains: Reduction from what? The word "reduction"—or, for simplicity's sake, "cut"—raises two obvious questions: A cut from what level? And is spending in inflation-adjusted or current dollars?

Did Biden's statement mean that there would not be a cut from the $741 billion defense discretionary budget authority that the Trump administration requested for fiscal 2021? That would imply flat spending in fiscal 2022-26 in current dollars.

The impact of that approach, if realized, would be quite substantial. There would be no reduction, true, but there would be a cumulative decrease from fiscal 2022 to 2026 of $221 billion from the Pentagon plan.

Military personnel has been difficult to reduce. Even with improvements in how the Pentagon uses resources, it is extremely unlikely that $221 billion in internal cost savings could be found over this time period. Readiness is likely to remain a paramount concern. So that leaves the Pentagon's procurement and research development test and evaluation accounts as most vulnerable.

Inflation is the other fact of life that can confuse how cuts are characterized. Consensus is that inflation could be approximately 2% annually, meaning spending would have to increase at that rate each year just to maintain the Pentagon's purchasing power. A budget with no reduction from $741 billion would entail an even steeper cut of $221 billion from Trump administration plans, factoring in inflation.

Biden could also mean that there will not be a cut in the plan that was revealed in February of this year. It entails Pentagon spending growth of 2% in current dollars for fiscal 2022-25, which, if inflation is about 2% annually, entails no real growth. If inflation proves higher, and the budget plan is held constant, that will result in reduced purchasing power.

If there is no reduction from the Trump plan, however, and spending is redirected to higher-priority growth areas, where would cuts fall? Base closings and retirement of older weapons platforms have been "third-rail" issues for Congress.

Finally, there could be minor changes from the tepid trajectory the administration has set forth for fiscal 2022-30. A Biden administration could still present a budget that grows in current dollars, but that would be a reduction from the Trump administration's plan. Maybe the $221 billion wedge would be cut in half from 2022 to 2026. But even a $110 billion reduction from the Trump plan is going to affect one of the three levers the Pentagon has to accommodate a cut: personnel, readiness or investment. The latter may be the easiest to reduce, even if there is not a "cut" to defense spending. That fact alone is going to create both risk and opportunity for defense contractors in the 2020s.

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

## GOING CONCERNS
# MICHAEL BRUNO

**ONCE UPON A TIME IN AMERICA**, the only new-build large commercial aircraft program worth tracking for potentially bringing new jobs and growth to local communities was Boeing's new midmarket airplane. Now with the NMA sidelined at best, and commercial aerospace well into what is likely its worst contraction since the dawn of the jet age, the last thing local politicians and economic boosters should look for is landing new aero manufacturing, right?

Guess again. It isn't clear yet, but we might just be entering the mother of all aero economic opportunities, especially if a bevy of emerging trends come to fruition.

## Up for Grabs

### Where to locate aero manufacturing **after COVID-19**

The instances of major aerospace manufacturing moving around the country could rise significantly, according to Scott Thompson, U.S. A&D leader at PwC. "There is a fairly high likelihood that you're going to see some physical movement in the supply chain," he tells Aviation Week.

The reasons range from the obvious to the nuanced, but they begin with pandemic-triggered production contractions in the midterm, as well as the increasing involvement of private equity investors and the coming digitally driven overhaul of A&D manufacturing processes. There is also potential reshoring as supply chains become more regionalized and less globalized. Underpinning all of it is a steadfast belief among industry executives and advisors that, long-term, commercial aviation traffic and passenger numbers will surpass prepandemic levels and keep growing.

Thompson in September released PwC's 2020 aerospace manufacturing attractiveness rankings (see table), the consultancy's annual review of the best and worst places, relatively, to locate aero manufacturing operations. While the rankings represent a yearly snapshot of the jockeying among U.S. states and countries to aggregate aerospace manufacturing capacity, the latest survey comes amid the industrial fallout from the coronavirus pandemic.

"Until COVID-19 appeared, the emphasis for the past two decades had been on expansion," the report notes. "Now the emphasis should be on liquidity and derisking the supply chain while planning for a return of volume in 3-5 years." Derisking means everything from protecting the capability of financially vulnerable suppliers to potential vertical integration by larger companies or growing midtier providers, and possibly deglobalization and increased regionalization of supplier bases.

On the latter point, Duff & Phelps' site selection and incentives advisory practice released an August report of their own that identified the North American market as one potential beneficiary of regionalization. "Today, cost isn't the only significant factor influencing U.S. corporations' manufacturing footprint," Duff said. "Based on the following factors, manufacturing in the U.S. may become economically feasible for more sectors, and the U.S. may experience active and passive reshoring effects." The consultancy goes on to name aerospace products and parts as one of the eight sectors most likely to reshore to the U.S.

Regardless, any one of the above factors could trigger aerospace manufacturing relocations. The PwC rankings are based on a weighted score of category and subcategory rankings. Those include cost, economy, geopolitical risk, infrastructure, labor, industry and tax policy. Thompson—a longtime industry advisor and partner with Aviation Week on past events—says lower local costs of living and taxes will play leading roles in deciding outcomes, but so will workforce pipelines and talent pools.

Manufacturing movement may include large production-line consolidation such as the Boeing 787 from Puget Sound, Washington, to North Charleston, South Carolina—as is being studied—or Lockheed Martin's transfer last year of F-16 production from Fort Worth to Greenville, South Carolina. But Thompson says more movement will come via small and midsize enterprises in the aftermath of COVID-19.

"There's roughly 10,000 aerospace and defense suppliers; 9,900 of them are small suppliers," he notes. "Many of them have been rattled by this."

## Aerospace Attractiveness

### Top 10 Countries/Regions and U.S. States

| | |
|---|---|
| U.S. | 1 |
| SINGAPORE | 2 |
| CANADA | 3 |
| SOUTH KOREA | 4 |
| JAPAN | 5 |
| AUSTRALIA | 6 |
| UK | 7 |
| GERMANY | 8 |
| SWITZERLAND | 9 |
| HONG KONG | 10 |

| | |
|---|---|
| GEORGIA | 1 |
| OHIO | 2 |
| WASHINGTON | 3 |
| TEXAS | 4 |
| NORTH CAROLINA | 5 |
| INDIANA | 6 |
| ARIZONA | 7 |
| MICHIGAN | 8 |
| FLORIDA | 9 |
| CALIFORNIA | 10 |

*Source: PwC*

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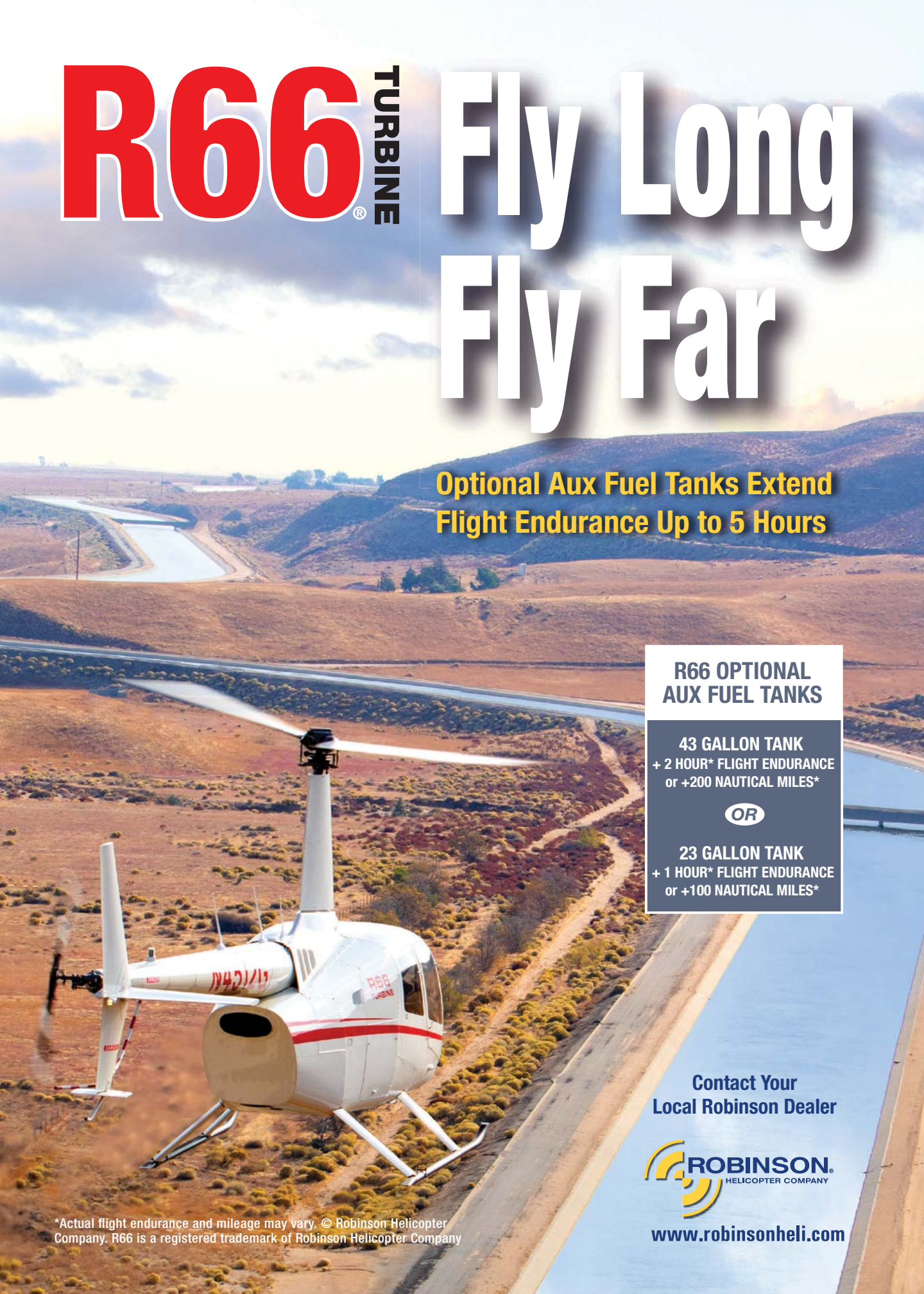

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## INSIDE BUSINESS AVIATION
# WILLIAM GARVEY

# Sleepy Little Airports

### Ready to **accommodate all**

**AS SHELL-SHOCKED AIRLINES** cut back on service, eliminating flights, personnel and destinations, as inquiries to charter operators and demands on flight departments steadily increase, and as alternate aviators—those proponents of electric, hybrid, multirotor, urban and autonomous flight—consider where to alight, the collective focus turns again and again to that underused but plentiful infrastructure asset: the general aviation airport.

Easily overlooked in the high-pressure, just-in-time machinery of massive road, air and marine transport, those municipal and county airports are at the ready to accommodate virtually all comers. And first-timers are in for some welcome surprises.

First off, getting there is likely to be more convenient than accessing a major airline-served facility, since that "sleepy little airport" is probably closer, with light road traffic—and you can park your four-wheeler within steps of the terminal. Second, once inside the fixed-base operation (FBO), there are no passenger queues, no security screens, no baggage drop-offs, since you or your pilot carry your overnighter to the aircraft.

And once you and your colleagues are ready to depart, you do just that, since you set the schedule. Oh, and there are no connecting flights involved: The one aircraft takes you from A to B and on to C, D and E, if you like. While the FBO and terminal design may differ at the destinations, the experience there is pretty much the same. And that little airport is probably closest to the person or place being visited.

The ease of travel anchored by general aviation airports is appealing, but is catering to private pilots and corporate aircraft passengers good for the public weal? Advocates contend that such facilities are indispensable and point to data supporting that position.

Why are they nearby? Because they're everywhere. According to the U.S. Transportation Department, there are some 5,100 public use airports in the U.S. accessed by general aviation versus roughly 500 (possibly now even fewer due to cutbacks) offering some airline service, however modest. For rural areas, the general aviation airport may be the only air transport access within reach, it is home to agplanes that keep us fed, and it is a key resource in times of medical or other emergencies.

Such airports also provide jobs—lots of them. A 2018 study by PwC pegged general aviation employment at 1.1 million jobs that year, all contributing to the nearly $250 billion in general aviation economic activity. And they serve as a home base for the majority of the country's 211,000 active piston and turbine aircraft.

For perspective, it can be instructive to look at a single facility. St. Mary's County Regional Airport (FAA identifier: 2W6) (see photo) in Leonardtown, Maryland, is arguably a facility for now and what's coming. Aside from being home to 200 aircraft—including two medevac helicopters—it was among a half-dozen airports selected by the FAA to support the safe integration of drones into the National Airspace System, and it helped lead to the development of the Part 107 regulations for commercial use of small, unmanned aircraft.

JAMES ALEXANDER

Located on a Chesapeake Bay peninsula 60 mi. due south of Washington and celebrating its 50th year of service, it is the only public use airport in a tri-county area—although NAS Patuxent River, home to the U.S. Navy Air Systems Command and test pilot school, is nearby. The airport has an FBO, flight school and charter operator.

According to a study conducted for Maryland's Transportation Department in 2017, the airport recorded 33,588 aircraft operations that year, supported 499 jobs, accounted for $52 million in business revenue and local purchases and delivered $6.2 million in state and local taxes.

The airport has become a high-tech center, thanks to an ongoing influx of tenant companies supporting "Pax River" activities and the University of Maryland establishing an unmanned aircraft systems (UAS) test site and education center there. The university is also adding a building focused on autonomous-systems research.

Although the county-owned airport turned a profit last year, that was an exception. Still, the commissioners clearly appreciate its economic draw. Accordingly, a construction project is underway to lengthen its single runway to 5,350 ft. from 4,150 ft. to accommodate larger business jets. In addition, Airport Manager Allison Swint says a cafe is expected to open in the terminal building in the near future, and plans call for the construction of additional box hangars.

Meanwhile, James Alexander, chairman of the airport's advisory board, notes that although absent scheduled service, 2WS "is definitely an asset, and the county sees it that way." And alternative aviators can expect a welcome. You see, the retired U.S. Air Force officer helps lead UAS research there, and whenever he can, he flies airplanes and drones out of that same not so sleepy, not so little airport.

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

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# Airbus' BIG BET

- AIRCRAFT-MAKER REVEALS THREE HYDROGEN-POWERED AIRCRAFT CONCEPTS
- SERVICE ENTRY IS TARGETED FOR 2035
- TECHNOLOGY CHOICES ARE SLATED TO BE NARROWED BY 2025
- INDUSTRIAL LAUNCH PLANNED FOR 2027-28


AIRBUS CONCEPTS


**Airbus is studying a 2,000-nm-range blended wing body, seen as the step beyond the next.**

**Jens Flottau** Frankfurt and **Thierry Dubois** Lyon

Airbus, like all aircraft manufacturers and the civil aviation industry as a whole, is under enormous political pressure to reduce its environmental impact after the sector recovers from the coronavirus pandemic. But without at least a roughly defined path toward much greater sustainability, a mandate to return to anything like precrisis levels of flying will be very hard to achieve. Add to that landscape billions in European government funds for research, and the scene is set for the next generation of commercial aircraft.

As far as the European OEM is concerned, the future is not yet electric and comprises synthetic fuels only to an extent. Rather, the future is hydrogen-powered aircraft, a concept that has not gone beyond the research stage in decades of study by aeronautical engineers. "Hydrogen is one of the most promising technologies," says Airbus CEO Guillaume Faury. "It has a lot of potential."

The renewed focus on hydrogen is not a coincidence, technologically or politically. The massive government funding in hydrogen research, both in France and Germany, is not only intended to promote a greener future for aviation but also to help keep to a minimum pandemic-related redundancies at Airbus and other aerospace companies. The French government in particular has made clear that it expects fast, concrete results: specifically, a hydrogen-powered aircraft that enters service by 2035.

And that is what Airbus plans to deliver. The company presented three concept studies Sept. 21 for liquid-hydrogen-powered aircraft. They include a regional turboprop, a narrowbody in the A320neo-family size category and a blended wing body (BWB). "A lot of investment is needed, and we have to be fast," Faury says. "But we are very convinced."

In its preliminary studies, Airbus has come to the conclusion that of the various options, liquid hydrogen combustion is the most realistic technology path to producing what it hopes will effectively be a carbon-neutral aircraft. "We don't need to invest in technologies that are completely disruptive," Faury says.

Airbus' timeline is five years, until 2025, to mature technologies and more closely define which of the three avenues it will pursue further for the 2035


**A hydrogen-powered narrowbody could seat as many as 200 passengers, but it would have a shorter range than the current A320neo family.**

aircraft. "It is fair to assume that we will start small and go up in size over time," Faury explains. But he does not rule out that the first aircraft could be a narrowbody or that the narrowbody could be developed in parallel with the turboprop—noting that Airbus worked on the A350 and A380 simultaneously.

Faury sees the formal industrial launch happening in 2027 or 2028, preceded by two years of work to set up an industrial concept, negotiate with partners and suppliers and build the business case. Airbus is allocating around seven years for the actual development phase, similar to that for conventional aircraft.

The liquid-hydrogen-powered narrowbody would likely have the most transformative effect on civil aviation, given that it would potentially replace today's narrowbodies, the most common and popular aircraft for airlines worldwide. Airbus is looking at developing a family of aircraft with 120-200 seats and a range of 2,000 nm or more. The aircraft would be somewhat smaller than the current A320neo family, which range from around 130 to more than 240 seats depending on the configuration of the A319neo, A320neo and A321neo.

The narrowbody concept is planned to be designed for a Mach 0.78 cruise speed, and its liquid hydrogen combustion would be complemented by a hybrid-electric system powered by fuel cells. A conventional tube-and-wing layout is the target, although the fuselage would be significantly longer to accommodate large hydrogen tanks in the rear.

A range of 2,000 nm, or somewhat more, is significantly shorter than that of the A320neo (3,400 nm), but it would be enough to cover all of Europe. A range well in excess of 2,000 nm would be needed for U.S. transcontinental services.

Faury is leaving open for now whether the hydrogen aircraft will be the only successor to the current A320neo family or whether another more conventional design—using synthetic fuels to reduce its environmental footprint—might complement or precede it. "Two things could be combined or could be independent in terms of timing or solution," he says.


**The turboprop would be designed to transport 100 passengers up to 1,000 nm.**

The A320neo will have been in service for almost 20 years by 2035; its first delivery came in 2016.

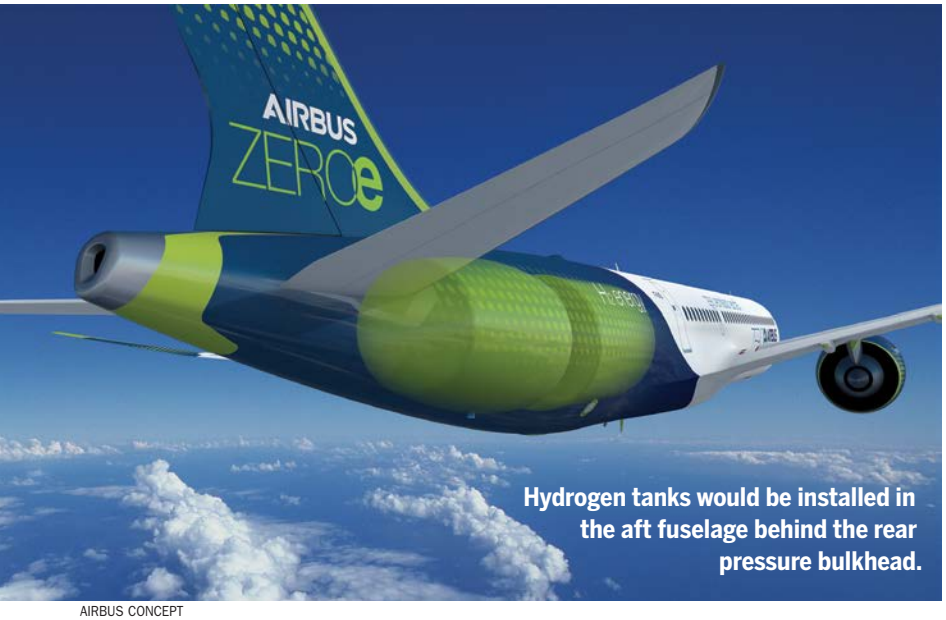
While the narrowbody could be somewhat smaller than the equivalent current in-service aircraft, the turboprop concept is the opposite: Its planned capacity of 100 seats would make it by far the largest aircraft in the segment, accommodating around 20 extra seats compared to the ATR 72 and the de Havilland Canada Dash 8-400. According to Airbus Executive Vice President Jean-Brice Dumont, the turboprop range would be 1,000 nm—the ATR 72-600 features a range of just 825 nm, while the Dash 8-400 can fly 1,100 nm.

ATR would play a central role in development of the next-generation aircraft if it is pursued and, as a consequence, so would Airbus' turboprop joint-venture partner Leonardo. The Italian aerospace group has been trying to convince Airbus for years to build a larger turboprop as a replacement for the aging ATR, so far with no success. Now the French hydrogen program could finally transform that market, too.

Universal Hydrogen, set up by former Airbus and Raytheon Technologies Chief Technology Officer Paul Eremenko, intends to retrofit hydrogen power trains to existing aircraft and plans to use a de Havilland Dash 8 as a testbed. Unlike Airbus, the start-up is using hydrogen-powered fuel cells and electric motors and, initially, gaseous—rather than liquid—hydrogen, further limiting range capabilities. Until the collapse of the planned joint venture with Boeing, Embraer had been studying a return to the turboprop market and was targeting a conventional though hybrid-capable design to enter service later this decade.

