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July 31-August 13, 2023 · Volume 185 · Number 15

47 *Falcon Neuro is fast enough to capture flashes of lightning.*

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FEATURES

ON THE COVER

More than 15,000 U.S. and allied forces are participating in a series of exercises across U.S. Indo-Pacific Command, such as this one at Andersen AFB in Guam, to showcase how they would fight a new type of war in the Pacific. Pentagon Editor Brian Everstine's coverage begins on page 36. U.S. Air Force photo by Tech. Sgt. Michael Cossaboom.

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FEEDBACK


LOCKHEED MARTIN

ENGINE ACCOUNTABILITY

"F-35 Engine Debate Prompts Paris Broadside From RTX" *(July 3-16, p. 20)* raises some questions about Lockheed Martin. Isn't the aircraft builder supposed to ensure that the engine it adopts is adequate to perform that aircraft's mission? If it is not adequate, shouldn't the cost of making it so (or of replacing it) be charged to that builder?

Furthermore, if the Adaptive Engine Transition Program (AETP) engine were to replace the F-135, what is to be done with the hundreds of new or low-time F-135 engines, which cost billions of dollars? If they are to be scrapped, junked or trashed, I say pile them in a giant mountain on the Pentagon lawn with a sign announcing: "Whoops!" As a taxpayer, my reaction would be a deep desire to see government and industry heads roll. (I assume taxpayers of our overseas allies, who bought many more of the F-35s, would be equally scandalized.)

I suggest that those who created this debacle, if they wish to survive it, fix the F-135 engine without further ado, and (properly this time) complete the development of an AETP engine in time for our next-generation air superiority fighter.

Anthony Teague, Palm Coast, Florida

CARAVELLE COMMENDATION

"Family Business" *(Oct. 24-Nov. 6, 2022, p. 42)* is an interesting look back at the Airbus A300, but it refers to the Dassault Mercure and Sud Aviation Caravelle in the same sentence in a negative way. True, only 10 Mercures were built and flew with Air Inter until retirement. On the other hand, 282 Caravelles were produced—a substantial number in those days.

Both the Caravelle and the de Havilland Comet IV started flying in the mid-1950s. The Caravelle was a much more advanced aircraft, with its modern hydraulics and other innovative systems. Pilots liked flying it, and when I was a passenger on a Finnair Super Caravelle from Amsterdam to Helsinki in 1979, I liked it. It was an attractive aircraft to look at on the apron.

Phillip Nackard, Flagstaff, Arizona

MOON AND MARS TRIPS

Reading "Doing Business on the Moon" *(July 17-30, p. 32)*, I recalled that in the early 1950s, Wernher von Braun speculated on the configuration of a trip to Mars—10 "ships" traveling together, reminiscent of Columbus' three, carrying seven passengers each.

His *The Mars Project* has calculations of fuel loads, altitudes, velocities, orbits, correction burns, reentry and three-stage launch along with lots of drawings and supporting equations, tables of materials, positions, times, etc. All of it was done with a slide rule.

A comparison of current real and in-progress trips to the Moon with von Braun's speculation of a trip to Mars would be fascinating.

Tom Budlong, Los Angeles

SUBSCRIPTION SAVIOR

In the June 19-July 2 issue, Editor-in-Chief Joe Anselmo mentioned that in 1960 Ed Kohl was refused a subscription because he was "not in the industry" *("Air Shows in the Digital Age," p. 114)*. In about 1958, I encountered the same refusal as a high school student and student pilot. (It was "Aviation Week" back then—"& Space Technology" was added two years later.) A friend of the family who was a Northeast Airlines pilot came to the rescue and convinced some staffer that I was worthy, and I got the subscription. Thanks to that unknown staffer long ago for influencing my varied 49-year career, all in aerospace.

David Skilling, Marietta, Georgia

ONLINE, in response to "Rolls-Royce Steps Up Hydrogen Fuel Tests For Zero-Carbon Goals" *(July 17-30, p. 54)*, **KURT** writes:

The deal here is designing a commercial aircraft that can carry a fair number of passengers that burns hydrogen and can make a profit for an airline in service. Well good gosh, that will take light enough and large enough cryogenic tanks that can store the liquid hydrogen stuff at 6,000 to 10,000 psi pressure. (Correct me if I'm wrong here on the psi.)

ROLLS-ROYCE

It's a pipe dream that I think might just be workable and better than flying on electric motors and batteries. Yeah, they're doing batteries now with low-capacity, short-range stuff, but in my opinion, battery-electrics are much farther down the road than hydrogen. Sure, get a turbine hydrogen-powered engine running and the problem becomes trying to carry enough cryogenic liquid-fuel hydrogen so it can fly anywhere. The research sounds like it would be fun for the researchers. With cryogenics, it's the tankage that's going to be the stumbling block.

AND EDDIE_AERO responds:

Kurt—very wrong, by orders of magnitude. Did you know LH_2 has about 3X the energy density of jet fuel? It does need much more volume and, as the article says, there are things that need to be worked out, but these are solvable engineering problems—do your research.

Is there another alternative to burning down our planet? As President Kennedy said: Too often we enjoy the comfort of opinion without the discomfort of thought.

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

WHO'S WHERE

Tony Gingiss has joined *Terran Orbital* as chief operating officer. He held the same position at Virgin Orbit, before which he led programs at Boeing Satellites Systems and Airbus OneWeb Satellites.

The *Air Charter Safety Foundation* has appointed **Bryan Burns** CEO, adding to his current title as president. **Debi Carpenter** has also been hired as executive director. She was head of marketing and communications at Natilus, an uncrewed aerial vehicle cargo manufacturer.

Matteo Genna has been named chief technology officer of *Fleet Space*. With 30 years of experience building space and near-space systems, he was most recently president of the remote sensing business unit at World View Enterprises.

Mercury Systems has hired **David Farnsworth** as chief financial officer. He joins from HawkEye 360, where he held the same title, and he also currently sits on the board of Merrimack Valley Credit Union. Former Leidos Chairman and CEO **Roger Krone** also joins as an independent director and member of the board's nominating and governance committee.

Lauren Beyer has been appointed president of the *Cargo Airline Association*, succeeding Steve Alterman following his retirement. Beyer brings an extensive background in government, working at the U.S. Department of Homeland Security, Transportation Security Administration and the National Security Council, where she was director for aviation and surface transportation security. Most recently, she was vice president for security and facilitation at Airlines for America.

Northrop Grumman has promoted **Kathryn Simpson** to corporate vice president and general counsel from vice president and associate general counsel for its mission systems sector, effective Oct. 30. She succeeds Sheila Cheston, who will retire effective Dec. 1. Before Northrop Grumman, Simpson worked for 17 years at Raytheon, and prior to that she was attorney-advisor for the U.S. International Trade Commission.

Chad Kirk has joined the *Aerospace Industries Association* as senior director of civil aviation. He was head of government and policy affairs at Airspace Link, and he previously worked at Reliable Robotics and the FAA.

Federica Berra has been promoted to senior vice president for global aviation from senior vice president for integrated gas and power at *Air bp*, succeeding Martin Thomsen.