At the February 2020 Singapore Airshow, Airbus unveiled its Maveric demonstrator project, a BWB secretly in the works since 2017. A scaled model flew for the first time in June 2019. The work on Maveric is now being filtered into the hydrogen BWB work. Dumont says the concept "may be seen as the step after the next," referring to the more conventional turbofan and turboprop layouts, although "it is much more scalable than the other two concepts."

Faury concedes there are major challenges to making the new-technology aircraft a reality. Massive investment in ground infrastructure would be required to ensure that "decarbonized




Hydrogen tanks would be installed in the aft fuselage behind the rear pressure bulkhead.

AIRBUS CONCEPT

hydrogen is available at airports," he notes. Aviation will also need "a regulatory framework that is very different from today's, and we will have to have clarity in 2027 or 2028," he adds.

Accommodating liquid hydrogen tanks on the aircraft is a challenge manufacturers, including Airbus, have been studying for decades. Their size and weight differ from kerosene tanks, and storing liquid hydrogen safely is a crucial hurdle. "The level of safety has to be comparable to today's aircraft," Faury makes clear.

Airbus is expecting to gather the first results from a demonstration program for onboard hydrogen storage and distribution in 2021.

Experiments will use gaseous and liquid hydrogen on the ground and on board, Dumont says. Research and technology work will be conducted at various scales. The French and German aerospace research councils will fund the trials.

Studying storage is one of the first demonstration programs in a series planned for 2021-24. "Technology bricks" are being created so that Airbus can choose mature technologies in 2025. The overarching goal is service entry of a liquid-hydrogen-powered commercial aircraft in 2035.

In parallel, conceptual analysis will help Airbus understand how the bricks could come together in a novel aircraft architecture. The concept aircraft will be refined with design office and wind-tunnel work, Dumont says.

The use of hydrogen is deemed fundamentally safe in an aircraft. "That does not mean there is nothing to be done. . . . We are on top of it," Dumont says. "We never brought hydrogen on board. . . . We speak a lot with ArianeGroup, which uses hydrogen on board the Ariane launchers." For commercial aircraft, a hydrogen system's failure mode and effects analysis remain to be written, he adds.

Dumont also addressed concerns about the safety of hydrogen in a passenger aircraft. "You should not refer to the tragedy of the Zeppelin Hindenburg airship [in 1937]; this would be comparing apples to oranges," he says. "You should not believe it will be easy, either. . . . But I do not see anything insurmountable."

On one of its concept aircraft, Airbus has designed a "chimney" as part of a leak management system. "In case of a leak, hydrogen tends to warm up and has to be vented," Dumont says. "Such an event is very unlikely, but we have to take this possibility into account."

While fuel cells may play a role by providing some level of propulsion hybridization, Airbus is focusing on burning hydrogen in modified turbine engines. Power from fuel cells could help cover energy peaks such as on takeoff, according to Faury. That would enable Airbus to make the engines smaller and optimize them around cruise flight requirements.

Dumont sees the BWB architecture as the most promising, as it gives designers freedom in properly placing fuel and passengers. The other two concept aircraft would use a large portion of the aft fuselage to store hydrogen.

Airbus' biggest challenge may well be convincing industry partners that it is time for the jump to new propulsion technology, even if it might require limited changes to current engines. Sources in the engine industry do not share Airbus' enthusiasm, yet their participation is imperative for the project to succeed. "Hydrogen is also a potential solution but a lot more ambitious [than synthetic fuels]," Philippe Petitcolin, Safran CEO, tells Aviation Week (see page 42). "We know how to burn hydrogen; we do it in space launchers. In large quantities, it has to be liquid and therefore kept at -253C (-423F). It is not easy to burn."

Many insiders believe that hydrogen will eventually become a solution, but not within the timeframe suggested by Airbus and the French government.

Getting the timing right will be crucial, and not just in terms of technology readiness. Airbus clearly must avoid another potentially expensive, conventional development program preceding the hydrogen projects, because it does not have the financial resources for both. And such an aircraft would likely have a much shorter life span, making the business case more difficult.

Petitcolin even goes so far as to contend that incremental improvements to the engines will be sufficient until whatever new aircraft enters the market in 2035. However, if the introduction of hydrogen-powered commercial flight takes much longer, such an incremental approach may not be sustainable, given the pressure on the industry to improve its environmental performance.

Airbus also is not arguing that hydrogen is the answer for all segments, even decades from now. Synthetic fuels are "a low-risk solution at an affordable cost for long-haul flying," Faury says. He does admit that the rise of hydrogen could have an impact on the already difficult business case for synthetic fuels, which are far from being available in anything near industrial quantities. Yet the two concepts could serve different applications, he says, noting that where they do not, "competition is healthy."

**Check 6** *Aviation Week editors discuss the technological, regulatory and other challenges Airbus' plan faces:* **AviationWeek.com/podcast**

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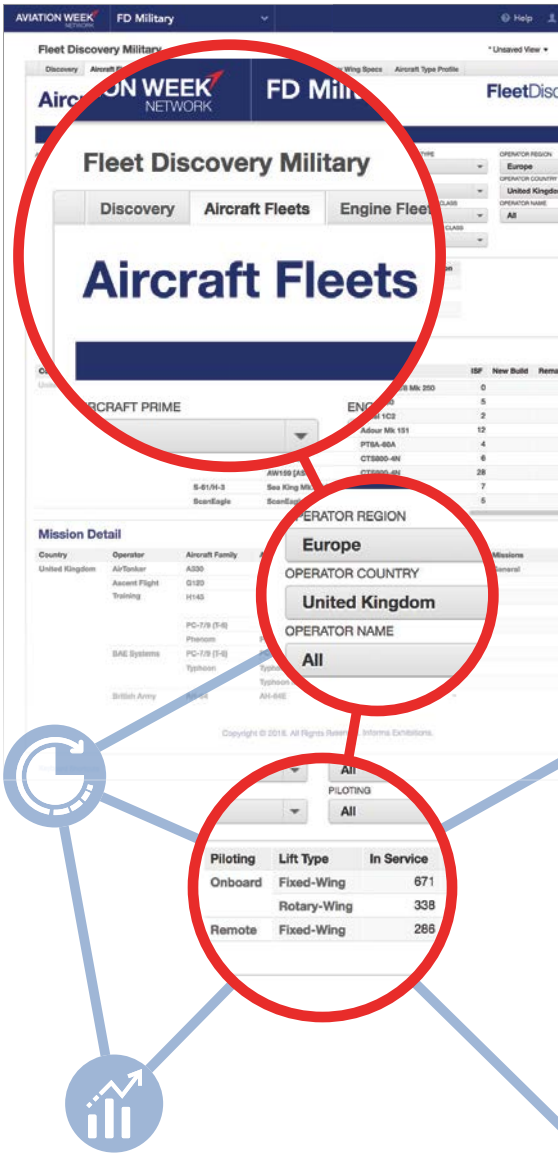


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# Early Simulator Trials Foreshadowed Boeing 737 MAX Pilot Issues

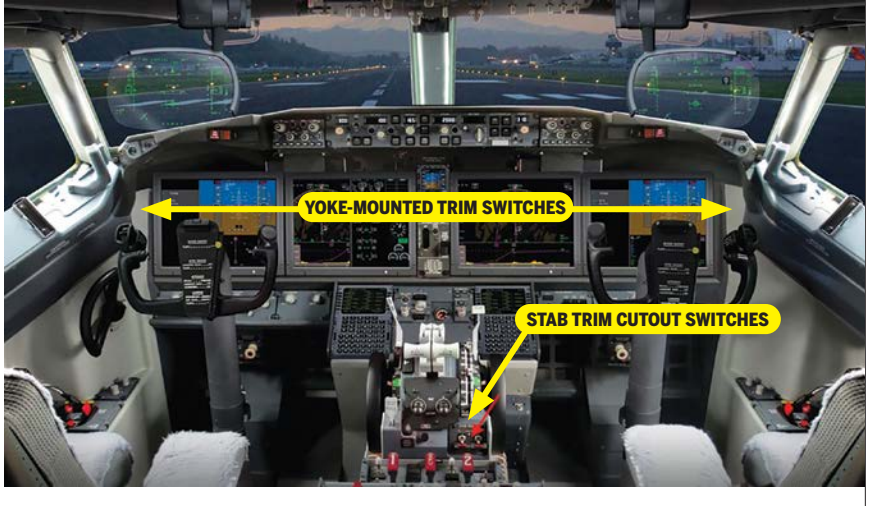
- NEW REPORT HIGHLIGHTS ISSUES WITH PILOT-AIRCRAFT INTERFACE DURING MAX DEVELOPMENT
- BOEING MINIMIZED HOW MUCH INFORMATION PILOTS RECEIVED

**Sean Broderick** Washington


Six years before the crew flying a Lion Air Boeing 737-8 reacted to an emergency in a very different way than Boeing assumed pilots would, something similar happened within Boeing's walls.

During simulator sessions to evaluate a new flight control law's potential hazards, Boeing test pilots took more than 10 sec. to diagnose and correct a runaway stabilizer. The session caused one employee to wonder whether pilots of the newest 737 family member, dubbed the MAX series for marketing purposes, needed more information to diagnose the hazard. A second employee who flew the simulator scenario responded that more analysis was needed.

COLLINS AEROSPACE




**Boeing assumed pilots would quickly use both the electric trim switches and cutout switches to counter an MCAS-related stabilizer runaway.**

Boeing ultimately determined that MAX pilots would react within seconds in such scenarios—and that the new control law, the Maneuvering Characteristics Augmentation System (MCAS), could not create new or more severe hazards. The assumptions were not challenged by regulators.

The similar accident sequences of Lion Air Flight 610 (JT610) in October 2018 and Ethiopian Airlines Flight 302 (ET302) less than five months later—both caused by unneeded MCAS activations—showed that Boeing and the FAA were wrong. Now Boeing, the FAA and others point to the accidents as hard, painful evidence that generally accepted assumptions used to evaluate how pilots will react during inflight emergencies need revamping (*AW&ST* Oct. 14-27, 2019, p. 18).

But newly revealed information collected by U.S. lawmakers investigating the 737 MAX development raises questions about how Boeing handled hazard assessments and whether it ignored evidence that showed MAX pilots would need more help than they were given.

"Multiple Boeing [employees] failed to inform the FAA that Boeing had discovered early on in the MAX program that it took one of its own test pilots more than 10 sec. to respond to an uncommanded activation of MCAS in a flight simulator, a condition the pilot found to be 'catastrophic,'" states a report released by the House Transportation and Infrastructure (T&I) Committee. "This should have called into question Boeing's assumptions about pilot response times. It did not."

The committee's view is based in part on email messages about the 2012 simulator sessions included among thousands of pages of documents Boeing and the FAA provided in response to lawmakers' requests during the 18-month investigation.

The email messages discuss two instances of the same hazard scenario being simulated.

In one instance, the crew responded in 4 sec., "with teamwork used to [toggle] the aisle-stand stab cutout switch and apply nose-up mechanical trim." This roughly follows Boeing's long-established 737 runaway stabilizer checklist, which calls for pilots to apply electric trim and, if necessary, toggle cutout switches to prevent automatic inputs from moving the stabilizer, which the MCAS does.

In a second run-through, "the reaction time was long," greater than 10 sec., the employee wrote, before the cutout switches were toggled, stopping the MCAS-triggered automatic nose-down inputs.

"Do you think that with pilot training/knowledge of the system there will be a sufficiently quick response to the [stabilizer] runaway . . . ?" the employee asked.

"I would like to take a look at how much time there is between a hazardous assessment and a catastrophic assessment," a second employee responds.

The T&I Committee report does not explain what happened next. Testifying before the committee in October 2019, former Boeing Commercial Airplanes chief engineer John Hamilton told lawmakers that subsequent simulator runaway-stabilizer scenarios showed "the typical reaction time was 4 sec."

Boeing also concluded that a reaction of 10 sec. or longer must be categorized as "catastrophic," which the


SEAN BRODERICK/AW&ST

**The MAX remains grounded while Boeing finalizes flight control software and training changes.**

FAA's large aircraft system design and analysis certification guidance defines as "failure conditions which would prevent continued safe flight and landing." The 10-sec. parameter was listed in 737 MAX internal design parameters, or "coordination sheets," right through the 737-8's March 2017 certification.

While the committee report does not discuss Boeing's response to the questionable simulator scenario, decisions later in the MAX's development suggest the company was not concerned. It determined pilots did not need special training on the MCAS since the software was an expansion of the speed trim system found on 737s. An MCAS failure would result in uncommanded stabilizer movement, which pilots would recognize, and a "SPEED TRIM FAIL" indication on the flight deck.

"Every new buzzword represents a company and airline cost via changed manuals, changed training, changed maintenance manuals," says a 2013 Boeing internal "problem statement" document discussing how the MCAS should be categorized. "Recommended action: investigate deletion of MCAS nomenclature and cover under 'revised speed trim.'"

While the MCAS name did not disappear, it was downplayed.

A 2014 Boeing presentation prepared for Southwest Airlines and included in the committee's report discusses the MCAS, underscoring that the system was not kept a secret. But Boeing opted not to include it in flight crew operations manuals, so most line pilots did not realize it existed.

Meanwhile, Boeing determined that the MCAS' original authority was not enough.

Developed in response to 2011 wind-tunnel testing that quantified the effects of the MAX's CFM Leap 1B engines on the aircraft's aerodynamics as a requirement to ensure the new model handled like its predecessors in certain rare flight profiles, the MCAS' original authority covered high-speed scenarios such as wind-up turns.

In early 2016, flight tests determined that the MCAS needed to address some low-speed scenarios as well. As part of the modification, the MCAS configuration was changed to command as much as 2.5 deg. of stabilizer input per 10-sec. activation. The MAX's stabilizer ranges from maximums of 4.2 deg. aircraft nose down to 12.9 deg. aircraft nose up.

Adding the low-speed authority meant that the MCAS could direct an aircraft from wings-level to full aircraft nose down in two cycles or an elapsed time of 25 sec., counting a 5-sec. pause between activations.

After the MCAS was expanded, Boeing reviewed its original MAX stabilizer trim control functional hazard assessment (FHA), completed in 2012, to see if any changes were needed. It concluded that the high-speed scenarios presented higher risk, even though the low-speed scenarios could move the stabilizer more.

Each MAX accident happened because a single faulty angle-of-attack (AOA) sensor activated the MCAS and triggered unneeded, repeated automatic nose-down horizontal stabilizer inputs. Instead of reacting within a few seconds, the confused crews struggled, countering nose-down movements by pulling back on their control yokes and using electric trim. The ET302 crew toggled the cutout switches for a short time and attempted to manually adjust the trim. Aerodynamic loads on the mistrimmed aircraft made the manual trim wheel hard to turn, however, and the crew reengaged the stabilizer motors in an attempt to direct the nose back up.

In both cases, the MCAS software kept functioning as designed, pushing the aircraft's nose down because a sensor signaled the AOA was too high. The confused flight crews failed to maintain control, and both aircraft nosed over and sped up until impact.

The day before JT610 went down, a different crew flew the same aircraft and experienced a similar emergency (*AW&ST* Nov. 11-24, 2019, p. 23). While the crew, aided by a pilot flying in the jumpseat, toggled the stabilizer trim cutout switches and eventually landed safely, their reaction did not match Boeing's assumptions. This flight and the two accident flights are the only three in-service reports of the MCAS triggering unneeded stabilizer inputs.

The T&I Committee report suggests that FAA experts developed concerns about Boeing's MCAS-related pilot-reaction assumptions before the ET302 accident. Days after the first accident—and prompted by Boeing's concerns that an MCAS-related malfunction had played a role—the FAA issued an emergency airworthiness directive (AD) that reiterated procedures for managing an "uncommanded horizontal stabilizer trim movement."

The AD reiterated established procedures—based on the now seemingly inadequate pilot-reaction assumptions—for managing the emergencies. The agency did not recommend any new steps or call attention to potentially faulty assumptions. It also did not reference MCAS by name.

Meanwhile, Boeing and the FAA had determined that the MCAS software needed modifications but that the risk to the operational fleet was not high enough to warrant additional action beyond the AD.

In January 2019, an FAA office responsible for Boeing safety issues began a review of the MCAS, including Boeing's submissions, safety assessment assumptions and the agency's work on certifying the system. A draft report prepared by the office found Boeing complied with all certification requirements but "implied that these 'assumptions' by both Boeing and the FAA regarding pilot reaction time, for instance, were faulty," the T&I report states.

A draft of the MCAS report was being reviewed by FAA senior management when ET302 crashed, and it was never finalized. The committee said it reviewed the draft report "remotely" earlier in 2020, but the FAA, citing the report's unfinished status, declined to provide a copy. The committee's final report does not detail what the FAA's draft findings said about Boeing's pilot-reaction assumptions.

The FAA declined to discuss the draft MCAS report but pointed to the November 2018 AD as evidence of its

pilot-response concerns soon after the JT610 accident.

"The FAA acted immediately following the first accident, based on all the information available, to issue an emergency AD," the agency says. "The AD specifically reemphasized the correct procedure for flight crews to follow if they encountered uncommanded horizontal stabilizer trim movement."

The T&I Committee's 238-page report cites Boeing's "disturbing pattern of technical miscalculations and troubling management misjudgments" as well as "numerous oversight lapses and accountability gaps by the FAA" as playing a "significant" role in the two accidents. The pilot-response issue is part of a long list that includes designing the MCAS to be activated based on one AOA sensor's input and deciding, with FAA approval, to keep any discussion of the MCAS out of pilot flight manuals.

Boeing is addressing the MAX technical and training issues as part of changes designed to win regulatory approval for the model's return to service (*AW&ST* April 22-May 5, 2019, p. 16). The FAA issued a draft AD in August detailing some of the required fixes, including new flight control computer software that revamps the MCAS (*AW&ST* Aug. 17-30, p. 12). The global grounding, which began right after the ET302 accident, could start to be eased later this year, although regulators are not expected to move in unison.

The T&I Committee has introduced legislation that targets changes to the FAA product-approvals process, including how much reliance the agency can place on applicants to conduct tests and other certification work.

"Our report lays out disturbing revelations about how Boeing . . . escaped scrutiny from the FAA, withheld critical information from pilots, and ul-

# IAG's New CEO Faces Tough Challenges

- GALLEGO TAKES THE GROUP'S HELM AFTER DELAYED WALSH RETIREMENT
- SECURING THE ACQUISITION OF AIR EUROPA WILL BE AN EARLY PRIORITY

**Helen Massy-Beresford** Paris

Luis Gallego is an industry veteran who most recently was Iberia CEO.

IAG

Six months into the biggest crisis in the history of aviation is perhaps not the ideal time to take over as CEO of one of the industry's biggest airline groups. But that is exactly what former Iberia CEO Luis Gallego did on Sept. 8, when he took the controls of International Airlines Group, the parent company of Aer Lingus, British Airways, Iberia, Level and Vueling.

IAG has been taking decisive steps to shore up its position to navigate through the next few turbulent months and years, most recently with the announcement of a €2.74 billion ($3.25 billion) capital increase. And Gallego's predecessor, Willie Walsh—the architect of IAG since its creation through the merger of British Airways and Iberia in 2011—describes Gallego as the natural successor.

But none of this means Gallego will have an easy transition: He faces the challenge of guiding IAG through what industry observers expect will be an extended period of painstaking recovery for the aviation sector.

IAG looks better placed to weather that tough environment than its peers. The group had €7.6 billion in liquidity at the end of August and has already made a start on restructuring plans that include a reduction in head count of up to 13,000 at British Airways—of which 8,236 layoffs have already been put in place. But Gallego also faces some issues that are specific to the group at large.

The first big challenge will be ensuring that the planned acquisition of Air Europa, aimed at boosting the group's Madrid hub to rival other major hubs around Europe, goes ahead despite the troubled times.

"The Air Europa deal is important to IAG in its role as a European consolidator and would significantly strengthen its position in the Europe-Latin American market," says John Strickland, director of JLS Consulting. "However, this cannot be fulfilled at any price, and it is now likely that if the deal is completed, it will be done so at a much reduced price given the extremely challenging market circumstances," he adds.

So IAG may benefit from the circumstances with a reduced price for the deal; it has been in discussions for some months with Air Europa owner Globalia over a possible restructuring of the transaction.

And if reports turn out to be correct that Air Europa has applied to the Spanish government for state aid, IAG could also indirectly benefit from state aid—as have its competitors Lufthansa and Air France-KLM.

"Air Europa is a good strategic play for when the world gets back to something resembling normal," says Patrick Edmond, managing director of Altair Advisory. "But it's a case of 'Can they hold their breath for long enough?'"

Even if IAG's financial position is more stable than those of its peers, industry watchers are skeptical about the wisdom of the group making more acquisitions in the near future.

"I think they're going to have plenty on their plate, not just with the Air Europa acquisition but also with rightsizing the existing business," Edmond says.

"There's likely to be some other airlines going out of business over the coming year or so," Edmond adds. "Meaning that without any requirement for more acquisitions, IAG may find its market share increasing in some key markets."

timately put planes into service that killed 346 innocent people," says committee Chair Pete DeFazio (D-Ore.). "What's particularly infuriating is how Boeing and FAA both gambled with public safety in the critical time period between the two crashes."

The FAA says it "looks forward to working with the Committee to implement improvements identified in its report." The agency adds: "We are already undertaking important initiatives based on what we have learned from our own internal reviews as well as independent reviews of the Lion Air and Ethiopian Airlines accidents."

The agency and Boeing are among industry stakeholders that back revisions to pilot-performance assumptions. The FAA is adding human-factors experts tasked with reviewing product certification plans and designs to flag possible man-machine interface issues.

Boeing says it is already applying lessons learned from the MAX development and subsequent accidents on how to better support pilots operating its products (*AW&ST* July 13-26, p. 18).