The *General Aviation Manufacturers Association* has promoted **Cate Brancart** to director of European safety and sustainability development from manager of European operations and safety. The group has also hired **Peter Marton** as director of European government affairs and **Zanthe Jordine** as airworthiness and regulatory specialist.

Former NASA astronaut **Garrett Reisman** has joined space habitation technology developer *Vast* as human spaceflight advisor. Reisman flew on multiple space shuttles and worked on the International Space Station. Since his 2011 retirement from NASA, he has also served as senior advisor to SpaceX.

John Stack has joined *B. Riley Securities* as senior managing director for aerospace and defense investment banking. He was the head of Canaccord Genuity's aerospace and defense investment banking team and before that held executive positions at Cessna Aircraft and Textron.

Artificial intelligence and autonomous systems provider *Scientific Systems Co. Inc.* has hired **David "Heat" Lyons** as vice president of business development. He was an operational advisor and later consultant to DARPA as well as a former U.S. Air Force F-16 combat pilot.

Ad Astra Rocket Co. has appointed **Steven M. Chapman** and **John C. Wall** to its board of directors. Chapman was vice president for China and Russia at Cummins and remains chairman of Cummins India as well as independent director on the board for Axalta Coating Systems. Wall was chief technical officer at Cummins for 15 years, before which he led Chevron's diesel and aviation fuels research department.

Miguel Pena has been brought on as sales director at *Celestia Technologies Group*. He joins from subsidiary TTI, where he was a commercial manager.

Timothy Ravich has been hired by *Tressler LLP* as senior counsel for aviation law. He was a founding partner and principal at Empennage Consulting and is an associate professor and chair of the department of legal studies at the University of Central Florida, where he teaches aviation law.

The *National Air Transportation Association* has elected Sheltair Chief Operating Officer **Todd Anderson** as chair of its board of directors, with predecessor and Atlantic Aviation Executive Vice President **Clive Lowe** staying on as immediate past chair of the executive committee. Joining the board as at-large members are **Travis Grimsley**, vice president of aircraft services at Duncan Aviation's facility in Battle Creek, Michigan; **Cristine Kirk**, president and CEO of Malone AirCharter; **Mary Miller**, vice president for industry and government affairs at Signature Aviation; **Kathryn Purwin**, CEO and owner of Helinet Aviation Services; and **Craig Teasdale**, vice president of operations at Ferrovial Vertiports.

Doug Parker has joined the *Qantas* board of directors. He was CEO of American Airlines for eight years, a role he had held at America West and US Airways as well.

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

FIRST TAKE

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COMMERCIAL AVIATION

BOEING

Boeing has teamed with Alaska Airlines, American Airlines, Delta Air Lines, Southwest Airlines and United Airlines to advise on the design and testing of NASA's X-66A Sustainable Flight Demonstrator (page 19).

Safran has made a $1.8 billion offer to acquire Collins Aerospace's actuation and flight control systems business from RTX (formerly Raytheon Technologies).

Russia's air transport industry is showing signs of recovery. In the first half of 2023, its airlines carried the highest number of passengers since 2020, says federal agency Rosaviatsiya.

Over a dozen airlines will challenge the latest judgment in a dispute over government plans to introduce a flight limit to reduce noise at Amsterdam Airport Schiphol.

Dale Vince, founder of renewable energy firm Ecotricity, plans to launch Edinburgh, Scotland-based Ecojet in 2024 with plans to operate hydrogen-electric-powered aircraft from 2025.

Boeing has completed redesign work and retrofit instructions on 737 Next Generation nacelles to better protect them from broken fan blades.

The FAA has finalized policy for demonstrating radio altimeters to operate without risk of interference in areas where 5G C-band signals are active.

DEFENSE

L3Harris Technologies' $4.7 billion acquisition of Aerojet Rocketdyne was expected to close around July 28 after the Federal Trade Commission decided not to block the deal.

The Indian Defense Acquisition Council on July 13 approved the procurement of 26 Dassault Rafales for the Indian Navy, ending the chance of procurement of Boeing's F/A-18E/F.

Saudi Arabia has signed a contract with Turkish manufacturer Baykar to acquire and manufacture Akinci twin-turboprop uncrewed aircraft systems.

Canada is buying nine Airbus A330 Multirole Tanker Transport aircraft that will be designated as CC-330 Husky, eight for aerial refueling and one dedicated to VIP missions.

Canada has selected incumbent service provider SkyAlyne Canada as the preferred bidder for the Future Aircrew Training program.

Poland has awarded Saab a 600 million kronor ($57 million) order for two Saab 340 airborne early warning and control (AEW&C) aircraft.

The heads of the air forces of Australia, the UK and U.S. have pledged to work together on future upgrades of the Boeing E-7A Wedgetail AEW&C aircraft.

L3Harris Technologies has unveiled a platform based on the Bombardier Global 6500 with a conformal airborne early warning system to replace the NATO fleet of 14 Boeing E-3s.

The UK Royal Navy's newest aircraft carrier, HMS Prince of Wales, has returned to sea after nine months of repairs.

Raytheon/Northrop Grumman will continue developing scramjet-powered hypersonic vehicles under a follow-on to DARPA's Hypersonic Air-Breathing Weapon Concept project.

Safran Helicopter Engines and Hindustan Aeronautics Ltd. have established a joint venture to produce engines for the planned 13-ton Indian Multi-Role Helicopter.

VIEW FROM WASHINGTON

Northrop Quits NGAD Race

Northrop Grumman has dropped out of the competition to lead development of the U.S. Air Force's next fighter.

The announcement by CEO Kathy Warden on an earnings call with analysts leaves Boeing and Lockheed Martin as the only bidders to be prime contractor for the Air Force's Next-Generation Air Dominance (NGAD) program, which is planned to begin replacing Lockheed's F-22 in the early 2030s.

"We have notified the U.S. Air Force that we're not planning to respond to the NGAD [request for proposals] as a prime," Warden said.

However, Warden left the door open for Northrop's aeronautics division to play a role as a subcontractor to either Boeing or Lockheed for the Air Force's F-X next-generation fighter.

Northrop also could continue competing to develop the U.S. Navy's F/A-XX fighter, planned to replace the Boeing F/A-18E/F Super Hornet starting around 2040.

Northrop built the YF-17 prototype that evolved into the McDonnell Douglas F/A-18 in the mid-1970s but dropped out of the fighter market after its YF-23 prototype lost to Lockheed's YF-22 in 1991.

Although Northrop has withdrawn from the Air Force's fighter competition, the company remains active in developing concepts for a new class of autonomous Collaborative Combat Aircraft.

FIRST TAKE

Leonardo UK and its U.S. subsidiary have signed a memorandum of understanding with Sierra Nevada Corp. to boost defense electronics sales.

DIAMOND AIRCRAFT

TECHNOLOGY

Diamond Aircraft's eDA40 electric trainer made its first flight July 20 from Wiener Neustadt, Austria, powered by an Electric Power Systems battery and Safran motor.

Chinese state-owned aircraft manufacturer Comac and battery producer CATL have joined forces to explore development of electric aircraft.

Eve Air Mobility and parent company Embraer have chosen Taubate, in the state of Sao Paulo, as the first air taxi manufacturing location in Brazil.

Hybrid-electric propulsion pioneer Ampaire has acquired Talyn Air, a U.S. electric vertical-takeoff-and-landing aircraft startup.

Lilium plans to raise up to $192 million in new financing, more than previously anticipated, through a public share offering and private placement.

SPACE

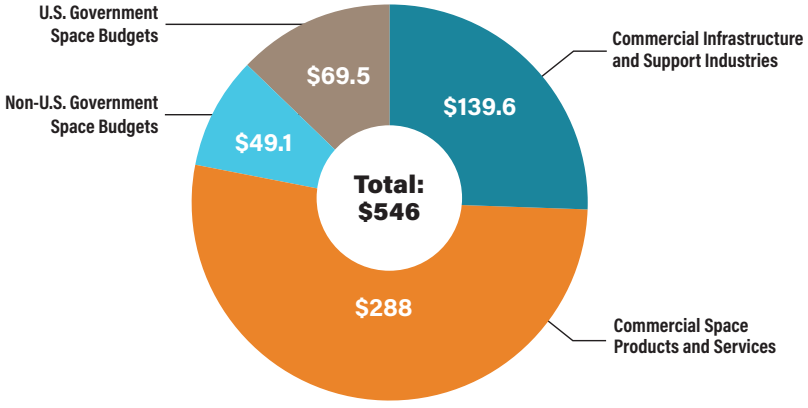
NASA has awarded KBR Wyle Services a five-year, $1.93 billion contract to provide mission and flight crew operations support for the International Space Station.

Amazon plans to build a processing facility at NASA's Kennedy Space Center to prepare Kuiper satellites for launch on Blue Origin New Glenn and United Launch Alliance Vulcan Centaur rockets.

Expecting surging demand for U.S. National Security Space Launch services, the Space Force plans to add a third provider to its list of contractors able to fulfill the full range of missions (page 45).

Commercial Grows to More Than Half of Space Market

(U.S. $ Billions)

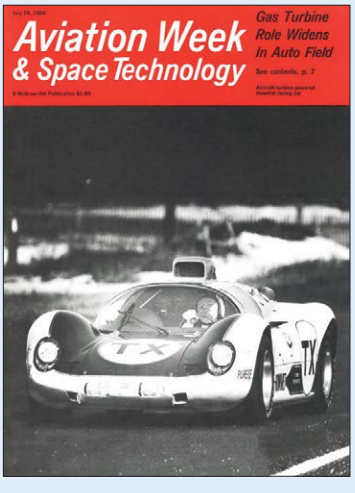


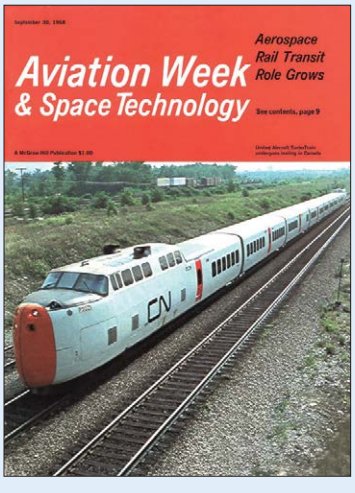
Source: Space Foundation database

The global space economy grew 8% in 2022, reaching $546 billion, the Space Foundation says. The commercial market climbed by almost 8% to $427.6 billion, while international defense spending rose to 45% of government space budgets in 2022. The space economy has grown by $260 billion (91%) in the past decade, the organization says.

55 YEARS AGO IN AVIATION WEEK

"Planes, Trains and Automobiles" is the name of a 1980s comedy film, but it also could describe the reporting of Aviation Week Technical Editor Michael L. Yaffee in 1968. The cover of our July 29 edition featured a Howmet racing car powered by an aircraft turbine. "Aircraft gas turbine engines, now being used in sports cars and Indianapolis-type racing cars, are proving powerful competitors to piston engines," Yaffee reported in a detailed analysis that spanned eight pages. Two months later, he had moved on to aerospace rail transit. Our Sept. 30 cover showcased a United Aircraft TurboTrain built for Canadian National Railway, which hoped to operate it between Montreal and Chicago. "Turbine powerplants and aerospace technology appear destined to play major roles in the evolution of high-speed surface transportation," Yaffee wrote, noting that GE and Grumman were also studying more advanced "air cushion vehicles" that could travel as fast as 300 mph.





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UP FRONT
KEVIN MICHAELS

AVIATION IS BREATHING A SIGH OF relief as air travel recovers in the wake of the COVID-19 crisis. If current trends continue, global air travel in revenue passenger kilometers (RPK) will reach pre-COVID levels sometime next year. Yet below the surface, important trends in the composition of air travel merit our attention—particularly a decrease in business travel that might be structural.

A recent survey by the USB Evidence Lab found that the number of short-haul leisure flights per person per year was down 4% in 2022 compared with 2019, and the number of long-haul leisure flights was 14% lower. This is roughly in line with broader industry RPK trends. However, the comparable figures for business travel are 31% lower (short haul) and 19% lower (long haul), respectively. The Global Business Travel Association, which represents corporate travel departments, echoes these findings. International business travel budgets have recovered to 58% of pre-pandemic levels; for domestic business travel, it is 68%.

Why is business travel, which accounts for about 30% of trips, lagging in its recovery? Corporate travel policies clearly have played a role, as restrictions remain, especially with Chinese travel. Geopolitical tensions don't help, either. A growing number of Western business travelers consider the risk of Chinese travel too high, particularly after government raids of several high-profile U.S. companies. Business aircraft have picked up some traffic formerly carried by airlines, buoying activity for charter and fractional operators.

These phenomena might not last, but a structural change could be unfolding. Approximately 30% of business trips are for intracompany purposes, including internal meetings and employee training. During the pandemic, many companies found they could substitute online meetings and training for these time-consuming trips. An added benefit is that the company's carbon dioxide emissions are curtailed.

"Business travel has forever changed," RTX CEO Gregory Hayes said. "About 30% of normal commercial air traffic is corporate-related, but only half of that is likely mandatory. Sophisticated communication technologies have really changed our thinking in terms of productivity." Hayes' use of the word "productivity" is telling. Are businesses more productive and profitable with fewer business trips? Most likely, yes. Face-to-face meetings are critical for developing customer relationships or conducting service calls, but for intracompany travel between people who already know each other or share a common culture, some business flights will be replaced by Zoom or Teams meetings.

What are the implications for airlines? Majors and network carriers, which traditionally derive the bulk of their profits from high-yield business travelers, are the most affected. Revenues were down in 2022 compared with 2019 for Lufthansa (-6%), British Airways (-5%) and Air France (-3%). In contrast, low-cost carriers less dependent on business travel experienced robust revenue growth, such as Wizz Air (12%) and Ryanair (8%).

Airlines are adapting to these challenges. Many are targeting higher-yield leisure travelers with upgraded products such as premium economy. On twin-aisles, the percentage of premium seats on international flights increased to 14% in 2022 from 11% in 2019. Airlines are pursuing a growing "premium leisure" segment. For example, Delta Air Lines flights for a Sunday-Thursday trip in September between New York John F. Kennedy International Airport and London Heathrow Airport cost $6,773 for Delta One Suites, $1,959 for Premium, $1,175 for Comfort+ and $825 for the main cabin. The premium economy cabin is growing while business and main cabins are shrinking.