"The assumptions that were made at the time were correct based upon what we [knew], but what we now subsequently know is that those assumptions have been proven incorrect," former 737 MAX program development chief Keith Leverkuhn told the T&I Committee in a May 2019 interview made public along with the report.

"I wish that we would have challenged those assumptions. But given that they were industry-standard and our best understanding at the time, that's what we used in crafting the design," Leverkuhn said. "That's a learning we've had on this program. It's a learning that we are now putting forth on the new aircraft."

Strickland agrees that acquisitions are unlikely for the time being.

"I would not expect IAG to make more acquisition moves in the short-to-medium term," Strickland says. "But with its cash reserves and its intense efforts to protect the financial health of its constituent companies, it will be well placed and likely better placed to do so than other European groups when the time comes."

In a post-coronavirus world of transatlantic travel restrictions and dampened demand for business travel, Gallego and his team may also be asking questions about the future of Level—the group's long-haul, low-cost unit.

Prior to the outbreak of COVID-19, IAG had already been set to change gear in its growth strategy. The group unveiled guidelines last year to revise capacity planning downward through 2022, but it was still planning for average growth of 3.4% over those years.

Now, like many of its peers, IAG does not see passenger demand returning to 2019 levels before 2023. Navigating the airline group's fleet and network development in this context of reduced demand will be Gallego's biggest challenge.

IAG said in September that capacity in available seat kilometers for the third quarter ending in September was expected to decline by 78% compared with 2019 figures. It had forecast a decline of 74% in its first-half results announced on July 31. For the fourth quarter, capacity is expected to decline by 60% compared with 2019—a bigger decrease than the 46% drop it had previously forecast.

The group said it still expected to reach a break-even point in terms of net cash flows from operating activities during the fourth quarter, despite the reduced capacity outlook, as a result of mitigating actions taken to reduce operating expenses further and enhance working capital.

For 2021, capacity is expected to decline by 27% compared with 2019. That forecast exceeds the 24% reduction previously anticipated, IAG said, adding that bookings had leveled off since July after a recovery in June.

Short-haul bookings fell slightly following the resumption of quarantine requirements by the UK and other European governments for travelers arriving from specific countries, including Spain.

As expected, the recovery of long-haul bookings has been delayed. The segment has been hit by ongoing travel restrictions to many destinations, including North and South America, although long-haul bookings have seen a "modest" increase since mid-August, IAG said.

"Where travel markets have reopened without border restrictions and quarantine requirements, IAG has been encouraged by the level of pent-up demand that exists for air travel," the group said.

IAG is suffering, like its industry peers, from the drastic decline in transatlantic demand.

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But IAG, like the rest of the industry, has no way of predicting when those travel restrictions will ease.

"Even if things start getting back to normal in the coming months, we don't know what is going to happen to transatlantic traffic," Edmond says. "That's a big part of IAG's business."

In that context, Gallego's role as the successor to Walsh is not going to be a flamboyant one, Edmond says.

"In the short term, it's just going to be about keeping the hatches very, very well battened down," he adds. "It won't be about flashy dealmaking. It will be about the unglamorous part—keeping costs down as IAG tries to build back."

# China's Big Airlines Intrude on Each Other's Home Bases

- CHINA SOUTHERN MAY SET UP A NEW CARRIER AT BEIJING'S DAXING INTERNATIONAL AIRPORT
- SHENZHEN AIRLINES SUFFERS INCURSIONS BY CHINA EASTERN AND HAINAN AIRLINES

Major Chinese airlines are increasingly encroaching on one another's turf, despite former official reluctance to let them do so. Air China, based at Beijing, has lately suffered most from outsider incursions. Among the encroachers, China Eastern and Xiamen Airlines have been unusually active. And in Xiamen, its hometown, Xiamen Airlines is on the receiving end of an intrusion by China Eastern.

Hainan Airlines has sustained a push into the home territory of another major carrier, Shenzhen Airlines. Support from the Shenzhen city government has presumably made this possible as Hainan Airlines' parent, HNA Group, struggles with debt.


*Source: Company statements*

By long-standing practice, the Civil Aviation Administration of China (CAAC) has generally let small airlines move into big airports that are other carriers' home territory, since the new arrival cannot affect competition much. But the agency has traditionally constrained big airlines more tightly, especially the six largest. Ranked by fleet size, these are: China Southern Airlines, Air China, China Eastern Airlines, Hainan Airlines, Shenzhen Airlines and Xiamen Airlines.

Only from time to time has one of the big carriers been allowed to raise its official status in the hometown of another. But over the past year, there has been a surge of such activity. Eagerness to fill new airport capacity appears to explain the CAAC's concurrence.

This has been most obvious in the national capital, where Beijing Daxing International Airport opened in September 2019. To create a satisfactorily large operation there, the CAAC offered upgraded status in Beijing to airlines from elsewhere.

A Chinese airline's presence at an airport can have one of four official status levels: a station, a branch company, a base company or a major base company. (A base or major base company is also a form of branch.) A fifth level is higher but unofficial: a major base company of an airline that is headquartered at the airport.

The higher the status, the bigger the operation. An airline assigns aircraft to a branch, which can keep them overnight. With the more extensive ground support of a base company, the airline can keep more aircraft at the airport, which will usually become a network focus. Crucially, higher status brings priority when an airline competes for route rights and runway slot times.

Air China, for example, is a major base company at Beijing Capital and is headquartered there. It dominates the airport's traffic. China Southern and China Eastern had base companies at Capital, but on moving to Daxing these were upgraded to major-base status. In keeping with their importance to Daxing, the CAAC also promised—and delivered—valuable intercontinental route rights for those two airlines at Daxing.

China Southern is going a step further: It has assigned a new brand, Xiongan Airlines, to its major base company at Daxing. This strongly implies that the operation will get its own air operator's certificate with a headquarters at Daxing, thereby ranking above China Eastern—and presenting a greater threat to Air China.

Xiamen Airlines moved to Daxing in March, stepping up from branch to base status. On Aug. 6, the carrier said it was setting up what it called a north China headquarters at Daxing to drive its business in Beijing and surrounding provinces. According to industry sources, this office will also coordinate the activities of subsidiaries Hebei Airlines and Jiangxi Air.

The government of Xiamen is building a second airport for the city and has arranged for two outside airlines to build up locally. One is low-cost carrier Spring Airlines, which will have a base company in Xiamen. This move is not so unusual or serious for Xiamen Airlines, since Spring ranks only ninth among Chinese airlines by number of aircraft. Similarly, 13th-ranked Juneyao Airlines is also setting up a base at Daxing, but it is far from Air China's biggest problem there.

At Xiamen, the main challenge for Xiamen Airlines is the local government's agreement for China Eastern to set up a base, presumably with a blessing from the CAAC. China Eastern, based in Shanghai, said it will build up at the city before the new airport opens, aiming to establish high-frequency services to Beijing, Chengdu, Kunming and Shanghai and "at a suitable time" connecting Xiamen with major U.S. and European destinations.

China Eastern agreed in January to build up at Shenzhen, the home of Shenzhen Airlines and a source of competition for China Southern, the home of which is Guangzhou, just 100 km (60 mi.) away. Detailed plans have not been stated but will surely include China Eastern elevating its current status at Shenzhen from station to at least branch level.

The move accords with central government policy to

promote the economy of the region around Shenzhen and Guangzhou, the Pearl River Delta. And it helps fill a new terminal and runway at Shenzhen Baoan International Airport that are under construction.

Hainan Airlines has a branch company at Shenzhen, and Air China has a base company at Guangzhou, both set up in the years of formerly slow encroachment. The China Southern and China Eastern bases at Beijing Capital were established in 2005 and 2007, respectively, in part to help handle the heavy flow of visitors expected for the 2008 Olympic Games in the city.

The Hainan Airlines operation at Shenzhen has become a serious source of competition for Shenzhen Airlines, a tightly controlled subsidiary of Air China. Hainan Airlines agreed with the municipal government in 2017 to build up at Shenzhen Baoan and continued to fulfill that promise even after HNA began running short of cash around early 2018.

Municipal subsidies have no doubt ensured that the airline has been able to do this without investing heavily. Even by the standards of Chinese cities, Shenzhen is unusually determined to buy air connections, especially international and, above all, intercontinental ones. Shenzhen Baoan International is strong only in domestic flights, hardly befitting the city's high state of economic development and its population—13 million officially but, according to a telecommunications company counting mobile phones in the city, perhaps 22 million in reality.

The limit on Shenzhen's airline services is its location, next to Hong Kong, one of the world's great intercontinental hubs.

So Hainan Airlines now has 11 intercontinental routes connecting Shenzhen with cities such as Brussels, Madrid, Paris, Rome and Vancouver. (None is operating amid the COVID-19 pandemic.) Moreover, the carrier bought a plot of land near the airport in 2019 with the intention of growing further in Shenzhen. It restated its commitment to building up there as recently as August.

This opportunity for Hainan Airlines has arisen in part because Air China has not permitted Shenzhen Airlines to develop a large international business, industry sources say. Air China's reasons are unclear, but one factor may be concern that such growth by the subsidiary would affect Cathay Pacific Airways, which is based in Hong Kong and also partly owned by Air China. Dissatisfied, the Shenzhen government has bypassed its local airline and brought in Hainan Airlines.

In Shanghai, Air China has been a creeping encroacher, setting up intercontinental services to notably strong European destinations there at the expense of China Eastern. Since before 2010, it has opened Shanghai services to Barcelona, Spain, as well as Frankfurt, Milan, Paris and, in 2019, London.

Meanwhile, the industry is awaiting restructuring of HNA Group, including its airline business. Nothing has been announced, and the timing is uncertain, but some reorganization of the group's capital and assets is widely expected by managers in other companies. The government is likely to be closely involved in this.

The issues to be addressed should include which HNA airlines, if any, should be sold as part of a strategy to establish a dependably profitable commercial aviation operation. The smaller carriers are mostly organized as subsidiaries of Hainan Airlines and owned in conjunction with provincial and municipal governments. Officials will presumably want Hainan Airlines to be robust enough to support Hainan's development objectives such as growing as a free-trade zone and attracting tourism.

Hainan Airlines subsidiary carriers such as Urumqi Air, Lucky Air and Tianjin Airlines were recapitalized in 2018 and 2019, as cities and provinces moved to ensure their local carriers would not suffer from the group's financial problems. This process has not continued in 2020, presumably because it will be part of the restructuring.

Hainan Airlines lost 11.8 billion yuan ($1.7 billion) in the first half of 2020. While the whole industry suffered amid the pandemic, this result was worse than that of any of the three larger Chinese carriers. The figures for Hainan Airlines include results from the subsidiary airlines.

# COMEBACK CARRIER

> A220 SEEN AS AN EFFECTIVE TOOL IN AIR TRANSPORT RECOVERY

> DESPITE PANDEMIC, PRODUCTION TO RISE IN COMING YEARS

> STRETCHED A220-500 COULD COMPLEMENT FAMILY

Airbus currently builds four A220s a month.

A. DOUMENJOU/AIRBUS

**Jens Flottau** Frankfurt

When Airbus acquired what was then called the Bombardier C Series in 2017 for essentially nothing plus guaranteed loss-sharing with the Canadian company, most analysts were full of praise for the move. They felt it would put Airbus in a much better strategic position vis-a-vis Boeing for years to come.

Aviation Week called the transaction Airbus' "deal of the century" (*AW&ST* Oct. 30-Nov. 12, 2017, p. 20). And when Airbus decided to take over the remaining stake Bombardier held in what is now called the A220 program, it was seen by most as a natural decision, given the aircraft's potential.

But now COVID-19 has changed the world—and with it, air transport. The big reset affects essentially all aspects of the industry.

Even the most modern narrowbody available today is suffering enormously from the impact. And though the strategic rationale for the deal and the positive long-term outlook for the program itself remain, the original business plan for the A220 is history and needs to be rewritten. That realization has come just as the program was about to take off in earnest. There are ample uncertainties about whether it can fill the role that Airbus envisioned, at least in the short and medium term.

In 2019, Airbus delivered 48 A220s, in line with the initial baseline production rate of four aircraft per month. The plan was to take it upward as fast as possible from there, both to have the program profitable by 2025 and to justify the politically driven introduction of the second final assembly line in Mobile, Alabama, which officially opened in May.

What happened, of course, is quite the opposite. In the first eight months of 2020, Airbus delivered only 13 A220s. Unless there is a sudden spike in deliveries between now and year-end, Airbus will fall short of even the most pessimistic analyst projections for the program. Agency Partners, for example, estimated the A220 at 38 aircraft for the year.

Richard Aboulafia, vice president for analysis at the Teal Group, is less pessimistic. He still expects Airbus to deliver 40 A220s this year and 55 in 2021. He believes it will reach a production rate of 10 per month in 2025. "I still believe things could come back fast once there is a [COVID-19] vaccine," he says.

The Mirabel, Quebec, assembly line was closed for seven weeks from late March and into May following a Quebec provincial government order. The line is now producing three aircraft per month and is going to five by mid-2021, one year later than planned. Mobile is building one aircraft per month.

Combined, the two production centers have a capacity of 14 aircraft per month: 10 in Mirabel and four in Mobile. That capacity could be expanded further with more investment should that be needed. Airbus is keeping to its target of expanding output to 14 by mid-decade but cautions: "This could be adapted as the market evolves over the coming years and in the context of the COVID-19 crisis."

"The production numbers are reasonable," says Adam Pilarski, senior vice president at consultancy

Avitas. "They can and should try to ramp it up. I have confidence in the Airbus plans. . . . [It can] easily be a 1,000-aircraft program."

The Mobile facility has five stations and can build both the A220-100 and -300. Before construction of the site was completed, the first few aircraft were assembled in the nearby A320neo hangar. Nine A220s are in various stages of assembly in Mobile. JetBlue is planned to become the second U.S. airline to take delivery of an A220 from the U.S. line by year-end.

In 2020, Delta Air Lines has taken three A220-100s; 10 additional aircraft went to Air Canada and EgyptAir and were delivered from the main base in Mirabel. Even before the novel coronavirus pandemic hit, Airbus' main sales challenge for the A220 was to find enough customers outside the U.S. to either enable the planned Mirabel ramp-up or at least sustain the existing rate well into the future. The prospects of resuming growth, or even sustaining rates—both there and in Mobile—are not good for the foreseeable future.

Another issue is the high dependence on just a few U.S. customers, particularly for the next five years. According to the Aviation Week Intelligence Network Fleet Discovery database, JetBlue, Delta and David Neeleman's start-up Breeze Airways are the three main customers for the Mobile line. In 2021, the three are due to take a combined 26 aircraft, then 40 in 2022, 52 in 2023 and 44 in 2024.

Over the next four years, Mirabel is planned to depend on three large customers—Air Canada, AirBaltic and Air France—but their combined backlog of 65 aircraft is not nearly enough to fill production capacity, even at much-reduced rates. Air Canada is due to take delivery of 37 remaining A220s through 2023, 27 of them planned for 2021 and 2022, according to Fleet Discovery. AirBaltic has 28 more aircraft on firm order and recently decided to stretch deliveries into 2024. The last of 50 aircraft originally were agreed to arrive at the end of 2023. Air France is slated to take five aircraft in 2021, rising to 14 each year in 2022-24.

Air Lease Corp. placed an order for 50 A220-300s in 2019, but the bulk will arrive only from 2025 onward. Production could be split between Mirabel and Mobile.

The A220 is well-positioned competitively. Its only real competition is the Embraer E2—and Embraer is further weakened after the collapse of the planned commercial aircraft partnership with Boeing. The A220 version that does compete with the E2 in terms of size is the -100. Depending on cabin layout, it sits somewhere between the E190-E2 and the E195-E2. However, at a maximum takeoff weight of 63 tons, it is much heavier than the E190-E2 (56.4 tons) and even the E195-E2 (61 tons). And it has a lot more range: 3,400 nm versus 2,800 for the E190-E2 and 2,600 for the E195-E2.

While they are competing superficially, the types really address different market segments. The A220-100 is a niche aircraft—most of the A220 orders are for the larger -300 version—suitable for long, thin routes. Airlines pay a cost penalty when they use it on shorter routes in spite of its weight. More traditional regional connections in Europe or the U.S. are better served with the E2 in principle, though none of the E2 versions including the smallest E175-E2 is compliant with scope clause limitations. But neither is the A220.

The larger A220-300 is effectively beyond the range of the E2. This is true not only in terms of size but also, literally, range. Airbus is working on versions of the aircraft that would extend the range to around 4,000 nm, making it capable of flying across the Atlantic or deep into Latin America from the U.S. But the A220 is also well-positioned to be stretched further, to cover what is now the Boeing 737-7 and -8 market.

Despite the differences, there will nonetheless be competition. The reality is some airlines are operating the A220 even if they do not need its range, in part because Airbus can combine A220 deals with other models such as the A320neo. That is

**Airbus expanded its Mobile, Alabama, site to assemble A220s. The line officially opened in May.**

AIRBUS

why Embraer tried to tie up with Boeing and offer a similar portfolio of aircraft.

A key element in the future competition will be Embraer's approach to pricing: It has so far sought to reach the same pricing premium vis-a-vis the E1 family that Airbus has targeted for the A320neo over the A320. That approach has not worked well, as demonstrated by the relatively low level of orders. Another challenge is bringing supplier costs down enough for healthy E2 margins despite lower volumes. The A220 faces the same challenge, except that under Airbus ownership the chances of actually making the program profitable are better due to the backing of a large organization.

It has been argued that the A220, and the Embraer 195-E2 for that matter, will benefit in the COVID-19 recovery as airlines focus on minimizing trip costs and revenue risk by flying smaller aircraft. Airbus says 80% of the A220 fleet had returned to service by July—with the trend continuing, essentially toward a complete return.

But that does not necessarily translate into future sales, as few airlines are currently in a position to invest in more aircraft. Even Airbus CEO Guillaume Faury recently commented that he believes that a steep, "quite brutal," ramp-up in production could arrive as early as 2022 as airlines rebound. In such a scenario of fast catch-up growth, will airline executives focus on risk containment, or will it be all about market share again?

Aboulafia still thinks caution could play to the A220's favor. "The history of traumatic events shows that [management teams] come back mindful that they want a smaller plane," he says. They must reconcile two conflicting targets: reestablishing as much of their former networks as possible with as little capacity as possible. Attempting both would require smaller aircraft. "There will be a much more conservative comeback [than after previous crises]," he predicts.

And while the A321neo became a major sales success before the crisis, and subsequent deliveries over the next few years will change the composition of the narrowbody fleet, Aboulafia believes the aircraft will mainly find a role as a widebody replacement—particularly the LR and XLR versions—and not necessarily operate in the roles formerly covered by the A320 or Boeing 737-800.

Airbus offers two versions of the A220, the -100 and the larger -300, and the market has indicated its preferences. There are 54 -100s remaining to be delivered, 10 of which are supposed to go to a crowdfunded airline project called Odyssey, based at London's Heathrow Airport and first announced in 2011. Odyssey has moved back its launch date several times. There are 10 additional orders for undisclosed customers. Meanwhile, the backlog for the larger -300 stands at 470 units.

There is an ongoing debate about whether or not Airbus will stretch the aircraft further and offer an A220-500 that would be equivalent in size to the A320neo and Boeing 737-8. Given that it would be a stretched and new-technology aircraft, it is widely expected to feature superior economics compared to the derivative models. Strategically, the A220-500 could be of great value in positioning Airbus' eventual new narrowbody, which would replace the A320neo family and compete with whatever aircraft Boeing develops to replace the 737 MAX.

With the -500 in place, Airbus could move the baseline version of its next-generation short- and medium-haul aircraft upward to 180-200 seats while leaving the segment below to the A220. Boeing instead could be forced to cover the entire segment with one family, which would likely make the economics of the smaller versions worse.

But the A220-500 decision is not simple. Charles Armitage, European Aerospace and Defense Analyst at Citi Research, points out that Airbus is making a substantial profit margin on the A320neo and would endanger that highly profitable program with one that is marginal so far. Aboulafia thinks "the -500's virtues outweigh the disadvantages." Cannibalizing the A320neo can be avoided by moving the -500's service entry to 2027, by which time a large part of the current A320neo backlog will have been delivered despite the current crisis, Aboulafia says.

While this may not be a good time to invest in any product, Pilarski thinks there is one exception: the A220. In the short term, he contends, Airbus should put money into improving an already good aircraft and increasing commonality with the legacy Airbus products. But he also thinks that further down the road a carefully planned and timed -500 is a good idea. Good timing means making it available only when the bulk of the A320neo backlog has been burnt off, as Aboulafia suggests. It also means sufficient spacing between its own entry into service and whatever "moonshot" hydrogen-powered aircraft Airbus will deliver in 2035.

But competition from a hydrogen-powered aircraft should not be too much of a problem for the A220, Pilarski believes, since the next-generation aircraft will not be available in great numbers until the late 2030s, and investment in the A220 will have been limited anyway.

And as -100 sales were tapering off before the COVID-19 pandemic, and some customers such as Swiss International Air Lines decided to convert part of their original orders to the larger -300, the A220 risks becoming essentially a one-type family without a larger version. Another argument in favor of the -500 is that Airbus has to keep its engineers busy when work on the A321XLR, currently its only major derivative program, is completed.