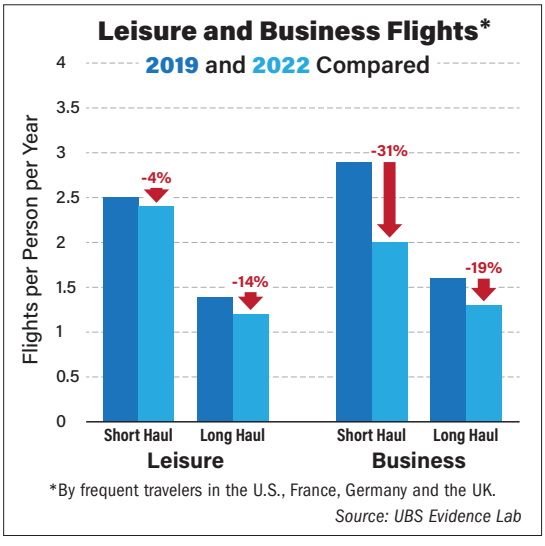
Another strategy is to capture more ancillary revenue from fees for seat selection, baggage, early boarding, hotel and car rental commissions and sales of frequent-flyer points to partners. In 2022, ancillary revenue exceeded $100 billion and comprised 14% of airline revenue.

While current pricing power is strong, airlines must prepare for the next downturn and the reality that more premium economy travelers cannot offset reduced business travel revenue and profits. Carriers might thus downgauge to smaller aircraft for international flights or simply reduce the number of long-haul aircraft. This may be why twin-aisles comprise 30% of jetliner sales, down from 50% last decade.

Aviation has always been about change, and the shift in business travel patterns will provide executives with a new set of opportunities and challenges in the post-pandemic era.

Downshift

How **business travel** has changed



*By frequent travelers in the U.S., France, Germany and the UK.

Source: UBS Evidence Lab

Contributing columnist Kevin Michaels is managing director of AeroDynamic Advisory in Ann Arbor, Michigan.

INSIDE BUSINESS AVIATION
WILLIAM GARVEY

Fire Country First Responders

Wheeled or wetted, **they are wildfire wallopers**

A LEGEND IN THE AGRICULTURAL aviation community, Leland Snow created the first purpose-built aerial spray aircraft as a college student in 1951. He went on to found two "agplane" manufacturing companies, both based in Olney, Texas. The first, Snow Aeronautical, he sold; the second, Air Tractor, produces a range of single-engine models that are ag-av mainstays.

Notably, in the late 1980s, he focused on an entirely different application: dousing wildfires. Although Canadair had been producing a twin-engine water scooper/bomber, aerial firefighting primarily involved former military and transport aircraft fitted with water/retardant tanks and dispersal systems. Snow thought a single-engine machine designed for the purpose would be more effective.

After years of design, refinement and testing, a certificated AT-802 firefighter emerged in 1993. The beefy aircraft featured an 800-gal. tank, 16,000-lb. takeoff weight (more than half being useful load), unrefueled endurance of 4 hr., computerized dispersal system and a PT-6A turboprop up front. At the time, Snow, who died in 2011, commented, "We'll probably build 10 or 12 of these." Not all visionaries see the future clearly all the time.

Soon, Snow's traditional customers wanted the big airframe adapted for ag work, and he complied. Later it was also adapted for oil spill cleanup and other roles, including militarized versions acquired by the U.S. Air Force for commando support. This past January, Air Tractor delivered the 1,000th AT-802, including some 280 firefighters.

Air Tractor's firefighter had been in production for less than a decade when Snow was approached by Bob Wiplinger, then-CEO of Wipaire, the Minnesota-based aircraft float-maker. He proposed fitting the AT-802F with amphibious floats, enabling it to skim and scoop water, fill its tank in seconds and return to the fire. Snow expressed doubt about the conversion's viability but wished Wiplinger good luck. Visionary myopia once again.

Wipaire proceeded alone and in 2003 received a supplemental type certificate for an AT-802F scooper it branded the "Fire Boss." Since then, the company reports more than 140 aircraft have undergone the conversion—and with a backlog exceeding 20, the challenge is satisfying demand.

In combating wildfires, the AT-802F and Fire Boss are employed primarily as initial-attack aircraft. Given plentiful fuel, heat and accommodating wind, a fire can spread alarmingly fast. An immediate and overwhelming response is key to halting its progress.

Because it readily operates out of short, forward strips and can conduct multiple attacks in minutes, Air Tractor's firefighter is well suited for the role. And Fire Boss backers note that since blazes often begin near scoopable water, their aircraft can fill and dump quickly for hours. Moreover, the AT-802F's relatively low base price of approximately $2.8 million—add another $1.5 million for the Fire Boss conversion—means some operators can field small squadrons that can douse flames in steady sequence.

AIR TRACTOR

The Conair Group is a major aerial firefighting outfit and Air Tractor dealer headquartered in Abbotsford, British Columbia, with subsidiary operations in the U.S. and France. Its fleet of 70 aircraft includes multi-engine air tankers and scoopers, fire control singles and, notably, 22 wheeled and float-equipped AT-802s. While each aircraft contributes to the firefight, Jeff Berry, a Conair vice president and wildfire expert, lauds the Air Tractors' reliability, short-runway capability and cost-effectiveness. Moreover, they "pack a pretty good wallop in either configuration," he says, adding that Conair has more on order.

Meanwhile, Dauntless Air of Appleton, Minnesota, operates 17 Fire Bosses, the largest fleet in the U.S. CEO Brett L'Esperance cites the aircraft's robustness for helping his team maintain fleet availability of 99.3%. Furthermore, he notes, equipped with head-up displays and infrared capability, their pilots can target hot spots within the thickest smoke, thereby providing extra protection for ground firefighters. He also praises his aircraft's operational efficiency, citing a $0.67 per gallon delivery average versus other firefighting aircraft, whose drop costs can be double that or far more.

Berry and L'Esperance agree that wildfires are a global, year-round threat and growing. In the U.S., L'Esperance notes, acreage lost to fire has doubled from the average of 3.5 million acres per year from 1980 to 2000. This year, Berry notes, hundreds of persistent wildfires stretched coast-to-coast across Canada, which is rare.

It appears Leland Snow saw clearly through the future miasma after all.

William Garvey was editor-in-chief of Business & Commercial Aviation *from 2000 to 2020.*

AIRLINE INTEL

JENS FLOTTAU

Boeing's 777-8 Troubles

What will **Emirates' loss of interest** mean for the program?

IN BOEING'S MOST RECENT UPDATE on orders and deliveries, an interesting detail appeared. According to an Aviation Week analysis of the June data, Emirates has converted an order for 16 Boeing 777-8s into the same number of larger -9s.