## A220 In-Service Fleet

| Operator | Units |
|---|---|
| **SWISS** | |
| A220-100 | 9 |
| -300 | 20 |
| **KOREAN AIR** | |
| -300 | 10 |
| **AIR TANZANIA** | |
| -300 | 2 |
| **AIR CANADA** | |
| -300 | 8 |
| **AIR BALTIC** | |
| -300 | 22 |
| **DELTA AIR LINES** | |
| -100 | 31 |
| **EGYPTAIR** | |
| -300 | 10 |

As of Sept. 1, 2020 *Source: Airbus*

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# EVOLUTION eVTOL

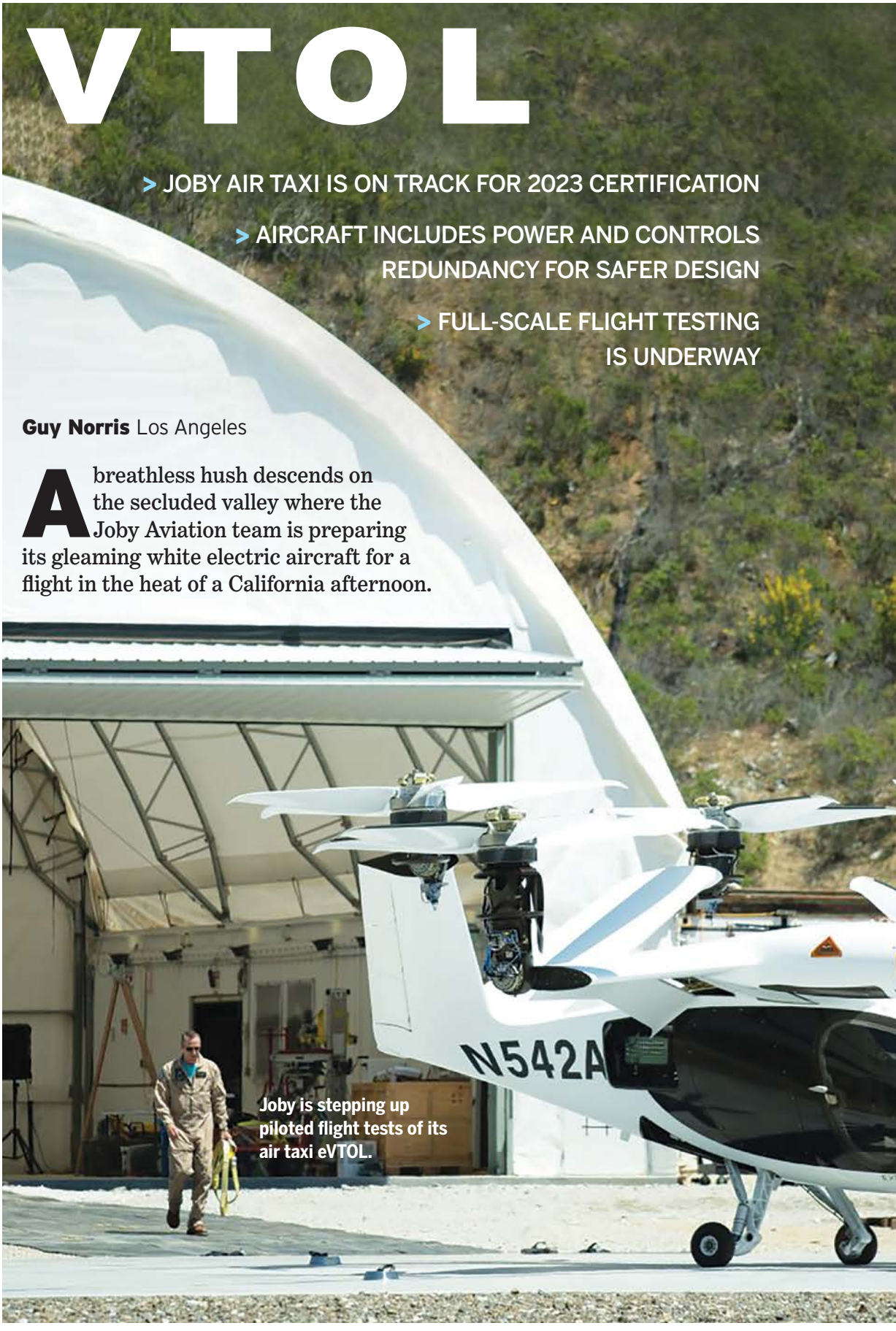
> JOBY AIR TAXI IS ON TRACK FOR 2023 CERTIFICATION

> AIRCRAFT INCLUDES POWER AND CONTROLS REDUNDANCY FOR SAFER DESIGN

> FULL-SCALE FLIGHT TESTING IS UNDERWAY

**Guy Norris** Los Angeles

A breathless hush descends on the secluded valley where the Joby Aviation team is preparing its gleaming white electric aircraft for a flight in the heat of a California afternoon.




Joby is stepping up piloted flight tests of its air taxi eVTOL.

Seldom seen and even more rarely heard, Joby's prototype electric vertical-takeoff-and-landing (eVTOL) aircraft have been developed in almost complete secrecy over the past six years. Now undergoing flight tests at an undisclosed site in central California, the company's first product—a pioneering air taxi design—is about to demonstrate that it will not only fly with ease and safety but do so extremely quietly.

Aviation Week has been invited to witness the flight and get a rare inside look at the aircraft and the steps underway to develop and certify what Joby believes will be a game-changing capability for advanced air mobility.

But first, the flight. Moments after the navigation lights show the vehicle is active, the propellers atop the aircraft's six upward-tilted electric propulsion units (EPU) whir into life. Almost instantly, the aircraft becomes airborne and, flown from a nearby ground-based remote cockpit, rises vertically to a relatively low altitude, where it begins a series of maneuvers and laps of the valley.

Designated the S4 for certification purposes, the yet-to-be-named air taxi is configured with four EPUs on the wing and two on the V-tail. Sized to carry four passengers and one pilot, it will be capable of operating day/night flights in instrument or visual flight rules up to 150 nm. Although only 21 ft. long overall, the aircraft has a wingspan of 38 ft., just 2 ft. less than that of an Embraer Phenom 100, giving a surprising impression of size as it moves in front of us.

Although not permitted to describe specifics about the maneuvers, speeds and altitudes flown, this Aviation Week editor was able to converse easily with Joby employees throughout the demonstration while standing within a few hundred feet of the takeoff-and-landing site. On start-up and liftoff for the demanding vertical-takeoff phase, the aircraft emitted a lower-intensity, lower-frequency sound quite unlike the urgent, high-pitched swarm-of-bees-like noise often associated with drones and large multicopters.

In the hover, the overall noise level of the air taxi sounded significantly lower than any helicopter this editor has heard. The five-blade propellers on each EPU are carefully optimized for low acoustic signature, while the distributed electric propulsion system enables a lower overall loading with a resultant reduction in associated blade loading noise. By spacing out the propellers, it appears the design may also reduce blade vortex interaction, an impulsive noise source on rotorcraft that occurs in descent when blades pass through the vortices shed by previous blade passes.

There is no engine- or gearbox-generated noise, and the S4 also lacks the traditional sound wave pulse, or "thickness noise," that helicopters produce through the repetitive rotary motion of air being displaced by the blades. While maneuvering over the valley several hundred yards away, the aircraft made only a partially perceptible sound that, in this editor's view, would almost certainly be undetectable against the everyday noise background of an urban environment. These characteristics appear to be consistent with Joby's claim that the design is around 100 times quieter than a helicopter and virtually silent in wing-borne flight.

Low noise is key to eVTOL acceptance, but that is only part of the equation, says Joby founder, CEO and Chief Engineer JoeBen Bevirt. "The No. 1 priority is safety, and at a level you see in commercial aviation, which is the safest mode of transportation we have," he says. "Second, we need this to be incredibly accessible, in that people can easily get to takeoff-and-landing locations. It also has to be incredibly affordable and to become progressively more affordable over time."

To Bevirt, who set up Santa Cruz-based Joby Aviation in 2009, the S4 marks a key step toward realizing a boyhood dream of using aircraft for short-distance travel and "saving a billion people an hour a day." But even three years after the first flight of the initial "1.0" prototype and ongoing flights of the current "2.0" version, he acknowledges: "We're just barely getting started."

Until now Joby was "a kind of show-don't-tell company, and now we're reaching a point where we have an opportunity to tell," says Executive Chairman Paul Sciarra. "We've purposely kept a relatively low profile—in part because this is a space where there's been a lot of smoke and very little fire for a while, and we've been doing the hard work of ensuring that we're able to hit the right commercial operating specifications for the vehicle."

Sciarra, who was co-founder of social media company Pinterest and one of the first outside investors in the start-up, says Joby is now shifting gears. "As a company, we are going from a project that was very much focused on development to now one that's far more focused on certification, initial manufacturing and, third, laying the groundwork for commercial operations," he says.

Test and development work is spread across the company's three main sites at Santa Cruz, nearby San Carlos in the San Francisco Bay Area and Joby's growing new production facility at Marina, California. Learning lessons from automaker Toyota, which is also a significant investor, Joby is "preparing for large-scale production," says Bevirt.

JOBY AVIATION

With certification becoming the key focus, Joby has less to say for the moment about its plans to also be the operator of the air taxi. Although it has partnered with Uber to provide and operate the aircraft for the ride-share company's forthcoming urban air mobility demonstrations, Joby also has "the opportunity to work with other partners," says Sciarra. The decision to be an operator as well as the manufacturer forms a key element of the company's safety strategy.

Joby's path to the S4 began with the Monarch personal air vehicle, an electric-powered VTOL motorglider concept unveiled in 2011. But Joby soon redirected efforts toward an S2 two-place air taxi eVTOL configured with a wing and 12 tilting and folding propellers.

The S2, while "super compelling," was too small to make the market impact Joby wanted, says Sciarra. "We really wanted to reconfigure this vehicle for everyone. So a number of changes were made to go to a higher-capacity, faster vehicle with longer range to deliver a wider set of missions, and that's the vehicle that we built."

Subscale S4 prototypes were flown more than 700 times starting in 2015, and in 2017 the company began remotely piloted tests of the first-generation, full-scale "1.0" version. Building on this high-wing, six-propeller configuration, Joby started flight tests in 2019 of the second-generation "2.0" version. Changes included increased gross weight—up to 4,800 lb.—and a revised swept-forward V-tail.

Joby says "several hundred" flights have been completed to date, including some with a pilot onboard. Although some testing can be flown remotely, the certified S4 will be piloted to enable integration into the existing national airspace.

Driven by the goals of safety, noise abatement and affordability, Sciarra says the six-EPU configuration provides adequate redundancy in the event of a motor failure. "We also tried to take that same thinking in terms of the redundancy into the design of the subsystems," he says.

The EPUs are arranged in an oval pattern to distribute the lift forces equally around the aircraft. If one fails, the control system will automatically reduce thrust on the opposing prop while compensating with extra torque on the other four. The tail-mounted and wingtip EPUs are mounted on simple pivots to transition from vertical to horizontal flight, while only the motor and propeller of the two inboard wing-mounted units tilt to avoid complexity.

Multiple redundancy is equally evident in the control surfaces, which are made up of dual-section ailerons outboard and six individual ruddervators on the V-tails. Two sections of simple slotted flaps are also fitted inboard of the ailerons. Control surfaces are moved by small but powerful linear electric actuators mounted at the inboard edge of each surface. "The surfaces and actuators are independent for redundancy, so if one breaks, we still have another, as well as all the props," says Chief Test Pilot Justin Paines.

The five-blade propellers are driven by highly integrated, lightweight motors that, like virtually everything on the S4, are designed and built in-house. Joby is vertically integrated "by necessity," says Sciarra. There were often no suppliers that could make the specific components needed. "And although it took longer and was more expensive to do that initial design and manufacturing work, we feel good about it because it allows for just the right component at just the right specifications for the vehicle," he adds.

Each EPU includes the inverter as well as motors for electric propulsion, variable propeller pitch, nacelle tilting and cooling. The cooling unit pumps fluid through an integrated radiator as well as driving a fan that pulls air past the motor and ejects it through a nozzle at the base of each nacelle. The entire unit is so closely packaged that the propulsion motor looks not much larger than a party-size cookie tin.

Representative of the multilayered safety philosophy behind the entire S4 design, the motors are configured with dual windings and dual-redundant inverters that take power from four separate lithium-ion battery packs. Two of the packs are housed spanwise in the inboard sections of the gulled wing, and two are aligned fore-and-aft in the fixed horizontal nacelles of the inboard wing-mounted motors.

JOBY AVIATION

Placed close to the center of gravity, the battery packs are installed flush with the lower surface of the wing and nacelles for improved thermal management, better safety and easier access for removal and maintenance. Each pack has a vent to dump gas overboard in a thermal runaway.

The battery technology within the packs has driven both the fundamental design of the aircraft and the intrinsic approach to safe and reliable operations. "Lithium-ion battery technology is pretty well understood. We're not relying on some new breakthrough or some secret technology that no one else has access to," says Jon Wagner, powertrain and electronics lead for Joby. "From the beginning, we understood what we could purchase as far as battery cells, and then we put it on ourselves to design the balance of the system to work." The cells are a high-volume design already in production for an automotive application.

Starting with battery capability, "you set up a vehicle design and start making budgets for weight and targets for performance," says Wagner. "One of the key things is the battery mass fraction, which is how much of the plane is made out of batteries and how much is everything else. So to achieve all those mass targets and the performance metrics, it starts to drive everything else."

Battery energy density therefore became a key parameter along with vehicle size, motors and other variables that fed the custom design optimization and mission analysis tools developed by Joby aeronautical engineer Alex Stoll.

"There are people who are saying that these types of aircraft are not viable with the lithium-ion we have today, and

that we need some major improvement in [watt hours per kilogram] before this is viable," Wagner says. "But we've realized that we can achieve this, and it has to do with the aircraft design. It's a glider with batteries that can take off vertically."

Beyond energy density, other key challenges include battery charging time. "We will make our revenue when we're flying people in the air," he continues. "Turning the airplane around between flights is a really critical aspect. Quite a bit of our battery development does go into fast charge and developing a system that's capable of turning around a 25-mi. flight in 6 min., so that's a key number that we focus on."

**Redundant propulsion and flight control systems are designed for extra safety.**

The S4 is designed to fly efficiently on routes ranging from innercity short hops and intra-suburban flights to intercity missions. "On a longer flight, you can have a longer turn time. But the 25-mi. flight is the most difficult one from the battery-charging perspective because you've got to put all that energy back in that took 25 mi. to expend. We want to accomplish the charge in the same amount of time it takes to get people out of the plane and put the new passengers in and load the luggage," he adds.

Battery safety, like that of the rest of the powertrain, is addressed using a layered approach. "That first layer is about taking something that's already mass manufactured for automotive customers and bringing that high level of quality and refinement into our program," Wagner says. "At the next level, we're doing very advanced battery electronics and software to monitor and control every cell in the airplane. That way we can control the way that they're being treated and their behavior."

Beyond this, additional measures include containment between individual cells within each liquid-cooled battery pack. "These ensure that if we did have a failure in a subsystem, it would be contained and would not spread," Wagner notes. "And then . . . we run physical testing for the worst-case scenario where maybe we have even more than one failure. And even in that scenario, we hold the standard, where we continue to allow safe flight and landing."

The highest power requirement during flight will be during the short periods of vertical flight, but the bulk of the S4 flight time will be spent in wing-borne operation when the vehicle's high lift-to-drag capability creates a "very low power requirement," adds Wagner. The ability to easily maintain level flight, even with a failed or degraded battery pack, is a key element of Joby's safety case and its drive to certify the S4 under the revamped Amendment 64 of the FAA's Part 23 airworthiness standards as a normal category aircraft that is also capable of vertical takeoff and landing.

Like most of the eVTOL concepts, the S4 fits somewhere in between the standard Part 23 rules for general-aviation aircraft and light helicopters that are certified under Part 27 regulations. Adding more complexity, aircraft certified under Part 23 or 27 must also comply with Part 33 and Part 35 certification requirements for engines and propellers, respectively.

Joby submitted its type certificate application for the S4 in 2018 and considers itself to be blazing a trail for eVTOL airworthiness qualification, says Garrett Homan, certification and systems engineering lead for the company. "We have a certification basis locked down with the FAA. The majority of the regulations—around 85%—reflect a normal category airplane, and they're relatively straightforward and traditional. Then the remaining 15% is comprised of special conditions to handle the novel aspects of the project including areas such as fly-by-wire, the batteries, electric propulsion and vertical-takeoff-and-landing capabilities," he says.

Joby's progress toward certification under the amended Part 23 shows the value of the effort going back almost 15 years to revise the regulations, says Peter Bunce, president of the General Aviation Manufacturers Association (GAMA). Introduced in 2017 to allow more flexibility for bringing new technology to aircraft, Amendment 64 is already being exercised to the full as other developers engage with the FAA over certification of the upcoming generation of other advanced air mobility designs.

"More than a decade ago, when companies like Joby didn't even exist, everybody got the idea that if we had a regulation that could be used for the new types of electric-powered aircraft that were on the horizon, then that could be very useful," says Bunce. "So it was written in such a way that Part 23 could be used, because none of these vehicles that we're seeing out there are like traditional rotorcraft." The rewrite also has big implications for where Joby will find pilots for the S4, at least initially, because Part 23 certification will open the door to recruiting fixed-wing pilots.

The details of the proposed S4 certification basis have been gathered into a document known as a G1 issue paper—a process by which the FAA documents technical issues related to a certification project. "The G1 is really the very first and required issue paper for any project because it's the establishment of all applicable requirements," says Walter Desrosier, engineering and maintenance vice president for GAMA. The G1 also includes any special conditions. "Some of the requirements might be an exemption or an equivalent level of safety," he adds.

Among many novel aspects of the Joby approach—and one likely to become more commonplace with other eVTOL projects—is that the company plans to certify the electric propulsion units as engines and propellers under one type certificate. This means that the airplane, engines and propellers will all be covered by a single type certificate rather than in the traditional process where the airframe-maker incorporates the existing type certificate already held by the engine-maker. "We're doing it all as one," Homan says.

"Because electric propulsion isn't fully addressed by Part 33/35, the FAA Engine and Propeller Division has worked for the last five years to create special conditions to assure the design details are appropriately addressed," Homan explains. "Joby will not receive independent type certificates for the engine and propeller, but just one for the airframe, propeller and motor designs."

Joby now is also formulating a certification plan that will include the ways it will demonstrate compliance to each of the requirements. Some areas will be covered by engineering and analysis, while others will involve tests. "We're focused on finalizing the means of compliance that will serve as the specific airworthiness criteria or airworthiness standards for our designs," says Homan. "In parallel, we're working on developing externally our methods of compliance that we'll be proposing to show compliance with those performance-based regulations. So there's a few steps that we're working through that are different with this Amendment 64 project."

Joby is "somewhere between 70% and 80% complete" with defining the means of compliance and is working with various FAA departments to organize the program around a series of more detailed certification plans. "There's one for the overall project, and then we're breaking up the project into a number of more specific areas," Homan explains.

"We're working toward a program plan that has us achieving type certification by the end of 2023," he continues. "We are currently working in order to finalize these planning details and get test plans submitted so we can start certification testing for credit in the near future."

Much effort is focused on the special conditions, primarily high-voltage power electronics and energy storage, flight envelope protection and aspects involved with vertical-take-off-and-landing performance. "Thermal safety is something that we're taking very seriously," says Homan.

Electrically powered aircraft are "still extremely new to the FAA," he adds. "How we're doing it with distributed propulsion and with our level of redundancy and safety is quite different than the other applications, as far as we can tell, so high-voltage electric propulsion, motor design and motor controller design are all getting quite a bit of focus."

Although the FAA is familiar with fly-by-wire flight

# *Flying the Simulator*

**Guy Norris** Los Angeles

**AVIATION WEEK HAD THE OPPORTUNITY TO SAMPLE THE** flight characteristics of the Joby air taxi in a company demonstration simulator. I was guided through the remarkably simple operation of the aircraft by Justin Paines, the chief test pilot for Joby who, as a military test pilot, played a key role in developing the unified flight control strategy for the Lockheed Martin F-35 Joint Strike Fighter.

My simulated flight began at San Francisco International Airport (SFO). With propellers stowed in up position, blades stationary and locked in the safe configuration, there was plenty of headroom for my imaginary passengers as they boarded the aircraft and settled into the four seats behind the pilot in the surprisingly roomy cabin.

Although the simulator is not the final version of the aircraft, it demonstrates the concept of operations and generic layout of the cockpit. I moved a switch from "load" to "taxi," and the props began turning. There is no need to start the engines with an electric aircraft—I just switched the vehicle on and confirmed activation with a second switch.

The electric motors provide instant power and, with a slight movement of the throttle-like left-hand inceptor that controls longitudinal acceleration, all six propellers angled slightly forward, and we began to taxi like a normal aircraft. Despite the appearance of the inboard props in my peripheral vision as they pivoted forward on either side, the all-round view remained excellent from the cockpit.

A short push on the left inceptor to a soft detent started forward motion, and I let go once we were underway. Meanwhile, a simple twist of the right-hand inceptor steered the nosewheel. There is no need for rudder pedals or a separate nosewheel steering control. We taxied to a clear area, and after clearance for takeoff and preflight checks, I selected another switch that allowed me to "enable" or "disable" flight.

A press on a "confirm" button completed the two-step procedure, and we were ready for flight. To take off, I simply pulled back on the right-hand inceptor and left the left-hand inceptor alone, as I wanted to fly vertically upward without also moving forward. Although at first it seemed strange not to be concerned about adding power for vertical lift, the system automatically converted my command for takeoff into the required motor torque. "We can go up like a champagne cork and pull 2g vertically if we need to," says Paine.

Letting go of the right inceptor brought the aircraft to a gentle stop and, with my hands off the controls, we entered a stable hover over the ramp. The integrated flight and propulsion control system will maintain position in crosswinds. In thrust-borne flight, aircraft control is through a combination of propeller RPM, pitch and nacelle tilt.