The development itself was hardly a surprise, since Emirates had become skeptical about the initial design of the 777-8 in the years after it launched the program. While the updated, larger -8 passenger variant was more to Emirates' liking, management was still disturbed that it was not informed about the change beforehand. After all, the airline had been the type's launch customer almost 10 years earlier. And while the new design is perceived as better than the initial proposal, it is also much closer to that of the -9, raising the question of why Emirates or any airline would want two relatively similar 777 versions.

BOEING CONCEPT

The move leaves Etihad Airways as the only remaining publicly identified 777-8 customer. Boeing still lists 25 Etihad 777X orders, without detailing the split between the -8 and -9. Like Emirates, Etihad ordered the 777X for the first time at the 2013 Dubai Airshow. At the time, the airline said it would take 17 777-9s and eight -8s. But in 2019, Etihad revised its widebody orderbook, canceling all but six 777-9s. Etihad also dropped 40 of 30 A350-900s from a 2013 Airbus order and converted the remaining 10 aircraft to the larger -1000 version.

In the last four years, Etihad appears to have changed strategy again—away from boutique airline status to more of a connecting model—so it may see a need for the -8s again after all. The airline did not respond to queries to clarify the order status.

Boeing says it is "committed to the 777-8 passenger airplane, which will follow the 777-8 freighter."

Two orders from Etihad and Emirates were not necessarily a good basis for the launch of a new aircraft variant, but the world's largest 777 operator saying no to the smaller version of the 777X family does send a strong signal to the market. If even Emirates is no longer interested in the -8, shouldn't Boeing drop it?

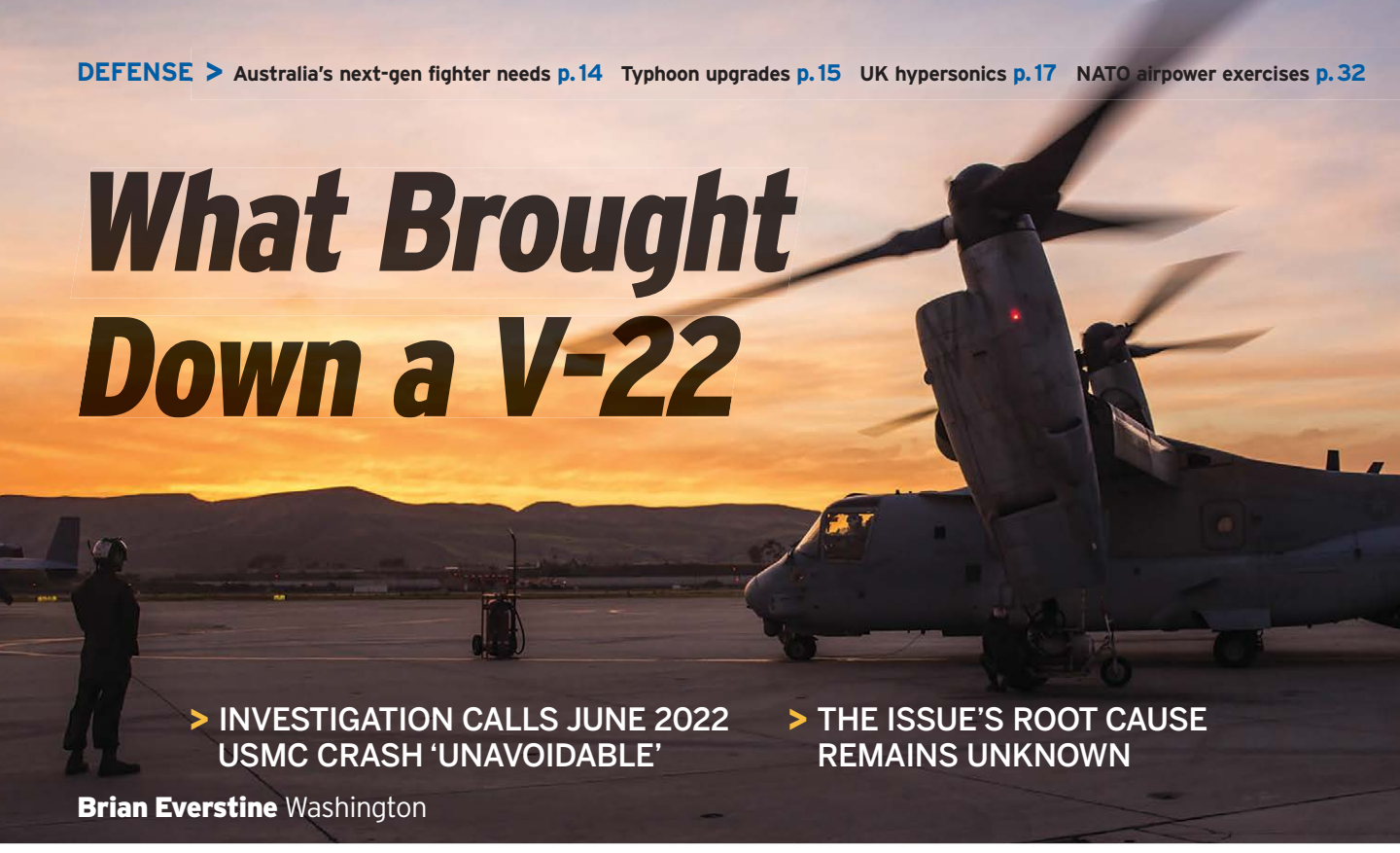
Industry veterans know it is not that simple. Boeing and Airbus have launched many derivatives they never ended up building—Boeing's 787-3 and Airbus' A350-800 and A380F among them. All were in limbo for years until the respective manufacturer finally confirmed their death long after the impending demise had become obvious. The 777-8 could go the same way, an outcome at this point far more likely than a strong revival, essentially because it is viewed by the market as a heavy aircraft with ultra-long-range capabilities that hardly any operator needs and is willing to pay for, much like the Boeing 777-200LR and Airbus A340-500.

Without the 777-8, the competitive dynamics of the widebody market would change significantly. The 777-9 would become a standalone aircraft in airline fleets, having only limited commonality with first-generation 777s and the 787. By contrast, Boeing is offering three versions of the 787, and Airbus has two variants of the A350, including the -1000, which is similar to the 777-8 in size but probably more efficient.

A single-type aircraft is never good, and more airlines might consider complementing their 777-9 fleets with a few 777-8s rather than adding another type for certain routes. That could compel Boeing to keep the -8, which would give the aircraft-maker another competitor to the A350, keeping Airbus margins on the program lower. That is the role the A330neo played vis-a-vis Boeing's 787 until new sales momentum put the A330neo program on better footing.

But—and this is a rather big "but"—the 777-8 would be a substantial additional development effort to a troubled program. The -9 is not nearly done, and then there is the -8F, arguably much more important than the smaller passenger version because it will replace the 747-8F and 777F and defend Boeing's quasi monopoly in the large freighter market. Moreover, if Boeing is serious about building a new-technology 737 replacement starting in 2035, it must launch that program well before 2030, adding further strain on engineering resources.

What Brought Down a V-22



> INVESTIGATION CALLS JUNE 2022 USMC CRASH 'UNAVOIDABLE'

> THE ISSUE'S ROOT CAUSE REMAINS UNKNOWN

Brian Everstine Washington

Since 2010, the U.S. Marine Corps has known of a critical safety issue on its Bell Boeing V-22 Osprey fleet—a gearbox flaw that can cause the tiltrotor's clutch to slip, severely impacting the safety of flight.