Using the twist grip, I yawed the aircraft around to face San Francisco and pushed the left inceptor through the detent to begin transitioning to wing-borne flight as we climbed to 2,000 ft. and accelerated toward the city. Speed quickly built up to the cruise maximum of 175 kt. "The idea is the pilot can push the inceptor all the way forward and they're not going to break anything. It will just go to the maximum permittable speed," says Paines.

En route to a rooftop landing pad, I was shown how to use an automated decelerate-to-hover "shortcut" feature Joby is developing to give pilots even simpler control options. With a press of the button—for the moment mounted on the right-hand inceptor—the control system automatically deploys flaps and other effectors to reconfigure from forward flight to a hover at whatever altitude the button is pushed. In the simulator, the landing gear also extended automatically to assist the deceleration. The aircraft initially will be certificated

envelope protection, mostly in airliners, the Joby approach of integrating flight control computers with control surfaces and six tilting propellers is novel, particularly in a Part 23 aircraft. "How we are implementing our design to provide envelope protection is different, which is really leveraging the strengths of the flight control system," he adds.

Describing the flight control system as the "critical enabler" for the S4 along with battery maturity and certification, Sciarra says: "That's one of the other pieces that has come together at the right time to make this happen." Pivotal to Joby's plan to make it simple and safe to operate, the S4 will be the first Part 23 aircraft to be certified with a version of the unified flight control law originally developed to make it easier to land the Lockheed Martin F-35B vertically.

The system splits velocity control over two inceptors. The left-hand inceptor controls fore/aft acceleration, while the right hand controls the vertical axis (up/down), as well as bank angle and roll rate. For hovering, the system automatically engages translational rate command, in which the pilot can make small corrections easily and which brings the aircraft to a standstill if the controls are released.

In hover mode, the triplex fly-by-wire system limits "how fast you can go sideways and aft, so we protect the airplane that way," says Buddy Denham, a former U.S. Navy test pilot who helped develop the F-35 control system. At higher speeds, in wing-borne flight, "there's envelope protection where we're not allowing the airplane to go faster than its design speed," he says. "We are putting in normal acceleration command and g-limiters, and then as we slow down, we also have alpha [angle of attack] protection in there as well.

"As a part of flight test, we are exploring what our control authority and control margins are, and then we're overlaying protection on those margins. We have sensing redundancy for angle of attack, sideslip and normal acceleration, so that keeps us in a protected envelope," he adds.

With flight-testing and plans for certification well advanced, it seems Joby is poised for success in the emerging eVTOL market. "People have been talking about electric vehicles for a while, and we finally have the building blocks in place to allow that to happen for the first time," Sciarra says.

with fixed gear, with the intent to introduce retraction later.

The deceleration brings the vehicle from cruise speed to a complete stop in around 20 sec. with a comfortable braking force significantly less than the 0.4g load sometimes imposed on airliner passengers by heavy braking during a landing roll.

From the hover, I then pressed the second "shortcut" button to accelerate to cruise. The nacelles tilted to accelerate the aircraft to a predetermined speed. Joby is still defining the speed options for this function, which reverses the decelerate-to-hover sequence. It is also likely the buttons will be merged into a rocker-type switch and relocated to the left-hand inceptor to fit better with the intuitive feel of its acceleration function, rather than the directional control function of the right-hand inceptor.

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**The right-hand inceptor controls ascent and descent.**

With the city now closer, I set my sights on the landing pad. To aid the approach, a blue line on the moving map display depicts the projected flightpath ahead of the aircraft and uses airspeed to calculate where it will stop if the "decel-to-hover" button is pressed at that moment. Pilots simply have to point the aircraft so the blue line rests on the destination and, when the end of the line touches the "H" of the helipad, a press of the button will bring them to a stop over the pad.

In my caution to make a safe approach, I pushed the button too early, which brought us to a hover just in front of the pad rather than overhead. Decelerating to a hover from wing-borne flight automatically blends the controls to the transitional rate command mode used for precision hover tasks.

Pushing the left inceptor forward, we edged in at just under 10 kt., and once over the pad, I let go and we stopped in the hover. I then pushed forward on the right-hand inceptor to descend, remembering the "push forward, houses get bigger; pull backward, houses get smaller" mantra used by pilots learning to fly the short-takeoff-and-vertical-landing F-35B using essentially the same aspect of the unified control law.

With my first vertical landing accomplished, I pulled back on the inceptor and lifted off—while pushing the "accel-to-cruise" button. "You're pointing where you want to go, and the airplane does all the flying," says Paines. Passing over the downtown skyscrapers, I headed to Alcatraz Island, where I allowed the blue line to guide me to another precision approach and landing by the old prison walls.

The simulator experience culminated with a conventional takeoff and landing at SFO. From a standing start on the runway, I pushed the left inceptor through the detent and rotated at 70 kt. Climbing quickly, I positioned for an approach. Aiming for a touchdown point halfway down the field, I slowed until I was over the runway threshold at just 26 kt. but with no concerns over directional control or descent rate, as the nacelles pivoted to provide lift and thrust until we gently touched down.

The simulator experience showed that, just as in the F-35, developers have taken away the concerns over flying the aircraft to enable the pilot to focus on the mission. At no point had I become worried about piloting the aircraft or about issues such as stall speed or, as a rotary-wing pilot, an overwhelming workload.

# TILTWING RESCUER

- DUFOUR AEROSPACE'S LARGE AERO3 eVTOL DEMONSTRATOR HAS COMPLETED 550 FLIGHTS
- THE STARTUP IS TARGETING THE MEDICAL TRANSPORTATION MARKET

**Graham Warwick** Washington

The tiltwing is an aircraft configuration waiting for its time to come. Despite successful prototype flights in the 1960s, no tiltwing design has entered production. But the emergence of electric propulsion has given the concept another chance.

Swiss startup Dufour Aerospace has chosen the configuration for its aEro3 electric vertical-takeoff-and-landing (eVTOL) aircraft, citing the technical success of Canadair's CL-84 Dynavert tiltwing program of 1965-75 as key to its choice.

The aEro3 will be a 5-7-seat aircraft that combines VTOL capability with cruise efficiency and speed through its tiltwing configuration and has substantially lower energy and maintenance costs than a helicopter, thanks to distributed electric propulsion.

Dufour is targeting the medical transport market initially. Thomas Pfammatter, co-founder and CEO, is

DUFOUR AEROSPACE

a helicopter rescue pilot and past chief financial officer with Switzerland's Air Zermatt. "That's where our expertise comes from," he says.

While Dufour sees the potential of eVTOL for urban and regional transport, "we believe there are a lot of hurdles to those future new markets, so we are designing aircraft that are usable for today's operations by today's operators," he says.

"I would like to have an aircraft that is plug-and-playable into the operation of a regular helicopter," Pfammatter says. "If you have an aircraft that is three or four times cheaper [to operate] than today's helicopters, we don't need a lot of other new markets to open up."

The Visp-based startup began by developing electric propulsion technology. Its first project was the aEro1 electric aerobatic aircraft. A modified Silence Twister kitplane, the aEro1 was able to stay aloft for 30 min. in aerobatic flight and 60 min. in regular flight, with a 15-min. reserve.

Dufour saw an aerobatic aircraft as a usable application for electric propulsion, as it makes only short flights and does not stray far from the airfield. "That was our baseline, to make an electric aerobatic aircraft that could fly not just for 5-10 min., but a 30-min. aerobatic flight and another 15-min. reserve so you can go around if something happens," Pfammatter says.

Having flown the aEro1 in 2016, Dufour began thinking about eVTOL concepts. "We did not want to develop anything new and saw we had to check what had already flown," he says. "The CL-84 had a fantastic reputation and turned out well in its flight behavior—how it flies and how it transitions."

The CL-84 was an experimental vertical/short-takeoff-and-landing (V/STOL) aircraft, a military transport/combat-support demonstrator that first flew in January 1965. Four were built, and the CL-84 logged 476 hr. over 709 flights. It was flown by 40 Canadian, U.S. and UK pilots who gave the tiltwing aircraft's flying qualities a generally positive review.

With a 12,800-lb. VTOL gross weight and a pair of 1,500-shp Lycoming T53 turboshafts driving large-diameter, lightly loaded propellers, the CL-84 underwent flight evaluations ranging from simulated rescue missions, dropping external stores and firing a gun, to operating from an assault carrier. But the design failed to make it into production.

The same fate befell the XC-142, an experimental tiltwing developed in the U.S. by LTV with Hiller Aircraft and Ryan Aeronautical. Intended as a triservice assault transport, with a

**Dufour's aEro3 tiltwing is designed to plug in to today's rescue-helicopter operations.**

DUFOUR AEROSPACE PHOTOS

37,500-lb. VTOL gross weight and four 3,080-shp GE T64 turboshafts, the aircraft made its first flight in September 1964. Five XC-142s logged 420 hr. over 488 flights, flown by 39 pilots.

Tests including carrier operations, simulated rescues, paratroop drops and low-level cargo extractions demonstrated the tiltwing's capability but, like the CL-84, the XC-142 did not lead to production. The idea of a tri-service V/STOL transport fell apart, only to be resurrected in the 1980s—ultimately leading to the Bell Boeing V-22 tiltrotor.

Looking back at the lessons learned, CL-84 program manager Fred Phillips in 1990 wrote that both tiltwings, while technically successful, failed because they were neither helicopters nor jets, and there were no champions for

**Two impellers inside the tail thruster provide pitch control in vertical flight.**

propeller aircraft within the military. He credited the tiltrotor's success to Bell's singular focus on rotary-wing aircraft and "prodigious perseverance over almost 40 years."

The CL-84 was mechanically complex, with cross-shafting between the engines for safety and a "mixing box" of cams and levers that ensured stick and rudder inputs produced the same responses in vertical and forward flight by scheduling the combination of control surfaces, propellers and tail rotor as a function of wing tilt angle.

Electric propulsion and fly-by-wire flight control greatly simplify the tiltwing. "We realized that this was the path to go," says Pfammatter. "It's efficient in hover because the props are big, as well having a wing and not much drag from any lifting props." Through simulation and small-scale models, Dufour has built up its understanding of the concept.

This year, the startup completed 550 test flights of a large-scale, 4.5-m-span (14-7-ft.) unmanned demonstrator. "We've been able to prove all of our models and simulations and

**The unmanned VTOL demonstrator is between one-third and one-half scale of the full-size vehicle.**

the European Union Aviation Safety Agency's Special Condition for VTOL (SC-VTOL) regulation.

Where Dufour's original concept had two propellers like the CL-84, the demonstrator has four, and the aEro3 could have four or six. "The number of props is a trade-off," Pfammatter says. "An electric aircraft has to be the most efficient design because it is limited by battery technology. Two big props are more efficient. The disadvantages come from regulations."

SC-VTOL sets a probability of catastrophic failure of $10^{-9}$ for commercial passenger-carrying eVTOLs. "If you have two props and lose one, you lose the aircraft," Pfammatter says. "Four or more props mitigate the risk of losing one. I lose a bit of efficiency, but gain redundancy."

The demonstrator showed another advantage. "Smaller props increase the propwash velocity, which improves handling characteristics," Kent says.


demonstrate we really do understand the aerodynamics of these aircraft," says Chief Technology Officer Jasmine Kent. "Actually, the simulation model was too conservative. The performance has been even better than we expected."

The data gathered is being fed into the design of the flagship aEro3, which is planned to be certified under

The wing is immersed in the propwash at all times. This keeps flow attached and also increases the effectiveness of the ailerons relative to a tail rotor, for yaw control in hover. A pair of impellers in the tail thrust up and down to provide pitch control in VTOL.

A tiltwing can also be flown in short and conventional takeoff-and-landing modes, Pfammatter says, the prop-

wash flowing back over the tail, providing aerodynamic control at low airspeed. This could allow the aircraft to carry a full seven persons on commuter operations from small airports, he says.

The aEro3 is expected to be hybrid-electric. "We put in enough batteries for the vertical phases of flight plus reserves, but the additional power for cruise can be delivered at a lower rate," Kent says. "So we can put in more batteries with a lower C [discharge] rating or a hybrid system with a range extender."

A hybrid system will be needed initially, Pfammatter believes, because the charging infrastructure will not be there. "We have days when we fly one rescue mission, but we have days where we fly 15, one after the other. I can't recharge my aircraft then. I have to be able to refuel, like a helicopter today."

Dufour believes tiltwing eVTOLs can take over 80-90% of emergency medical service (EMS) helicopter operations, except for special missions such as sling loads and long-line mountain rescue. A majority of EMS operations are hospital-to-hospital transfers, and the aEro3 is projected to be three times less expensive to operate and 1.6 times faster than a helicopter.

AW&ST ARCHIVE

The eVTOL is also expected to be four times faster than a ground ambulance, yet 1.1 times cheaper to operate. "If you take those hospital-to-hospital operations that are today done by ground transportation and you provide a more efficient solution, then you have increased the demand by a factor of 10-20," Pfammatter says. The tiltwing's speed will also increase the radius of the "golden hour," the first hour after a traumatic injury considered most critical for successful treatment.

**Canadair's tiltwing CL-84 Dynavert logged more than 700 flights from 1965 to 1975.**

Dufour plans to build a full-scale experimental prototype in 2021. "As for the certification process, we have a few more years ahead of us," says Kent. But the startup's ambition is clear. "We want to build something that can be used for lifesaving operations by today's helicopter operators," says Pfammatter. "I would like to give them the best tool, with all the advantages of eVTOL like less noise and more safety."

# Vertical Visions

> VERTICAL'S WINGED EVTOL IS PLANNED TO FLY IN 2021

> HILL'S LIGHT HELICOPTER IS TARGETED TO FOLLOW IN 2022

**Tony Osborne** London and **Graham Warwick** Washington

A pair of British startups are seeking to reboot the UK's vertical-flight industry while taking radically different approaches to breaking into the commercial market. Vertical Aerospace is backing electric propulsion with a winged tilt-prop air-taxi design, whereas Hill Helicopters is reimagining the light single-turbine helicopter.

Both companies have set aggressive timetables. Vertical plans to fly its VA-1X electric vertical-takeoff-and-landing (eVTOL) prototype within a year and is targeting European Union Aviation Safety Agency (EASA) certification for 2024. Hill plans to fly its five-seat HX50 in 2022 and is aiming for market entry in 2023.


**Vertical hopes that the 100-mi.-range eVTOLs emerging from its VA-1X design will be able to link cities as well as operate within them.**

VERTICAL AEROSPACE CONCEPT

These tight schedules are built on experience both companies have already accumulated. Founded in 2016, Vertical has flown two earlier eVTOL demonstrators: the ducted-fan POC (proof of concept) in 2018 and the multicopter Seraph in 2019. Hill has been working on development of the HX50 for 13 years and finally revealed the concept online on Aug. 24.

Vertical's gull-wing VA-1X is a radical departure from the configurations previously flight-tested by the Bristol, England-based company. "Multicopters make great technology demonstrators. . . . They are an ideal way to get to that full-scale demonstration," Vertical CEO Michael Cervenka says.

But their value proposition is "quite limited," he notes, because their low speed and short range mean the batteries must be recharged or swapped after even a short flight. "The wing gives us that opportunity to fly much faster and still be able to do some of those 15-25-mi. missions without the need for a massive recharge on the ground," Cervenka says.

Vertical has designed the VA-1X around a four-seat passenger cabin and separate cockpit. The 3,000-kg (6,600-lb.) eVTOL is designed for speeds up to 130 kt. and ranges of around 100 mi. with a payload capacity of about 450 kg.

The vehicle has been designed to fit into a 50-ft.-dia. box, allowing it to use 80% of the world's helipads and proposed urban air mobility vertiports. The main wing has a dihedral angle that provides head clearance for even the tallest passengers within the "95th percentile" of height, Cervenka says.

The VA-1X has eight wing-mounted electric motors. They are powered by eight lithium-ion battery packs distributed around the fuselage on a "ring main," so if any one pack fails, the electrical system will continue to operate on the others.

Four of the motors are mounted in the vertical position behind the trailing edge, driving four-blade lift props that operate during vertical takeoff and landing. The lift props stop and stow in a low-drag position in cruise flight.

The other four motors are mounted forward of the leading edge and drive five-blade propellers that tilt to support vertical and forward flight; the process is controlled by a Honeywell-developed fly-by-wire control system.

Vertical has put significant focus on development of the flight control system, Cervenka says, in part because he expects regulators to become "incredibly demanding" after the issues with Boeing's 737 MAX.

The VA-1X will be piloted, at least initially. "We strongly believe we're going to need pilots for a number of years," he says. "The Honeywell technology gives us an ability to have a vehicle that is not autonomous but is heavily automated."

In addition to the flight control system, Honeywell is providing the avionics and associated touch-screen displays. Vertical has not named other suppliers, but Cervenka says it plans to leverage UK expertise; as much as 85% of the aircraft will come from the UK.

"We've designed the aircraft from the start to be upgradable under the skin," he says. "It will be a modular architecture." The VA-1X prototype will feature retractable landing gear, a nod toward future-proofing the design, which could lead to a family of eVTOLs, including larger platforms with hybrid power systems such as gas turbines and fuel cells.

To help get to flight sooner, Cervenka says the VA-1X prototype will likely have a "nonoptimum power train" for initial flight tests. "Off the back of that, we will launch detailed design for our certification program," he says. The company already has a system test rig running the flight control software, and a simulator with a virtual reality headset to prepare the company's test pilots.

"We have some quite aggressive,

but we believe achievable, timescales," Cervenka says. "It is a deliberately racy program, but I think that's important in terms of maintaining that early-mover advantage." Vertical is also beginning to think about how it will produce the aircraft, recognizing that when the UAM market takes off, demand likely will exceed supply.

Although some eVTOL startups will need to raise significant investment because they are developing and planning to produce much of their aircraft in-house, Cervenka says Vertical will rely on "several key suppliers" to provide major parts of the aircraft already preassembled and tested. This will require only the establishment of a final-assembly line.

"That means we need a lot less money in terms of a capital raise than others, but it also means that we can leverage existing industrial footprints to enable us to industrialize," he says. "We think we can be one of the first to market. . . . So that ability to ramp up production and really get an early foothold is key."

Hill Helicopters, meanwhile, is leaning heavily on the expertise of Chairman and Chief Engineer Jason Hill's wholly owned company, Dynamiq Engineering. This gives Hill and his team "complete creative control to meet ambitious designs and timelines," he says. The Staffordshire, England-based company has also received a £1.4 million ($1.8 million) grant from the government's Innovate UK agency to support use of green technologies in the aircraft.

Hill believes the HX50 could reboot rotary-wing general aviation, even at a time when billions of dollars are pouring into development of eVTOLs. The "disruptive" clean-sheet rotorcraft will weigh in at 1,650-kg maximum takeoff weight with a payload capacity of around 800 kg. A 500-shp turbine engine will be capable of delivering cruise speeds of around 140 kt.

The HX50 "is not an aerial pickup truck; this is an exquisitely appointed aerial grand tourer," Hill states in videos accompanying the online launch. The few options available for private owners looking to purchase a helicopter, he says, are either older aircraft that come with higher maintenance bills or new-build machines that quickly depreciate. Addressing that gap could make private rotorcraft desirable again.

HILL AEROSPACE CONCEPT

**Hill Helicopters has set an aggressive timetable for the HX50: A first flight is planned for 2022, and market entry is slated for 2023.**

The HX50 has a conventional configuration with a three-blade main rotor and shrouded antitorque system similar to Airbus' Fenestron. Other design features include a composite structure and rotor system as well as a "reimagined" avionics suite, although no suppliers have been named. Production is planned for a site near Birmingham, England.

Unusually, the HX50 will use a turbine engine developed in-house by Hill, which has opted for a powerplant "optimized" for the helicopter rather than an off-the-shelf engine. The GT50 turboshaft will be capable of maintaining 400-shp cruise power while consuming 34-35 gal. of jet fuel per hour. Leading the work is Dynamiq Engineering, which had previously announced it was developing an "advanced sub-500-kW industrial gas turbine" but has not said when this work began.

The cockpit design separates critical flight parameters, which are hard-coded into the aircraft, from functions based on data entry, which use a centrally mounted tablet and "puck" controller. The conventional up-down collective lever is replaced by a fore-aft control more like a thrust lever and, as Hill says, is "compatible with having an armrest . . . [that] makes long flights more comfortable." The cyclic stick is mounted on the forward panel rather than the floor and pivots up to "aid entry and egress."

Hill plans to build three prototypes that will each fly 1,000 hr. to support EASA certification. "There is a lot of skepticism in the market, but what people don't realize is that Jason has been working on this for 13 years," says Mischa Gelb, a chief pilot with Vancouver-based BC Helicopters leading Hill's sales and marketing efforts.

Gelb says the HX50 is "fully funded" up to production. He does not disclose how much has been invested but insists the competition "is going to be worried." That competition is likely to come from the Bell 505 Jet Ranger X, Robinson R66 as well as Enstrom's range of light helicopters.

The light-helicopter market has failed to modernize in recent years, Gelb argues, and the HX50 will bring 2020 levels of technology to a market still dominated by technologies from the 1980s and 1990s. This is a little unfair to the competition since the Jet Ranger X was certified in 2017, although it does lean heavily on the dynamic system of the 1960s-era Bell 206L LongRanger.

Hill hopes the HX50 can capture part of the private aviation market and demand to replace hundreds of earlier-model Bell 206s and Airbus H120s now flying. Competing helicopters benefit from their appeal to markets beyond private flying, but "if you look at the market for private aircraft, [Hill] has a lot of years ahead of him in terms of good sales," Gelb says.

One of the key selling points will be low operating costs, the company says. Gelb suggests the HX50 will "achieve Robinson levels of operating cost" but with performance exceeding that of the Bell 505. The grant request to Innovate UK puts annual running costs at about £15,000. Flyaway cost has yet to be revealed.

THOMAS LAISNE

# THINK TANK FOR THE FUEL TANK

To preserve Safran amid the impact of the pandemic, CEO **Philippe Petitcolin** chose fast and strong action: cutting jobs and resorting to shortened work hours. While confident about the company's business model, he is turning to the longer-term challenge of decarbonizing propulsion. **France Bureau Chief Thierry Dubois** sat down with Petitcolin at Safran's headquarters, and **Executive Editor for Commercial Aviation Jens Flottau** joined by phone.

***AW&ST:*** **How do you see traffic recovery shaping up? In China, narrowbody traffic is now at 85-92% of its 2019 levels, but the rest of the world is nowhere close to that.** We are not at the level we expected 3-4 months ago. For our projected accounts, we were anticipating a flat third quarter, compared to the second quarter—which itself was 40% down from the same period in 2019. We were planning on an uptick in traffic in September and an acceleration in the fourth quarter.

The only area where we see a nice recovery, maybe greater than expected, is China. In Europe, traffic has been flattish, at about 50% of its precrisis level and with no sign of recovery. European states should ease restrictions and, at least, agree on a common restriction system. The situation would be a lot better.

For the U.S., we were still optimistic a week ago. We follow the Transportation Security Administration's (TSA) passenger statistics at airports, and they were showing a nice 51% increase in the first week of September compared to August. And then the numbers were down again last week. Perhaps it was due to Labor Day. We are eagerly waiting for upcoming TSA statistics.

Overall, in North America, traffic remains disappointingly flat, at 50% of its precrisis level. There is a recovery in the Middle East and South America, but this is not where we need it to sustain our activity.

**Are the production rates planned by Boeing and Airbus still too high, and where do you see them going over the next five years?** I do not think they are too high, at least for narrowbodies. Forty aircraft per month at Airbus and restarting production at Boeing—given the 450 or so 737 MAXs that were built and have yet to be delivered—are the right levels.

There is a possibility for good news in 2021 if a global recovery happens along the lines of what has taken place in China. Airbus CEO Guillaume Faury said a recovery may begin in 2022, but this could be pushed to the left. The day people start flying again, the upturn can be fast.

Widebody production is a different picture. Before we have a vaccine, it is difficult to see how the situation can evolve. Five A350s, one A330 and six Boeing 787s per month are still a lot to deliver. Such production is not in line with the current level of traffic. If it does not grow, these rates will be impossible to maintain.

If a vaccine is available in the next 3-6 months, widebody traffic can recover quickly, and the Airbus and Boeing rates will be fine.

**Airbus' strategy is to keep production relatively high, knowing not all aircraft will be delivered for now, to avoid disrupting its supply**

**chain further. Is it playing to your advantage?** In July and August, they delivered 49 and 39 aircraft, according to plan. Over the first 10 days of September, they delivered three A350s. I was expecting more aircraft to be stored but, looking at these numbers, I am optimistic that Airbus is going to deliver the aircraft they build.

**How often these days do your salespeople find themselves renegotiating contracts with airline customers? What kind of guidelines have you set?** It has happened [that] we had to renegotiate, and it will happen again. Cabin equipment is where we have been most affected.

We want to protect the relationship with our customers. We try to satisfy them, but this does not mean we say yes to every request. These are one-on-one situations, every time very specific.

**Is the engine OEM business model fundamentally at risk, given its dependence on services and aftermarket revenues?** No. Whatever the type of contract, an engine must go into a shop visit after a given number of cycles. This translates into visits 6-8 years after entry into service, 12-14 years after, 17-18 years after, and more than 20 years after (if a fourth visit happens).

We sell most of our new spare parts at the first and second shop visits. Then there is a mix of new and used spares—the latter account for up to 90% of the total at the fourth visit. So this is not where we make the profit needed for all the investments we make.

I do not expect engines less than 15 [years old] to be retired. So we can live with our current business model. Those being retired are too old to make a difference.

**Have you talked to your new counterpart at GE Aviation, John Slattery, yet?** Yes, on Day 1 . . . and even before Day 1.

**There is a thought that he would bring a lot of changes to GE Aviation, and that your relationship with Airbus possibly could benefit from being European. What is your first impression?** As far as CFM is concerned, it is a 50-50 joint venture with GE on narrowbody engines. We want to continue to work for Airbus, and even develop the next generation of engines with Airbus.

We are totally aligned with our partner GE, [in] that Airbus and Boeing are key customers for today and the future. We will equally support them.

**There is a lot going on in hydrogen and other breakthrough technologies for the next generation of engines. In the shorter term, could a geared Leap engine have a role?** In today's picture, Airbus is happy with its narrowbody market share. They have 2035 in mind for the entry into service of the next generation. This entails launching the development by 2027, and therefore the basic definition of the aircraft should be completed by 2025. This is the picture I believe Airbus has.

Now look at Boeing; in a few weeks, the MAX will just be back. If the return to service goes smoothly, CEO David Calhoun may have the same timeframe. If so, there will be no need for an enhanced, intermediate version of the Leap. Keep in mind we will make regular, small improvements on the Leap, as we did on the CFM56. Apart from that, the current Leap will be produced until 2035.

Our focus for the next five years will be to mature the best technologies for them to support an aircraft program launch in 2025-27.

**The move to greener aircraft has picked up speed. What are the pros and the cons of the various options: batteries, hybrid architectures, hydrogen as a fuel for turbine engines, hydrogen in a fuel cell?** I cannot give you the outcome of the next five years. Hundreds of millions of euros will be spent, thanks to in-house funding in addition to funding from the French government in 2020-22.

But for narrowbody and larger commercial aircraft, we do not see electric propulsion being a solution for 2035. Later on, yes; but not for 2035. We may still have some kind of hybridization to give the aircraft a little boost when maximum thrust is needed. But most of the thrust would come from thermal engines. They could use hydrocarbon fuel—synthetic fuel or biofuel—or hydrogen. The first option is the leading potential solution. Hydrogen is also a potential solution but a lot more ambitious.

We know how to burn hydrogen, we do it in space launchers. In large quantities, it has to be liquid and therefore kept at -253C (-423F). It is not easy to burn.

We are following both options without deciding up front. With GE, we want to offer, for 2035, solutions that will be mature enough to enable Airbus and Boeing to say, "We are going in this direction," or "No, we cannot."

**Do today's turbofan engine-makers have what it takes to lead in electric propulsion? In other words, could you be outpaced by a company from another sector?** It is always possible. We have not seen a lot of newcomers in the last decades, but we could imagine a SpaceX-like startup.

What I have told my teams since I have been in charge—and my predecessor was saying it already—is: "Let's keep a challenger spirit. Keep in mind an idea may come from out of our scope." For five years, we have tried to increase our understanding of electric systems to build an expertise in electric propulsion. Look at [electric vertical-takeoff-and-landing (eVTOL)] projects today—we are their preferred supplier for electric propulsion. But electric propulsion in 10-15 years will start with eVTOLs and end at 20-30-seat commuters.

**But the French government seems clear it expects a hydrogen aircraft to arrive by 2035. Is this realistic?** I have been asked this question many times, and I have one single answer. It is a very ambitious objective. Not impossible but very ambitious. For 2035, the solution with the highest potential for maturity is synthetic fuel.

**But you are cutting R&D spending by 30% this year.** We do [as] our OEM customers do. Projects are being pushed to the right if they are not a must-do. Some other projects have had their budgets cut 30-50%.

The [state-led] aerospace CORAC research committee has decided to help our industry by bringing in €300 million ($350 million) this year, €600 million next year and, again, €600 million in 2022.

**Where are you with adapting to the sharp downturn?** We have had

different approaches in France and abroad. The headcount stood at 95,000 before the crisis. This included 45,000 in France and 50,000 abroad. Some 5,000 "contract people" were coming on top of that and they are now down to 1,000. Abroad, we now have 35,000 employees. For those we laid off, we had no work over the coming years.

In France, we have benefited from extremely generous government support. At some point, we had 30-40% of our French workforce under a short-time scheme [shortened work hours].

We have been talking to unions since April, and we have played a straight game. We told them we would have to lay off 10,000-12,000 people if we did nothing. In July, we signed an agreement with all the unions.

The French government has extended the possibility to use short-time schemes in the long term. This enables us to keep 6,000 employees.

Then early retirement plans where we make contributions for employees to receive their full pension will enable us to save another 3,000 jobs.

The financial support we receive for research and development is helping us keep another 1,000.

Note that if we compare the efforts made in France and internationally, they are equivalent.

Our total headcount now stands at 81,000, but it has to decrease further. We are closing a few plants.

**The COVID-19 crisis seems to be accelerating a few things. You have fast-tracked the reorganization of your cabin interiors business. How is it progressing?** From 12,000, the cabin activity is down to 8,000 employees. We are transferring work to low-cost countries.

Let me give you one example. We were manufacturing galley monuments for the MAX in California and are transferring the activity to Mexico. Before the crisis hit, we had been contemplating the move for implementation over the next 18-24 months. We are actually going to complete it by year-end.

**What about your supply chain?** We have a long list of suppliers, mainly small ones in France. When we look at the reduction in the orders they receive from us and the rest of their customer base, we think some need support.

We have participated to the setup of a €1 billion fund, with Airbus, Dassault and Thales, to secure the supply chain. Does that mean we will be able to keep 100% of the suppliers alive? No, some will not survive, and we will see consolidation.

**Are you interested in acquisitions, as prices may drop for some targets?** Talking about suppliers, if we have no choice, we may be forced to buy some expertise. But vertical integration is not our strategy.

More broadly, things will happen at the end of the crisis. There will be winners and losers. This will be a catalyst for consolidation.

**Video** *Safran CEO Philippe Petitcolin answers further questions:* **AviationWeek.com/Petitcolin-Interview**

BUSINESS

# State Aid Will Limit French Aerospace Job Cuts

- INDUSTRY WANTS TO RETAIN SKILLED LABOR FOR THE RECOVERY
- AIRBUS MANAGEMENT TEAMS AND UNIONS ARE IN FIERCE NEGOTIATIONS

**Thierry Dubois** Lyon

As Airbus and its commercial aviation business suppliers struggle to cope with drastic reductions in production rates, jobs are under threat. In France, management teams and unions have been engaged in tricky negotiations: Although they are endeavoring to make the most of state aid, the two sides often diverge on the extent to which employees must sacrifice benefits in order to save the company.

A critical concern in the industry has been ensuring the retention of skilled labor in anticipation of a recovery. The implementation of the government's generous long-term partial activity scheme (APLD, under the French acronym) will be key.

The outcome of discussions over the coming weeks will be a critical factor in determining the eventual number of job cuts the industry must face.

French aerospace industry association GIFAS estimates that its members are operating at an average of 70% of their pre-COVID-19 level of activity. Those companies that

largely depend on Airbus Commercial Aircraft are close to 50%, following a 40% cut in Airbus' production rate that was compounded by the need to use the inventory they had built to ensure on-time deliveries.

GIFAS does not yet have an estimate of the impact of the downturn on employment. Early this year, it had anticipated its members would hire 15,000 workers in 2020.

Airbus, which has 48,000 employees in France, announced on June 30 that it plans to cut 5,000 jobs in the

country. This was part of a wider goal of 15,000 job cuts globally. After negotiations with unions, Airbus hopes to reach agreements this fall. The OEM intends to implement its so-called Odyssey plan by the summer of 2021.

The company has the opportunity to enact various measures to reduce the number of layoffs. One option is to offer bonuses for early retirements, which might be effective but would be costly. "At stake in the current negotiation is finding ways to fund such age-based measures," says Michel Pierre, the secretary of the CFDT union for Airbus Commercial Aircraft.

Employees who apply for early retirement may hope to receive 50-65% of their salary for two years in addition to a one-off bonus—better than the one usually given at retirement, Pierre explains. After two years, the standard pension would apply.

Due to the high cost, however, Airbus is effectively limiting the number of early retirements to 650, Pierre says. "We estimate more than twice that number are interested." As of late August, more than 2,400 employees had applied for one of Airbus' "mobility pathway" schemes: early retirement, entrepreneurship, training, moving to another entity in the group or starting another project.

Pierre is concerned that the airframer's management team will ask for adjustments in the pay scale such as decreasing seniority raises. Management might also ask to save on subsidies to the works council, Pierre fears. In many large French companies, works councils distribute bountiful social benefits, typically vacation packages offered at a major discount.

But employees were forced to take vacation days during the lockdown, so in essence, the CFDT says, they have already given up some of their benefits this year.

P. PIGEYRE/AIRBUS

**Partial activity schemes, funded by the French government, are intended to mitigate the impact of the downturn on employment.**

And the union contends that Airbus should be able to absorb the cost of job-saving measures, estimated at a couple of hundred million euros. In comparison, the company early this year agreed to pay €3.6 billion ($4.3 billion) to settle a corruption case. "We see Airbus maintains a high rating on financial markets and can therefore raise funds at low rates," the union adds.

Predicting an acceptable 500 aircraft deliveries this year, CFDT anticipates Airbus will emerge from the crisis in a much stronger position than Boeing.

Of the aforementioned 5,000 jobs, some 1,200 may be spared by a long-term partial activity scheme, CFDT estimates. Another 400-500 could be safeguarded, thanks to the funds the government has earmarked for the design of a carbon-neutral aircraft, according to CFDT and Airbus CEO Guillaume Faury as quoted in French finance daily *Les Echos*. For the remaining at-risk jobs, mobility pathway schemes should suffice to avoid layoffs, CFDT argues.

The APLD scheme has received almost unanimous support from unions and management teams. It involves employees working a minimum 60% of their normal week while retaining a minimum of 84% of their net salaries. Meanwhile, the employer receives state aid and has to pay only 15% of the reduced salary.

The employer has to substantiate, every six months, the rationale for maintaining the APLD scheme. It also has to commit to hiring a certain number of people, notably recent graduates, says Philippe Dujaric, GIFAS' director of social affairs and training.

"The overarching goal of an APLD is to maintain skills over a two-year period—we believe this is when the recovery will come," he emphasizes.

At Airbus, the negotiations underway may also produce a "collective performance agreement" (APC). In exchange for retaining jobs, employees make concessions on their compensation, perhaps working a shorter week with a commensurate salary reduction. Under an APC, some measures may be temporary, whereas others may be permanent.

At service provider Derichebourg this past June, majority union FO and the management team signed an APC, which FO says saved 700 jobs. The accord was controversial, however. The reduction in the workweek was substantial, and pay cuts have been painful. Moreover, 160 employees who did not sign the APC were fired.

In the French industry, "we have seen few APCs," Dujaric says. "We have [other] transformation plans that change the company's organization."

CFDT has said it would reject an APC at Airbus.

Some Airbus subsidiaries have suffered far more than their parent company. Airbus Interiors Services, for instance, plans to cut 100 of its 140 employees.

Other branches have seen little change in their productivity. There is no plan for an APLD at Airbus Helicopters in Marignane. ArianeGroup, jointly owned by Airbus and Safran, is catching up on delays that accumulated during the lockdown period, and Airbus and Safran employees have been assisting at ArianeGroup sites.

A company with dual activity may benefit from training schemes that help an employee transfer from civil to military business.

Meanwhile, metal-component supplier Figeac Aero has announced 320 job cuts at its main site, out of a total 966. An APLD is helping, the company says. CEO Jean-Claude Maillard is looking to consolidate with other players such as Lauak, Mecachrome or Nexteam, according to La Tribune finance information website and *La Depeche* daily.

The latter publication also says Liebherr-Aerospace, a major aircraft system supplier, is considering 100 job cuts and will reveal the final number after it negotiates an APLD with unions.

Engineering specialist Sogeclair Aerospace has announced a maximum 245 job cuts out of approximately 550 in France. In the first half of 2020, revenue fell 32% compared with the same period in 2019.

Unexpectedly, Normandie AeroEspace (NAE), a cluster of aerospace companies in northwest France, is seeing an opportunity and has announced its member companies are hiring. When looking for skilled workers and engineers, Normandy has long been outpaced by the southwest and Paris. NAE members, which are also active in the less affected sectors of space, defense and security, are hoping freshly trained graduates will consider locating to their region.

# DIGITAL REALITY

> FLYING FULL-SCALE NGAD FLIGHT DEMONSTRATOR ANNOUNCED

> USAF SAYS IT HAS "BROKEN RECORDS"—BUT WHAT KIND?

**Steve Trimble** Washington

The first confirmation of the existence of a flying, full-scale flight demonstrator for the Next-Generation Air Dominance program by the U.S. Air Force on Sept. 15 dropped like a lightning bolt from the black world of secretly funded military projects.

But the exciting, albeit terse, announcement during the virtual Air, Space and Cyber Conference, hosted by the Air Force Association, comes after a long series of revealing statements by defense officials over nearly a decade that point to the existence of such a program and illuminate critical details about the scope and limits of the project.

Most of the Next-Generation Air Dominance (NGAD) program details remain among the Air Force's most tightly guarded secrets. But two parallel objectives are clear: to revolutionize the air superiority mission by fragmenting the mission set among multiple aircraft types, and to disrupt how the defense industry has produced most of the state-of-the-art combat aircraft during the past half century.

The NGAD flight demonstrator confirmed by Will Roper, the Air Force's assistant secretary for acquisition, technology and logistics, plays a critical role as a proof of concept for both objectives.

Senior Air Force officials attending the virtual conference declined to elaborate on the only two statements provided by Roper about the NGAD flight demonstrator.

"NGAD has come so far that the full-scale flight demonstrator has already flown in the physical world," Roper said during his keynote address. "It's broken a lot of records and is showing digital engineering isn't a fluke."

Pressed for elaboration during two follow-up appearances with journalists, Roper offered only one other direct comment about the aircraft's performance so far: "All I can say is the NGAD [flight demonstrator] test flights have been amazing. Records have been broken, but I've been impressed at how well the digital technology transitions to the real world."

Before Roper's comments, the closest hint of the flight demonstrator's existence came about a year ago. In previously unreported comments, Gen. David Goldfein, who was then chief of staff of the Air Force, offered the most explicit, unclassified description of the NGAD program during a September 2019 press conference.

"Here's our NGAD strategy: We have five key technologies that we're investing in that we don't intend to have all come together on a single platform," Goldfein said. "They will all mature and accelerate at different paces. As they become ready, you will see us adapting them on existing platforms, sensors and weapons and also looking at new platforms, sensors and weapons."

With the exception of an adaptive-cycle propulsion system, the Air Force has not specifically linked other new technologies to the NGAD program. But the new family of systems is likely to require further advances in communications and networking, onboard electrical-power generation, thermal management of waste heat and potentially new types of armament and sensors such as directed-energy weapons and passive detection systems. Such technologies can be developed and tested on the ground but still must be validated in flight in a relevant air vehicle configuration. In his comments in 2019, Goldfein hinted about the necessity of a flight demonstrator but stopped short of providing a timeline for the first flight.

"There has to be a test article to be able to take some of these technolo-

**Boeing has released a concept of a future air dominance system linked to the Australia-based Airpower Teaming System concept, which pairs multiple advanced unmanned aircraft systems with existing or future fighters.**

BOEING

gies to mature," Goldfein said. "That's probably about as far as I can go."

But the Defense Department's interest in developing new prototypes to support the air dominance mission goes back nearly a decade. In 2014, DARPA completed an Air Dominance Initiative study, in which leading military and technology experts concluded that "no single new technology or platform could deter and defeat the sophisticated and numerous adversary systems under development," according to written testimony by a Pentagon official to Congress in March 2014.

That study prompted DARPA to launch the little-known Aerospace Innovation Initiative (AII) in fiscal 2015. The official's testimony outlined the explicit purpose of AII: "To develop and fly two X-plane prototypes that demonstrate advanced technologies for future aircraft. Teams will compete to produce the X-plane prototypes, one focused on future Navy operational capabilities and the other on future Air Force operational capabilities."

The Defense Department stopped referring to the AII program shortly after submitting the fiscal 2016 budget request, but DARPA's website remains active for the Aerospace Projects Office, which manages the AII prototyping program.

In 2016, the Air Force followed up on DARPA's study by establishing an enterprise capability collaboration team to produce the Air Superiority 2030 flight plan. The unclassified version of the plan released in late 2016 echoed elements of the DARPA study, especially the need for a family of systems. "There is no single capability that provides a silver bullet solution," stated the 11-page summary of the classified flight plan.

But the Air Force flight plan still appeared to focus on one specific member of the family called the Penetrating Counter-Air (PCA) system. This platform appeared to resemble the sixth-generation fighter concepts released about the same time by major defense companies such as Boeing, Lockheed Martin and Northrop Grumman. The industry concepts invariably featured a large, tailless, supersonic and highly stealthy aircraft with certain exotic capabilities such as defensive lasers. The flight plan described the role of the PCA as targeting and engaging other aircraft by itself as well as using the data from its sensors to feed targeting information to standoff aircraft carrying long-range missiles.

The Congressional Budget Office (CBO) has used the PCA concept to project Pentagon aircraft spending. In December 2018, the CBO forecast that the first of 414 PCA aircraft would enter service in 2030, costing an average of about $300 million each. Overall procurement spending for the PCA could total $130 billion between 2028 and 2050, the CBO reported in January 2020.

The CBO's cost estimates for the PCA appear to be based on a concept of a monolithic weapon system, such as the Lockheed F-22 and F-35. Both of those aircraft are equipped with all the sensors and weapons necessary for the aircraft to perform any mission within its operating role by itself, although they also possess a limited ability to collaborate with other aircraft types in stealth mode.