For years, the Corps says it has trained crews to be aware of and work around the issue. While the U.S. Air Force grounded its V-22 fleet in August 2022 because of it, the Marine Corps kept flying, saying it was confident in the safety of the aircraft.

On June 8, 2022, a hard clutch engagement (HCE) damaged a V-22 as it flew over the deserts of Southern California, causing the Osprey to crash, killing all five on board. Despite assertions that pilots can work around the issue, an investigation released July 21 states that the crew could have done nothing to prevent the accident. The pilots could not have known the problem was going to strike, and they did not have time to react before the Osprey crashed.

Aviation Week reporting shows the newly released investigation was one of at least four such gearbox problems that occurred in serious crashes of both Marine Corps and Air Force V-22s last year. While the new accident investigation board report into the June 2022 incident states that the HCE was the primary cause of that crash, an investigation into a March 2022 fatal MV-22 crash in Norway said a gearbox problem did occur but blamed the accident on pilot error.

At least two proprotor gearbox problems caused crashes or emergency landings of Air Force CV-22s, according to information obtained by Aviation Week on the Class A incidents—defined as causing at least $2.5 million in damage or severe injuries or deaths. One high-profile incident in August 2022 in Norway prompted the Air Force to stand down its operations. This came after another incident on May 17, 2022. Investigations into those have not been released, and multiple similar incidents have occurred, including another Air Force CV-22 forced to land on July 8, 2022, and an MV-22B that experienced an engine fire while landing in October 2022.

The June 2022 crew killed were from the "Purple Foxes" of Marine Medium Tiltrotor Sqdn. 364 (VMM-364): Capt. Nicholas P. Losapio, Capt. John J. Sax, Cpl. Nathan E. Carlson, Cpl. Seth D. Rasmuson and Lance Cpl. Evan A. Strickland.

Interviews with commanders and other Marines in the investigation along with family member statements show that if an inflight emergency were to happen on an Osprey, these pilots were among the best to handle it. The squadron's commander, in a statement attached to the investigation, said Losapio, also known as "Sloppy," had a reputation as a "phenomenal" and "stellar" pilot who had been accepted into the elite Marine Helicopter Sqdn. One (HMX-1)—the unit that flies Marine One and the logistics support MV-22s. Losapio, 31, was engaged to be married two months after the crash.

Sax was new to the unit, but the commander wrote that he was a "natural stick" who was "leaps and bounds ahead of his peers in terms of capability and stick control." He was a flight instructor before joining the Marines and had entered training for strike fighters before deciding to transfer to Ospreys. Sax's widow, Amber Sax, says he chose the Osprey because he wanted to fly with a crew. Sax, 33, left behind two daughters, and his wife has created the Capt. Sax Foundation to provide financial aid for future aviators and engineers.

The commander wrote in a statement that the crew on the flight—Carlson, Rasmuson and Strickland—had plenty of experience from combat missions, including the Special Purpose Marine Air-Ground Task Force tasked with crisis response and a variety of other training missions. Carlson, 21, was married about one year before the crash after returning from a deployment as part of the task force,

The June 2022 crash of a V-22 from Camp Pendleton, California, is the first fatal accident connected to an ongoing problem with the Osprey's gearbox.

SGT. LILLIAN STEPHENS/U.S. MARINE CORPS

according to an obituary. Rasmuson, 21, is survived by his wife and young son. Strickland, 19, was new to the Marines and had just been stationed at Camp Pendleton for one month.

According to the accident investigation board (AIB) report, the Osprey was one of two flying near Glamis, California, for a live-fire tail gun training mission from Camp Pendleton. After the third pass, the V-22 crew reported via radio it had "hot boxes," meaning the aircraft's gearboxes were running at a high temperature. The crew then climbed to a higher altitude to cool the gearboxes. After coming down for another weapons pass, the Osprey's wingman lost visual of the V-22 during a turn because of the angle of bank. Seven seconds after the last radar contact, the V-22 crashed.

The AIB states that the cause of the crash was a dual HCE creating a single-engine and interconnect drive system failure. This caused a "catastrophic loss of thrust" on the right proprotor, creating an unrecoverable departure from controlled flight.

"It is clear from the investigation that there was no error on the part of the pilots and aircrew and nothing they could have done to anticipate or prevent this mishap," Headquarters Marine Corps says in a statement. "They were conducting routine flight operations in accordance with applicable regulations when this catastrophic and unanticipated mechanical failure occurred."

The V-22 has two proprotor gearboxes, one in each nacelle, that transmit power from the engine to the proprotor mast. An interconnect drive system runs through the wings to synchronize the proprotors. If one engine fails, this transmits power from the operating engine to the gearbox on the failed engine side.

Within each nacelle, the engine output shaft drives the proprotor gearbox through an input quill. A one-way sprag clutch within the input quill transmits torque during normal operation and permits overrunning during single-engine operation, autorotation or if engine speeds are not matched.

An HCE results from a slippage of the input quill clutch and occurs when the clutch reengages. This can cause severe damage to the drive system including engine and gearbox overtorque, failure of the shaft-driven compressor and nacelle blower, and damage to the engine output shaft. In the June 2022 accident, the dual HCE effectively sheared the Osprey's gearbox, causing loss of thrust.

The Marine Corps says in a statement that since 2010 it has made "numerous actions associated with defining, mitigating or eliminating HCEs."

In February, the V-22 Joint Program Office (PMA-275) announced the whole fleet would undergo input quill assembly (IQA) replacement even though the root cause of the HCE has not been determined. The AIB report says IQAs are being replaced every 800 hr. Since this plan was announced, V-22s have logged 22,258 flight hr. with no reported HCE events.

Bell Boeing recently has received multiple contracts focused on the issue, including a February award of $12.7 million for nonrecurring engineering for an improved IQA design and an April award of $53.5 million for a V-22 Gearbox Vibration Monitoring/Osprey Drive System safety and health information system to detect degrading gearbox components.

"The completion of this investigation does not close the HCE effort within PMA-275," Col. Brian Taylor, PMA-275 program manager, said in a statement. "The implemented IQA life limit, which reduced overall V-22 HCE risk by greater than 99%, was not a result of this investigation but is certainly reinforced by its findings."

This 99% statement is not enough for some family members, who have hired an attorney to press the Marine Corps and Bell Boeing about why HCE problems were not addressed sufficiently before the crash.

"John loved being a Marine, and he loved flying the Osprey. If he were with us today, he would still be flying them; our friends are still flying them. Their faces, their spouses' faces, their children's faces are playing through my mind and fueling my need for answers," Amber Sax wrote in a statement after the investigation was released. "This is precisely why the fight isn't over. We won't stop seeking answers and a solution to hard clutch engagement. The Marine, aviation and Osprey communities became our second families throughout our marriage. We will do everything in our power to protect that family and find answers."

The HCE issue is one of 13 Category 1 deficiencies on the V-22 fleet, issues that are defined as possibly affecting safety of flight. The program office has declined to identify the other deficiencies.