During the same period, however, the Air Force's approach to the NGAD program significantly changed. As Goldfein noted, in 2019, the conventional understanding of a PCA aircraft as a monolithic system able to perform a wide set of missions by itself no longer applies. A glimpse into the internal debate that led to the transformation of the NGAD into its current form first appeared in September 2018. Roper had assumed control of Air Force acquisition seven months earlier and spearheaded a dramatic reimagining of the concept.

"I would say [NGAD now] looks more like a portfolio than a single initiative," Roper told reporters during a September 2018 press conference.

The transition to a federated architecture for the NGAD program carried significant budget implications. Four months later, the Air Force released a spending plan for fiscal 2020-24. The NGAD budget over the five-year period amounted to $6.1 billion. Only a year before, the Air Force had planned to spend $13.2 billion during the same five-year period on NGAD. Air Force officials justified the 50% five-year reduction for one of the service's most high-profile weapon systems, saying any trace of a traditional monolithic fighter had been eliminated.

"Instead, NGAD is investing in technologies and prototypes that have produced results and demonstrated promise," the Air Force said in a statement released to Aviation Week in June 2019 (*AW&ST* June 17-30, 2019, p. 92).

At the same time, Roper introduced a new element of the NGAD strategy. The goal was no longer merely to revolutionize air warfare technology. The NGAD is a critical element of the Air Force's strategy to disrupt the traditional business model for developing, fielding, modernizing and sustaining combat aircraft. The Digital Century Series effort kicked off in October 2019, seeking to use a new set of digital engineering tools to break the traditional model.

In his indefatigable style, Roper has proselytized his vision for a "digital trinity" of engineering systems that unite the digital models for flight performance, production and sustainment into the same database. In his vision, this approach would allow designers to immediately realize the full impact of even a minor design tweak on the life cycle of a new aircraft, including the effect on the cost of production and the service life of the part.

Moreover, the Air Force—not the prime contractor—would own the underlying design rights and source

code for the operating system. The aircraft designer would deliver a set of digital blueprints, but the production, modernization and sustainment of the aircraft could be opened to competition by any company.

Although the concept invokes the Century Series of six fighters that entered service in the 1950s, Gen. Mark Kelly, the newly appointed head of Air Combat Command, says the concept more closely resembles elements of the F-117 program. Lockheed produced only 59 F-117s over the life of the program, a remarkably short production run. The F-117 also ushered a transformational capability into combat in 1991 by introducing an airframe configuration with a very low radar cross-section. Despite the F-117's record, the Air Force unsentimentally retired the fleet from regular service less than two decades later, although a handful of aircraft continue to be sighted flying on test ranges.

"It was a bleeding-edge technology that was a unique, game-changing product in the field, which we fielded and operated for a specific amount of time and then moved on to another rapidly emerging technology that we just couldn't adapt to that exact same platform," Kelly says.

The Air Force's approach to the NGAD program will be similar. Leveraging the five key technologies referenced by Goldfein a year ago, multiple types of aircraft will be developed and fielded simultaneously in small production runs, then retired within 15 years, Roper said. If realized, his vision poses severe implications for the defense industry. Defense companies are now oriented to capture winner-take-all contracts for major new weapons systems, then wield a monopoly power based on rights to the underlying intellectual property to sustain the platform over a life cycle that can last a half century or longer.

But the success of the Digital Century Series approach hinges on Roper's "digital trinity" vision. For such a dramatic departure from the traditional system, there seems little evidence that such an approach could be successful. Boeing embraced the digital engineering philosophy for the T-X program. In partnership with Saab, Boeing delivered the first T-7A prototypes within three years of launching the self-funded program during the competition for the contract. But the first production version of the T-7A has not yet flown, and the type is still four years away from the scheduled

# Reaper Replacement Reveals Bold New GA-ASI Vision

- ULTRA-LONG-ENDURANCE UAS PROPOSED
- GA-ASI HINTS AT PROPULSION ADVANCES

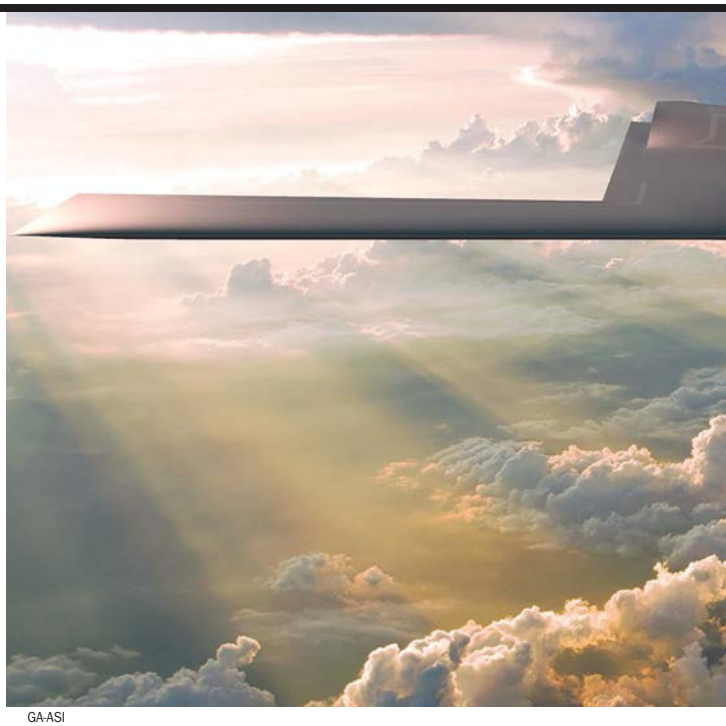
**Steve Trimble** Washington

In December 2018, General Atomics Aeronautical Systems executives still felt the bitter sting of losing a bid two months earlier for the U.S. Navy MQ-25 contract, but a clearly disappointed company president vowed to return for the next competition against the aerospace industry's largest companies. "If the [request for proposals] comes out for a major program of record, we're all-in," said David Alexander during that December 2018 interview in his offices in Poway, California.

"We'll maybe have a few more lessons learned on what to do and what not to do," he added. But we'll go in with both feet planted again and go after it."

Eighteen months later, General Atomics Aeronautical Systems (GA-ASI) is doubling-down on Alexander's commitment, releasing exclusively to Aviation Week a concept rendering of a next-generation unmanned aircraft system (UAS) that reflects the characteristics the company's designers view as essential for the class of aircraft that could replace the MQ-9 by the early 2030s.

GA-ASI was among at least five industry teams that responded to the U.S. Air Force's request for information (RFI) for a next-generation intelligence, surveillance and reconnaissance (ISR) and strike UAS to enter service in fiscal 2030. Northrop Grumman and Lockheed Martin shared concepts for next-generation UAS designs on Sept. 11. Boeing and Kratos also responded to the Air Force RFI by the July 15 deadline but declined to release concepts at this nascent stage of the bidding process.



GA-ASI

Arguably, GA-ASI invented the role of the ISR/strike UAS with the MQ-9, and the company's concept for the Reaper is no less provocative, featuring a jet-powered aircraft with distinctive, tear-shaped inlets and a long, high-aspect-ratio wingspan that appear optimized for ultra-long-range flight at high altitudes.

"We're embracing ultra-long endurance to keep our next-generation ISR/strike UAS in the fight for longer periods than many ever imagined possible," Alexander said in a statement to Aviation Week.

Although GA-ASI released no specifications with the rendering, it is clear Alexander means the next-generation concept should have even longer range than the 27-hr.

initial operational capability milestone.

By unveiling the flight demonstrator for the NGAD program now, Roper delivered a message to any critics of his approach in the industry, in Congress or, indeed, within the Air Force. As a digitally engineered aircraft fully reflecting the "digital trinity" philosophy, the NGAD flight demonstrator offered the proof his approach could deliver the next generation of combat aircraft faster and more cheaply than the traditional approach.

As proof, however, the newly revealed NGAD flight demonstrator suffers from some drawbacks. The knowledge of DARPA's AII program dating back to fiscal 2015 suggests an NGAD prototype could have been developed and flown two or three years ago. All schedule, design and performance details of the flight demonstrator remain classified, so there is no way to verify how closely the concept validated Roper's vision for the NGAD program.

Although Roper declined to elaborate, the suggestion that the flight demonstrator has already "broken a lot of records" may be significant. In a traditional program, the assumption would be that he was referring to performance records such as an average speed flown between two cities or the amount of time required to climb to a certain altitude. The spirit of Roper's vision for NGAD suggests the broken records are more likely related to production schedules, development costs and upgrade options.

Even the term "flight demonstrator" appears intentionally vague. It has been loosely applied to full-scale, competitive prototypes such as the Lockheed YF-22, but the term was also used for the F-16A Advanced Fighter Technology Integration aircraft that played a role as an early testbed in the Advanced Tactical Fighter and Joint Strike Fighter programs.

The budget documents released by the Air Force this year contained another surprise about the NGAD program. For the first time, the Air Force revealed that the Next-Generation Adaptive Propulsion (NGAP) program is scheduled to deliver a certified engine in fiscal 2025. Not all members of the NGAD family of systems may need an adaptive-cycle propulsion system, but the timing of the NGAP program suggests that an application for such an engine is likely to enter flight testing as early as fiscal 2026 and not merely as a flight demonstrator. At that point, Roper's vision will be put to the next test.

**Two years after the MQ-25 contract disappointment, GA-ASI is doubling down on its next-generation UAS with a provocative concept rendering for an MQ-9 replacement.**

endurance currently offered by the Air Force's MQ-9. The Air Force Research Laboratory defined ultra-long endurance in 2019, when a popular light sport aircraft, the Pipistrel Sinus, was modified to fly autonomously for 2.5 days over the Dugway Proving Ground, Utah. The modified aircraft was called the Ultra-Long-Endurance Aircraft Platform.

How the new GA-ASI concept achieves ultra-long endurance is likely to include intriguing surprises beyond the disproportionately long, narrow-chord and highly swept wings. The tear-shape inlets appear to feed airflow through parallel ducts down the middle of the fuselage into a mysterious propulsion system. Alexander's statement hints that the aircraft's engine is a critical element of the ultra-long-endurance capability.

"Our advancements in propulsion technology will give commanders a longer reach than ever before," Alexander said.

In the late-1990s, GA-ASI designed the MQ-9 to perform the hunter-killer UAS mission's three "F's"—find, fix and finish—by itself if necessary, with a targeting sensor embedded beneath the nose and AGM-114 Hellfire missiles along with GBU-12 laser-guided or GBU-38 GPS-guided gravity bombs under the wing. GA-ASI's next-generation UAS concept appears capable of performing the role in a similar stand-alone fashion. A faintly visible bulge under the leading edge suggests capacity for a large payload bay, allowing the future concept to carry sensors and weapons internally, unlike the MQ-9.

But the Air Force's concept of operations is changing. Whether manned or unmanned, any aircraft in the future combat fleet must be capable of finding and striking targets on their own, but they are expected to be able to operate as part of a network. Data from onboard sensors must be shared to the network, and data coming from other sensors elsewhere on the network must be receivable. GA-ASI's concept is adapted to that approach, Alexander said.

"We envision [the] next-gen ISR/strike [aircraft] as a conduit, supplier and consumer of information," he said. "We believe it is imperative that future unmanned systems are able to communicate, share information and collaborate—together and intuitively with their human counterparts—across systems and domains in record time."

The next-generation UAS also addresses the workforce needed to operate the MQ-9, including separate teams of pilots and sensor operators during cruise flight and takeoff and landing. GA-ASI notes that the company has already qualified technologies to enable the existing fleet to taxi, take off and land autonomously as well as a ground-control system that allows a single pilot to control six UAS.

"Our team has been developing and delivering automation solutions for years," Alexander said.

ALEXANDRE BEUZEBOC/FRENCH AIR FORCE

**Greece's Rafales would likely be delivered in the F3R configuration, enabling the use of the Meteor air-to-air missile and the Talios targeting pod.**

# Mediterranean Tensions Prompt Greek Rafale Plans

> GREECE WANTS 18 RAFALES TO REPLACE EARLY-MODEL MIRAGE 2000s

> ATHENS ALSO BUYING MH-60 NAVAL HELICOPTERS

**Tony Osborne** London

Greece has turned to France to urgently provide it with new fighters as tensions ratchet up in the Eastern Mediterranean.

Athens is hoping that a fleet of Dassault Rafales—the country's first major defense procurement since the 2008 financial crisis decimated the Greek economy—can provide a deterrent against what Greek ministers see as an increasingly militaristic approach in Turkish foreign policy.

Greece and Turkey have quarreled for decades over the sovereignty of the Aegean Islands, and their fighters routinely scrap in the disputed airspace above.

More recently, however, hostilities have intensified over Ankara's oil-and-gas exploration in waters disputed by both nations and Cyprus.

The Rafales, particularly if armed with MBDA Meteor beyond-visual-range air-to-air missiles, could give Greece an edge in what are generally well-balanced dogfights between Lockheed Martin F-16s from both nations as well as Hellenic Air Force Dassault Mirage 2000s. This is especially the case now that Turkey's own fighter modernization plans have disintegrated, following Ankara's decision to purchase a Russian S-400 ground-based air defense system, prompting the U.S. to kick Turkey out of the Lockheed Martin F-35 Joint Strike Fighter program.

The Rafales form part of a defense modernization plan announced by Greek Prime Minister Kyriakos Mitsotakis on Sept. 12.

A squadron of 18 aircraft would be made up of six new-build aircraft and 12 secondhand aircraft from French Air Force stocks.

Mitsotakis said he hoped the first aircraft would arrive in mid-2021 and that deliveries could be completed in early 2022. This seems unlikely unless Greece can secure production slots currently reserved for Indian and Qatari Rafales.

It takes three years to build a Rafale, so any new-build aircraft may not arrive until 2023 or later.

Even if Greek plans call for just six new-build Rafales, the deal is still a significant win for Paris: Greece will be the first European export customer for the Rafale, continuing a tradition of French fighter sales that includes the Mirage F1 and 2000 models.

Greece previously evaluated the Rafale and the Eurofighter Typhoon for a 90-aircraft buy in the mid-2000s, but ministers ultimately opted for additional batches of F-16s.

Greek officials have also confirmed that the Rafales will replace older-model Mirage 2000s currently in service, but the 2000-5 models capable of firing the MBDA Mica air-to-air missile will be retained. Some 24 of the upgraded Mirages are in service, according to the Aviation Week Intelligence Network's Military Fleet Discovery database.

Mitsotakis said the Rafale was selected because the Hellenic Air Force was already operating French-built aircraft.

"We have a close relationship with France, and an opportunity was found to restore that," said Mitsotakis. "France was willing to withdraw some very slightly used Rafales to buy new ones. We found an opportunity to significantly strengthen our aviation with aircraft in which we already have experience." He also noted that it was "very easy" for a Mirage pilot to be trained on a Rafale.

"The [Hellenic Air Force] has been looking at beginning to recapitalize its combat aircraft fleet for some considerable time—economics, however, got in the way," says Douglas Barrie, aerospace fellow with the London-based International Institute for Strategic Studies. "With relations with Turkey deteriorating, this may have proved the required impetus to revisit acquiring a new combat aircraft," he adds. "And the Rafale as such was a credible contender."

Adding the Rafale will mean that Greece will again face the expense of operating no less than four different frontline fighter types, with both the Rafale and Mirage 2000 flying alongside different blocks of the F-16. The Greek fleet is also one of the last bastions for the McDonnell Douglas F-4 Phantom.

In addition to the Rafales, Athens' defense modernization plans also include four new Sikorsky MH-60R naval helicopters supplied from the U.S. to equip the Hellenic Navy's four Hydra-class frigates, based on the German MEKO warships, which will be upgraded.

The Hellenic Army will receive new anti-tank weapons, while the navy will receive heavy torpedoes for its submarines, and the air force will receive guided missiles, likely as part of a weapons package to equip the Rafales.

Mitsotakis said he is confident the country's fragile economy will be able to support the modernization plans because of the long-term nature of the programs. Ministers had previously said they were planning to use cash reserves to bolster the armed forces, having built up a buffer of unused bailout funds and money raised from markets.

The French defense ministry said the selection of the Rafale would strengthen links between the Greek and French armed forces and allow them to intensify operational cooperation. It is unclear, however, how France might spare any Rafales, given commitments of the fleet to both the nuclear deterrence mission and operations overseas and since it has also proposed selling 12 Rafales to Croatia, delivering a bid to Zagreb on Sept. 9.

On top of the planned Rafale buy, Greek industry is undertaking the upgrade of 80 F-16s with an active, electronically scanned array radar. The armed forces are also planning to lease Israel Aerospace Industries Heron medium-altitude, long-endurance unmanned aircraft systems to patrol the country's maritime borders and have begun talks about purchasing F-35s. But such a procurement is unlikely until the mid-2020s, ministers have said.

# RAF Targets Technology as Review Shapes UK Armed Forces

> ASTRA INITIATIVE IS PREPARING AIR FORCE FOR INFORMATION AGE

> NEXUS/RAVEN COMMUNICATION HAS BEGUN FLIGHT TESTS

**Tony Osborne** RAF Waddington, England

The British Armed Forces are engaged in a technology race—as opposed to an arms race—as they look to gain the advantage in the government's upcoming Integrated Review.

Ministers have promised that the review—the largest since the end of the Cold War—will provide direction for post-Brexit Britain's foreign policy and defense posture, deliver much-needed reforms and modernization and, in addition, bolster the UK's defense industry (*AW&ST* March 23-April 5, p. 46).

Defense Secretary Ben Wallace has called on the armed services to be "more capable in new domains" and "active in more theaters," reflecting concerns that the UK's adversaries have spread themselves out across the world.

The Royal Air Force (RAF) believes it can answer that call to arms. On Sept. 15, the 80th anniversary of the key RAF victory in the Battle of Britain, Air Chief Marshal Mike Wigston said it was making investments so that the air force could "understand, decide and then act faster, with even greater precision, lethality and in more places around the world simultaneously than we do today."

Wigston added: "Instead of mass and mobilization, defense will focus more on speed, readiness and global reach—what air and space power does best. . . . Air and space power give our government the ability to act worldwide: at range, at speed, precisely and with minimal physical and political risk."

While the review may not be the existential clash the Battle of Britain was, commanders are hoping the RAF's unmanned aircraft systems (UAS), network-centric warfare, accelerated development, preparations for a greater role in space and support of the UK's prosperity agenda—with grand plans for the UK to develop a Future Combat Air System (FCAS), Tempest—will all combine to help them maintain the status quo and keep their future procurement plans intact.

Although the review is still at least two months from publication, there are some signs the RAF may well emerge as a winner and largely unscathed; the other services perhaps less so.

British media reports that the British Army could lose its main battle tanks have not been entirely dismissed by ministers. "We're not scrapping all tanks," Wallace told reporters.

Indeed, he has previously warned that the UK's "sentimental attachment . . . [to a] static, armored-centric" force in Europe has timed out and that the UK needed to look more globally.

Developing the Tempest appears to be a priority for the review, in part because it is generating "cutting-edge technology," said Wigston. Just as important, it is stimulating innovation and encouraging international partnerships such as those with Italy and Sweden. In addition, it is creating and retaining jobs for thousands in the North of England, a region the ruling Conservative government has promised to economically "level up" after years of regional stagnation and unemployment.

Work on combat aircraft has boosted UK prosperity. The Lockheed Martin F-35 program is expected to generate £35 billion ($45 billion) for the British economy, while the UK's share of Eurofighter Typhoon work has brought in another £28.2 billion. Questions remain, however, as to whether the UK can afford the Tempest and a full complement of 138 Lockheed Martin F-35s, albeit over the lifetime of the program.

Initiatives such as the RAF's Astra program are expected to update the RAF's facilities and infrastructure and—most crucially—prepare its personnel for the information age. It will enable them, said Wigston, "to manage vast amounts of information and make decisions more quickly and accurately."

The RAF is exploring the use of digital air traffic control towers and will soon begin testing one at RAF

Lossiemouth, Scotland, one of its busiest stations. In addition to supporting the force protection of airfields, wider use of digital control towers—notably at airfields with only a small number of movements a day—could enable the RAF's surplus of air traffic controllers to be reassigned to different tasks.

Another base in Leeming, England, is planned to become a live testbed for a next-generation station, with the RAF partnering up with academia and tech companies. RAF Waddington, England, home to the RAF's intelligence, surveillance and reconnaissance (ISR) platforms and future home of its MQ-9 Protector UAS fleet, will become part of a regional science and technology cluster.

The wind seems to be blowing in the right direction for the RAF's Future Combat Air System to replace the Typhoon in the 2030s.

BAE SYSTEMS

One of Astra's key aims is to consolidate the numerous networks the RAF operates and transition them to a combat cloud capable of handling terabytes of data. Testing for the airborne element of such a network, known as Nexus and developed by the RAF's Rapid Capabilities Office, took to the air for the first time on Sept. 15, onboard an RAF Airbus A330 Voyager Multi-Role Tanker Transport aircraft. Part of the RAF's Babel Fish data link trials, Nexus works off Raven, a micro-virtualized server, which is then able to distribute data from Nexus to compatible air, land and sea units.

Increased combat mass will also be realized through the addition of remote and autonomous additive capabilities. These include the Alvina swarming drones program to overwhelm enemy air defenses, led by Blue Bear Systems Research and demonstrated to commanders in the spring. Meanwhile, decisions are imminent on the next stage of the Lightweight Affordable Novel Combat Aircraft (LANCA) technology demonstration program—also known as Mosquito. One or two of the three bidders will be selected to proceed with manufacturing and limited flight testing of a demonstrator.