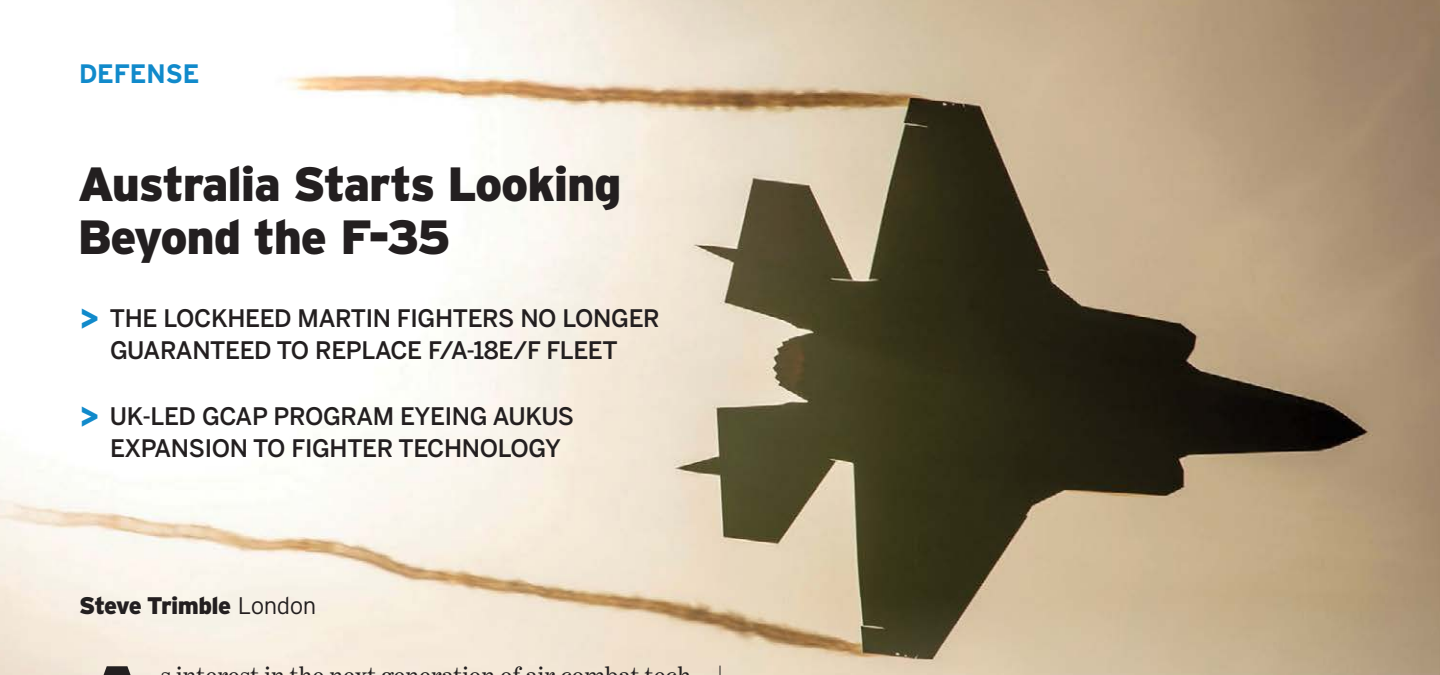
After the grounding was announced in August 2022, Air Force Special Operations Command (AFSOC) was the first command to look at past V-22 incidents to see if what is now understood about the HCE would have changed the findings. The U.S. Navy and Marine Corps followed suit. AFSOC said at the close of that investigation that what is known would not "materially" change—while HCEs could not be completely ruled out of some, it did not merit reopening the investigations.

One of the most notable accidents was the April 2010 crash of an Air Force V-22 in Afghanistan that killed four and injured 16. The official account of the crash did not identify a main cause because key pieces of evidence, such as the flight data recorder and an entire engine, were missing. However, then-AIB President Brig. Gen. Donald Harvel wrote that there was an "abnormal engine response," and the proprotor's speed was low when it attempted a rolling landing. AFSOC at the time disagreed with the findings and issued a statement blaming the pilots.

Harvel, who retired shortly after and died in 2020, wrote his account of the investigation in a book titled *Rotors in the Sand*. In a chapter called "My Unofficial Opinion of What Really Happened," Harvel wrote that gearbox problems were likely a cause.

Australia Starts Looking Beyond the F-35

- THE LOCKHEED MARTIN FIGHTERS NO LONGER GUARANTEED TO REPLACE F/A-18E/F FLEET
- UK-LED GCAP PROGRAM EYEING AUKUS EXPANSION TO FIGHTER TECHNOLOGY



AUSTRALIAN GOVERNMENT

Three squadrons of Lockheed Martin F-35As will remain in RAAF service for decades, but the service is keeping its options open to equip a fourth squadron with new fighters in the mid-2030s.

Steve Trimble London

As interest in the next generation of air combat technology increasingly encroaches on funding for existing aircraft, Australia has started looking for options beyond the Lockheed Martin F-35A for its future fighter fleet.

The Royal Australian Air Force (RAAF) currently operates four fighter squadrons, with three already flying F-35As and the fourth operating Boeing F/A-18E/F Super Hornets. The F/A-18E/Fs were expected to be replaced by a fourth squadron of F-35As to be ordered and delivered by the end of the decade, but that plan is no longer guaranteed.

"What the fourth squadron of F-35s has become is the Super Hornet replacement, not just [a plan to buy] the fourth squadron of F-35s," RAAF Air Marshal Robert Chipman told Aviation Week here at the Global Air and Space Chiefs' Conference July 12-13.

Instead, the RAAF plans to upgrade and extend the service life of the Super Hornet squadron before replacing those aircraft in the mid-2030s. The new replacement schedule means the RAAF will have more options beyond the F-35A, including a new generation of uncrewed collaborative combat aircraft (CCA) and crewed fighters scheduled to be fielded in the mid-2030s by the U.S. and a UK/Italy/Japan consortium.

"We will look at the F-35, and we're very, very comfortable and very happy with the capability of the F-35," Chipman said. "But it would be remiss of me not to look at what else is available for us to replace our Super Hornets in the future."

The options include the U.S. Next-Generation Air Dominance program and the Global Combat Air Program (GCAP), which in 2022 merged the UK-led BAE Systems Tempest and Japan's Mitsubishi F-X projects into a common aircraft system. The French/German/Spanish Future Combat Air System program plans to field a crewed fighter in 2040, which is possibly beyond Australia's ideal time frame.

Through the tripartite AUKUS security pact, Australia is already partnered with the U.S. and UK to receive nuclear-powered submarines and collaborate on advanced technologies such as hypersonic propulsion, autonomy, quantum technologies, cybertools and electronic warfare.

GCAP officials also view the AUKUS pact as a potential path for sharing next-generation combat aircraft technology from the UK to Australia, Richard Berthon, the UK Defense Ministry's director of Future Combat Air, said in addressing the same conference.

"I think there's an interesting future in which you can see combat air and GCAP developing," Berthon said. "I think AUKUS is a fantastic foundation, obviously focused on a different domain to what we are focused on today, but the nations are considering opportunities for broadening the partnership."