LANCA platforms could be an adjunct for the RAF's frontline fighters, capable of carrying weapons or sensors into the fight. They could also be used in operations alongside F-35s and Typhoons, long before the Tempest platform enters service in the mid-to-late 2030s—a modern version of Douglas Bader's Big Wing approach to air combat during the Battle of Britain.

More than 90% of the RAF's frontline combat air fleet is manned, but widescale use of systems such as LANCA and the introduction of the Protector will shift the ratio the other way in the coming years, ministers have suggested (*AW&ST* July 27-Aug. 16, p. 50).

UAS also feature in the investment plans of the other services. Funding is being made available for the development of UAS that could eventually be armed to operate in urban environments to reduce the risk to dismounted soldiers. Meanwhile, an initiative called Tiquila calls for a man-portable UAS for ISR in the field, and the Royal Navy is looking at drones that would deploy unmanned underwater vehicles or even lightweight torpedoes, instead of using shipborne helicopters.

RAF commanders are also exploring how to better use existing assets, including making more use of synthetic training, targeting a 70:30 synthetic-to-live flying mix by 2030.

Such a move could allow combat aircraft that are currently attached to operational conversion units or training squadrons to then be used by frontline squadrons, enabling an increase in the available operational fleet.

Despite identifying long-range missiles as a threat to the UK and its allies, there was no mention by Wigston of developing an anti-ballistic missile capability, ground-based air defense or seeking a hypersonic capability.

Fleet numbers could also be affected. *The Times* newspaper reported on Sept. 22 that defense planners had reopened negotiations with Boeing to reduce the number of E-7 Wedgetail airborne early warning aircraft on order, from five to as few as three. The result would be little slack in the fleet in the event of surged operations. The first of the Wedgetails, which will replace the UK's E-3D Sentry fleet, is due to enter service in 2023.

The review is also expected to call for a new medium-lift helicopter to replace the RAF's aging Pumas, which are some of the oldest airframes in the fleet despite a 2012 upgrade. Such a program could be a boost for Leonardo Helicopters, but the British Army, which is often the primary customer for the helicopter, has agreements with the U.S. Army for "closer affiliation" on its Future Vertical Lift modernization initiative. The review may also outline the need for a new Command Support Air Transport aircraft to replace the four-strong fleet of BAe 146s used for VIP and transport missions.

"It will be the superiority of the decisions our people make that will preserve the Royal Air Force's decisive edge into the future," Wigston said. "That's as true today as it was in 1940."

# Hints of Life in Clouds of Venus

> HIGH CONCENTRATIONS OF PHOSPHINE FOUND

> GAS IS PRODUCED BY LIFE ON EARTH

**Irene Klotz** Cape Canaveral

The search for habitable environments beyond Earth has led to Mars, several moons of outer Solar System planets and Ceres, the largest body in the main asteroid belt. Now a new discovery has scientists looking at Earth's nearest neighbor, Venus, which could be harboring life in its clouds.

It is difficult to imagine anything surviving on Venus, a hellish place with a dense carbon dioxide atmosphere, a surface pressure equivalent to 3,000 ft. below sea level on Earth, and the hottest ground temperatures anywhere in the Solar System.

Roughly the size of Earth, Venus is shrouded in persistent clouds of sulfuric acid. It may have once sported oceans on its surface, but those are long gone due to a runaway greenhouse effect that has pumped surface temperatures to about 867F, hot enough to melt lead.

But temperatures and pressure are more benign high up in the Venusian clouds, fueling speculation about the possibility of life—though how microbes shield themselves from the highly dehydrating and corrosive effects of sulfuric acid is unknown.

Scientists have a powerful new incentive to figure that out. A team led by astronomer Jane Greaves, with Cardiff University and the University of Cambridge in the UK, has discovered phosphine gas ($PH_3$) in Venus' atmosphere, a combination of phosphorus and hydrogen that on Earth is associated primarily with biological activity in oxygen-free environments. The research was published in the Sept. 14 issue of *Nature Astronomy*.

"We are not claiming we have found life on Venus," says study co-author Sara Seager, with the Massachusetts Institute of Technology. "We are claiming the confident detection of phosphine gas, whose existence is a mystery."

Using the James Clerk Maxwell Telescope at the Maunakea Observatory in Hawaii, scientists in 2017 found $PH_3$ in concentrations of 20 parts per billion in cloud layers 33-38.5 mi. above the surface of Venus. The discovery was confirmed in 2019 by the Atacama Large Millimeter/submillimeter Array in northern Chile.

Another year of work followed to analyze if meteorites, lightning, chemical processes within the clouds or something on the surface of Venus could account for existence of the gas.

"Phosphine can be produced by some processes on Venus, but only in incredibly tiny amounts. It's not enough to explain our observation," Greaves says. "We're left with this other exciting, enticing possibility that perhaps there is some kind of life in Venus' clouds."

Earth has life in its clouds, the result of bacteria swept up from the planet's surface making new homes in liquid water droplets or floating in the clouds. Sometimes they are transported across continents before rain carries them back to the ground.

On Venus, where the clouds are permanent, scientists hypothesize that any bacteria-like particles would reside inside droplets of hydrosulfuric acid—even though the acid itself is incredibly harsh.

"Life would live inside these droplets, metabolizing and reproducing," Seager says. "The droplets collide and, over months or a year or so, would get big enough and heavy, so that they would fall or rain out of the atmosphere. Unlike here on Earth, where the rain hits the surface of the planet, the sulfuric acid rain droplets would evaporate, leaving a dried-out hypothetical spore, which—being light enough now—would not fall any further.

"These spores could populate a lower haze layer right beneath the Venus clouds," she adds.

"The haze layer is mysterious. People don't have much understanding of it, but it is long-lived and very stable," Seager continues. "After some time, some of the spores would eventually be up-drafted back into the temperate zone, absorb liquid, become hydrated and the life cycle will continue."

The question about whether the phosphine is being produced by microbes or some unknown phenomenon has regalvanized interest in Earth's nearest neighbor. Two Russian Vega missions launched to Venus in December 1984 included balloons and landers for atmospheric descent. They detected atmospheric phosphorus as an element, but their sensors were not equipped to assess additional chemical speciation. Earlier this year, NASA selected four possible future Discovery-class missions, including two focused on Venus, for further concept studies and development.

"We hope our work will motivate space missions that go to Venus and directly measure gases in the atmosphere," Seager says.

*—With Mark Carreau in Houston*

### Missions to Venus

Probes do not last long on Venus, where surface temperatures are 800F hotter than Earth's and the pressure at ground level is like being 3,000 ft. beneath the surface of the ocean. Still, nations have tried. Here is a look at present and past missions to Venus.

| Spacecraft | Country | Time at Venus |
|---|---|---|
| Akatsuki | Japan | 2015-present |
| Venus Express | Europe | 2006-14 |
| Magellan | U.S. | 1990-94 |
| Vega 1, 2 | Soviet Union | June 11 and June 15, 1985 |
| Pioneer Venus 1, 2 | U.S. | 1978-82 |
| Venera 4-16 | Soviet Union | Intermittently 1966-1983 |
| Mariner 5 | U.S. | 1967-68 |
| Mariner 2 (first flyby) | U.S. | 1963 |

*Source: NASA/Planetary.org*

This false-color image of Venus was taken by the ultraviolet light imager on Japan's Akatsuki spacecraft, currently operating at Venus.

JAXA/ISAS/DARTS/DAMIA BOUIC

# In-Orbit Asset Defense To Shape France's Space Command

> FRENCH AIR FORCE BECOMES AIR AND SPACE FORCE

> NANOSATELLITES IN DEVELOPMENT FOR ARMED PATROL

**Thierry Dubois** Paris

States increasingly view satellites as strategic assets. And the French government believes that some spacecraft are under threat from emerging anti-satellite weapons on the ground as well as from in-orbit hostile spacecraft. A Russian satellite, Luch Olymp, is believed to have neared a French-Italian satellite used for military communications in 2017 and attempted to intercept its signal.

MIREXON

France's Syracuse military communications satellites will receive proximity surveillance cameras.

It was a watershed event for the way the French military regards space. Now, like its counterparts in a growing number of countries, it envisages space as yet another field of confrontation.

China has increased its military spending in space eightfold, to an annual $7 billion, says Gen. Michel Friedling, France's chief of Space Command.

Last year, the U.S. established the Space Force as a separate branch of the military, and Italy announced the creation of a Space Command; now the UK is about to follow suit.

In the summer of 2019, the French armed forces ministry created its Space Command and announced that the Air Force would become the Air and Space Force. The latter change was effective this past July. The Space Command is replacing a joint organization that was considered ineffective.

A wide-ranging force restructuring is in full swing. The idea is to bring together all of France's expertise in the field—be it operations support, orbit monitoring or active defense—and grow it.

France aims to have a fully fledged organization to protect its satellites by the middle of this decade. As planned, that will include an exhaustive range of sensors in orbit and on the ground, powerful data-analysis capabilities and associated operator-training schemes.

"We essentially have optical and radar data," Friedling says. "We need other electromagnetic sources. . . . At stake, in the current capability expansion effort, is monitoring every object on every orbit. We are moving from predictable orbits to tracking objects on less predictable trajectories—these [unfriendly] objects are fetching something."

An object's entire history should be ascertained from launch, to determine its origin. This entails massive data storage capacity, quick access and powerful computing. The Space Command is aiming at autonomy in data analysis.

For sensing, it will partly rely on third parties. ArianeGroup was tapped for the optical monitoring of the geostationary arc with its GeoTracker network of ground stations.

Existing sensors include the Graves low-Earth-orbit monitoring radar, the Tarot telescopes and some means that were designed to follow the trajectory of tested missiles such as the SATAM radars and the French Navy's Monge ship.

And new means are on the way. Graves' successor is in development for initial operations in 2023 and full capacity in 2030. Two new-generation military communications satellites, Syracuse 4A and 4B, are due to be launched in the early 2020s. Armed Forces Minister Florence Parly has required the addition of proximity surveillance cameras to the design.

The first of a pair of new-generation Earth-observation satellites for military purposes, CSO-1, was placed into orbit in 2018. CSO-2 is to follow by year-end. They are part of the €5 billion ($5.9 billion) earmarked for space-related capabilities in the 2019-25 military programming law.

In addition to observation, the Space Command will have capabilities to act in orbit. Nanosatellites designed for patrol missions are planned for entry into service in 2023. To "dazzle" a threatening spacecraft, lasers are in development for integration into patrol spacecraft and strategic satellites. Spacecraft developed to recover debris with a net or harpoon could be repurposed.

France's Space Command will have its headquarters in Toulouse and unite staff currently scattered across four sites in the country. A temporary building will be installed next year; a permanent one is expected in 2023.

The total head count in the Space Command will gradually increase to a targeted 470 in 2025, from last year's 220. Know-how such as satellite station-keeping is being transferred from CNES, the national space agency.

The Air and Space Force is still in the process of defining the way the operations center will work. It is taking inspiration from CNES as well as Italian and U.S. sites, Friedling says.

International cooperation will be crucial, especially in space situational awareness. A framework agreement was signed in that domain with Germany as well as a letter of intent with Australia. Since February, France has been a partner in the Combined Space Operations initiative along with Australia, Canada, Germany, New Zealand, the UK and the U.S.

ASK THE EDITORS

# Why Do Airlines Continue To Resist Electric Taxi Motors?

**Aviation Week Executive Editor for Technology Graham Warwick responds:** As a way to reduce airliner fuel consumption and emissions, electric taxiing looked technically promising when it was first demonstrated in 2005. But economic reality can be different. One project is progressing toward certification, but others have been canceled or put back on the shelf for future use.

Without doubt, taxiing on the power of electric wheel motors works. It has been tested often enough to prove that. The problem is the ratio of benefit to cost in commercial operations. Of the two programs that continue, one is aimed at retrofitting older aircraft, for which the benefit would be higher; the other is targeting integration of the system into the design of future aircraft, for which the cost could be lower.

WHEELTUG

The premise is simple: Using wheel motors and not engine thrust to taxi reduces fuel burn, emissions and noise. Electric taxiing was first demonstrated in 2005 by Boeing Phantom Works and Chorus Motors, using an electric motor attached to the nosewheel of a Boeing 767 and driven by the auxiliary power unit (APU). The company WheelTug was formed to commercialize the technology.

Other demonstrations followed. In 2011, German aerospace center DLR, Airbus and Lufthansa Technik modified an A320 to test an electric-driven nosewheel powered by a zero-emissions fuel cell. That same year, Lufthansa teamed up with L-3 Communications and Crane Aerospace to demonstrate electric taxiing using motors in the main wheels of an Airbus A320. But the GreenTaxi project was later quietly dropped.

At the Paris Air Show in 2013, Honeywell and Safran demonstrated the jointly developed Electric Green Taxiing System (EGTS), catching the world's eye by pirouetting an A320 around the Le Bourget concrete on mainwheel drive and APU power only. Air France and Airbus signed on to support development.

But in 2016, in the midst of low oil prices, Honeywell terminated its EGTS joint venture with Safran. The French systems manufacturer continued on its own with development but in 2019 was forced to shelve plans to equip A320s when Airbus lost interest, publicly citing insufficient system performance and maturity.

Safran says it continues to work on an electric taxiing program "to be directly incorporated into the next generation of short- and medium-haul [single-aisle] aircraft." The company says the system will reduce fuel costs 4%, cut emissions and noise as well as increase on-time takeoffs.

That leaves WheelTug as the only company still working on an electric taxiing system that could be fitted to today's airliners to reduce fuel consumption and emissions. It has been a long haul. At one time, Delta Air Lines planned to begin using the system on its Boeing 737NGs in 2009.

Today, WheelTug is expecting supplemental type certification on the 737NG by the end of 2021 and entry into service early in 2022. The A320 is planned to follow. The company staged a public "test drive" at Memphis International Airport on Sept. 15 with a preproduction system fitted to a 737-800.

With letters of intent from more than 25 carriers to fit more than 2,000 aircraft, WheelTug CEO Isaiah Cox says airlines are increasingly supportive of electric taxiing. But because it benefits older, shorter-range aircraft more than new longer-range ones, there is no natural incentive for the OEMs to support e-taxi. This is because the system adds weight.

On longer flights, the fuel burned carrying that extra weight offsets the fuel saved taxiing electrically. And orders for single-aisles have shifted dramatically toward longer-range, more fuel-efficient aircraft such as the Airbus A321LR, reducing the perceived benefit. That may change when e-taxis can be designed into the next generation of single-aisles from the outset as part of concerted efforts to minimize carbon emissions. For now, WheelTug's slow progress toward an aftermarket modification holds the only hope for fielding the technology in the near term.

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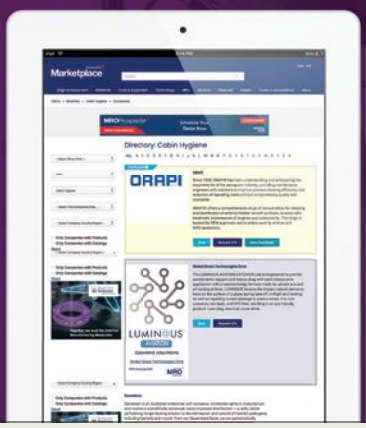


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# Aerospace Calendar

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**Sept. 29-Oct. 30**—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations. See rtca.org/content/upcoming-committee-meetings

**Sept. 28-29**—UAV Technology 2020 Conference. Virtual event. See asdevents.com/event.asp?id=22251

**Sept. 30**—Mediterranean Business Aviation (MBA) Summit 2020. Virtual event. See asdevents.com/event.asp?id=22372

**Oct. 5-8**—Forum 76: The Future of Vertical Flight (Vertical Flight Society's 76th Annual Forum & Technology Display). Virtual event. See vtol.org/forum

**Oct. 5-8**—Association for Unmanned Vehicle Systems International (AUVSI): XPONENTIAL 2020. Virtual event. See xponential.org/xponential2020

**Oct. 5-9**—National Business Aviation Association GO–Virtual Safety Week. Virtual event. See nbaa.org/professional-development/on-demand-education/nbaa-go/virtual-safety-week

**Oct. 6-7**—Air Mission Planning and Support Conference. Virtual Event. See smi-online.co.uk/defence/uk/air-mission-planning

**Oct. 12-14**—International Astronautical Congress–The CyberSpace Edition. Virtual event. See iafastro.org/events/iac/iac-2020

**Oct. 13-16**—Association of the United States Army (AUSA) Annual Meeting. Virtual Event. See meetings.ausa.org/annual

**Oct. 19-20**—SpaceCom. Virtual event. See spacecomexpo.com

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**Oct. 19**—Aviation Week Laureates Awards. Virtual event.

**Oct. 19-21**—Aviation Week DefenseChain Conference. Virtual event.

**Oct. 20-21**—Aviation Week Program Excellence Awards. Virtual event.

**Oct. 26-27**—TakeOff North America 2020. Denver.

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

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

**Nov. 11**—CAPA Live. Virtual event.

**Nov. 16**—Business & General Aviation Conference. Virtual event.

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

**Nov. 30-Dec. 4**—Routes Reconnected. Hybrid event. Amsterdam.

**Dec. 2-3**—CAPA World Aviation Outlook Summit & Global Awards for Excellence. London.

**Dec. 9**—CAPA Live. Virtual event.

## ADVERTISERS IN THIS ISSUE

VIEWPOINT

# How To Break Exponential Cost Growth

By **James Chew**

The recently published viewpoint "Can the Pentagon Spend More Smartly?" (*AW&ST* Aug. 31-Sept. 13, p. 58) highlights the consequences of increased dependence on technology to maintain an edge. In fact, the core issue of the exponential growth in cost associated with the linear growth in technology capability is highlighted in Norman Augustine's 1982 book *Augustine's Laws*. Specifically, two of "Augustine's laws" focus on what needs to be avoided within the Defense Department acquisition community.

One law states: "In the year 2054, the entire defense budget will purchase just one aircraft. This aircraft will have to be shared by the Air Force and Navy three and a half days each per week, except for leap year when it will be made available to the Marines for the extra day."

Additionally, the book highlights the Defense Department's growing dependence on electronic systems with this law: "After the year 2015, there will be no airplane crashes. There will be no takeoffs either, because electronics will occupy 100% of every airplane's weight."

Even if these laws seem outlandish, the book's underlying lessons still ring true today.

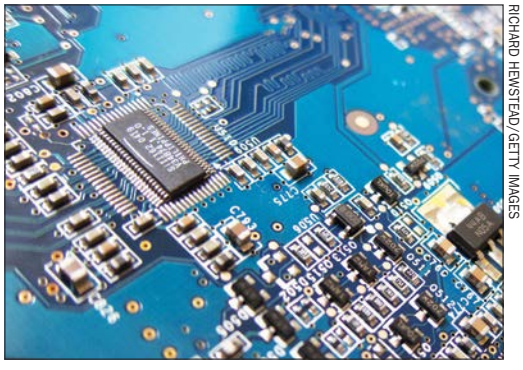
For decades, the Pentagon was the driving force behind the development of microelectronics until, interestingly, the commercial sector ended up in the driver's seat.

To share a little history, the Army-funded Micromodule project was the precursor of the integrated circuit, and the Very Large-Scale Integration project created today's electronic design automation companies and resulted in the development of multichip wafer fabrication technology. The fact is, today's microelectronics technology would not exist or would almost certainly be less sophisticated if not for a few brave and visionary Defense Department project officers.

The electronics industry is likely the most visible and significant example of a commercial market that not only transitioned from but significantly advanced technology developed by the U.S. military. Without the government investment, the device on which I am writing this article and the one on which you are reading it would perhaps not exist.

There are lessons to be learned from both the public and private sectors, and best practices from each can certainly be applied cross-functionally to optimize outcomes.

For example, the commercial electronics industry has enabled electronic systems companies to develop high-quality, sustainable and modernizable products on a "can't-miss-Christmas" schedule. Much of the industry's success is due in large part to an adherence to "first-pass success" and the computational software tools and processes that enable it. These tools and processes have been developed by companies that invest significant portions of their annual sales—some up to 40%—into research and development ("IR&D" to you in the Pentagon) and are a result of the intense competition within the unforgiving consumer electronics market. These tools and processes, which have institutionalized the product development practice of "emulate before you fabricate," make up the foundation of on-schedule, on-cost product development.



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**THE ANSWER IS OUT THERE—ADOPT COMMERCIAL BEST PRACTICES TO SAVE TIME AND MONEY.**

The best-case scenario is that the current Defense Department and defense industry electronic development process matches up with the commercial electronics development process, where they both seek to achieve "first-pass success." Even if all things were equal, which they aren't, the commercial timeline would still be around 30% that of the defense timeline. Eliminating the need for prototype hardware and the associated tests and reworks is a major reduction in design time and cost.

So after so many years of funding research into electronic design and development, why have the Defense Department and defense industry turned away from the commercial processes that stemmed from that investment? Why aren't these processes being adopted?

Congress appreciates that transitioning to commercial electronics best practices is the basis for much-desired firm, fixed-price acquisition. The fiscal 2017 National Defense Authorization Act, reinforced by the fiscal 2021 Defense Appropriations Act, has an entire section on transitioning to commercial electronics best practices. Program offices and some individuals within the defense industrial base are seeking to better understand the commercial industry-proven way to develop electronics that reduce design schedules by at least 70%, producing "first-pass success" electronic systems that are immediately sustainable and agilely modernizable.

The answer is out there—adopt commercial best practices to save time and money. With nontraditional companies entering the picture (what's the name of that space company?), the public sector should have plenty of motivation to implement tools and processes that are prevalent and successful in today's private sector.

*James Chew chairs the National Defense Industrial Association's Science and Engineering Technology Division and is the global group director for Cadence Design Systems.*

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