The comments show Australia remains interested in obtaining new combat air technology. The government's Defense Strategic Review released in April put an end to speculation that the RAAF might acquire Northrop Grumman B-21 bombers. By deferring the acquisition of the fourth fighter squadron about 12 years, the review also created an opportunity to integrate next-generation fighters alongside Virginia-class submarines and Hunter-class frigates.

In the meantime, the RAAF will raise its F-35As and F/A-18E/Fs to the same standard as those of the U.S. fleets. For the F-35A, that means the RAAF will upgrade its 72 jets to the Technology Refresh 3 standard after the hardware becomes available for retrofit kits, Chipman said. The RAAF also plans to upgrade the 24 Super Hornets to the Block III configuration, which includes a 10,000-hr. airframe, widescreen cockpit displays, tactical targeting network technology and a distributed targeting processor network.

"We're looking at the Super Hornet capability now thinking that actually there's a lot of value in keeping that out to sort of midway through the next decade," Chipman said.

Australia's future airpower also includes autonomous aircraft. The RAAF has signed an agreement with the U.S. Air Force to demonstrate a CCA capability based on the Boeing MQ-28 Ghost Bat in the mid-2020s.

"That will be with a representative aircraft with representative payloads and doing representative missions. And that will be a small set of what we think in time will be the total capabilities of the MQ-28," Chipman said.

Eurofighter Typhoon Nations Make Progress Toward Upgrade Milestone

> PHASE 4 ENHANCEMENTS PACKAGE DUE FOR 2028 SERVICE ENTRY

> EUROFIGHTER CONSORTIUM EXPECTS 150-200 NEW ORDERS

Tony Osborne Le Bourget, RAF Fairford and Warton, England

The four nations behind the Eurofighter Typhoon are putting together their wish lists for the latest upgrade to the combat aircraft.

But the glacial pace of decision-making, as well as potentially missing critical ingredients, could harm the Euro-canard's chances in future export campaigns—particularly compared with the more certain road map offered by the French Dassault Rafale.

Work on systems definition for the so-called Phase 4 Enhancements (P4E) program kicked off in June, UK Royal Air Force (RAF) officials say, and could thin out the numerous upgrade requests by the four Eurofighter nations—Germany, Italy, Spain and the UK. That thinning out may be essential: The proposed wish list is long, and the upgrade package that emerges likely will be the most extensive yet for the aircraft. But industrial capacity could also challenge that package.

Germany would like the P4E upgrade to enable some of its Eurofighters, like the one pictured, to take over the suppression and destruction of enemy air defenses mission from the air force's Panavia Tornados.

The UK's priority is to prepare the aircraft for the third iteration of the Eurofighter's active, electronically scanned array radar, the £2 billion ($2.6 billion) European Common Radar System Mk. 2. Radar 2, as it is commonly known, is due to fly in a test aircraft in early 2024 and would introduce significant changes to the human-machine interface of the Eurofighter, moving from a mode-based model of operation to a task-based management software designed to assist the pilot in the sensor's use.

Germany seeks to ensure that the Eurofighter will be ready to take on the tasks performed by its Panavia Tornado fleet, particularly the suppression and destruction of enemy air defenses mission previously performed by the electronic combat/reconnaissance (ECR) version of its Tornados. This likely will involve the integration of an emitter location system, the Saab Arexis electronic warfare suite—selected by the German military in June—and the Northrop Grumman Advanced Anti-Radiation Guided Missile.

PATRIK BRANSMOLLER/GERMAN DEFENSE MINISTRY

Germany and Spain are also looking for integration of the air-launched Taurus KEPD 350 cruise missile, which is carried by both the Tornado and Spain's Boeing EF-18 Hornets.

The four nations have plans for Praetorian defensive aids suite upgrades, too, including adding digital receivers as well as new signal processing algorithms and processor capabilities. The countries want the capabilities added before the end of the decade—around 2028—with Germany's need perhaps the most critical, as its Tornados need to be retired.

Eurofighter CEO Giancarlo Mezzanatto said at the Paris Air Show in June that the partner nations had endorsed a 10-year road map for the aircraft's development and that the P4E would demonstrate "how flexible the Eurofighter system is to include new capabilities and integrate new products."

But the pace of Eurofighter upgrades has slowed, perhaps due in part to the different directions the partner nations have taken for their Future Combat Air Systems (FCAS). Germany and Spain are on one side, working with France on the European FCAS, while Italy and the UK are cooperating on the Global Combat Air Program. The two sides have different visions of how the Eurofighter needs to evolve to support their planned programs and disagree about how long to keep the Eurofighter in service once the FCAS and GCAP have arrived (*AW&ST* Oct. 25-Nov. 7, 2021, p. 30).

Industry had hoped that by now it could start addressing the needs of the Eurofighter's Long-Term Evolution (LTE) program, but this looks set to slip toward future upgrade phases P5E and P6E. "The further you look into the future, the more open it is about what precisely LTE will entail," Airbus Defense and Space CEO Michael Schoellhorn told Aviation Week ahead of the Paris Air Show (*AW&ST* June 5-18, p. 42). "There is growing clarity of what is going to be part of LTE, but there are

also still some finalizing discussions that need to be had."

In the UK, BAE Systems has been trying to accelerate some of the work it is bidding into the LTE program so it can be "ready for insertion by the customers at whatever appropriate point," BAE Systems Business Development Director Anthony Gregory said at the company's Warton, England, facility in July.

MARK WRIGHT/BAE SYSTEMS

These efforts, known internally as Typhoon Tranche 5, include rearchitecting the aircraft's complex mission system, enabling the use of off-the-shelf multicore computer processors. These processors, based on Intel Corp.'s Tiger Lake, could increase the aircraft's computing power by 200 times in the first instance—and raise it further as more processing cores are added. The software is being made compliant with the UK's Pyramid open-architecture standard as well as enabling the safety-critical and mission-critical software to split apart, making the aircraft easier to upgrade. The company is due to fly a Eurofighter with the multicore processors installed by year-end.

BAE is also considering technologies such as dynamic adaptive solid-state power management systems, which could squeeze more electrical power from the aircraft's Eurojet EJ200 engines.

Another challenge for the consortium is the speed at which nations can implement the upgrades. The RAF is arguably several years ahead in operationalizing the new capabilities. That includes the introduction of MBDA's Brimstone missile, now also ordered by Spain, and the use of the MBDA Meteor beyond-visual-range air-to-air missiles by British Typhoons operating in the Baltic region. The other partner nations are only now introducing the Meteor capability.

Mezzanatto said one of his objectives during his term as Eurofighter CEO was to align the customer fleets "as much as possible." But he added that achieving that will be difficult given the differing national requirements. Indeed, the UK is preparing to go a step further in enhancing the aircraft by adding BAE Systems' Striker 2 helmet-mounted display as part of a national upgrade for the aircraft.

Pilots will benefit from the helmet's daylight-readable color display and integrated night vision when it reaches the fleet around 2027-28, Group Capt. Matt D'Aubyn, the RAF's Typhoon program director, said at the Royal International Air Tattoo in July.

"[Striker 2] is an absolutely vital capability for Typhoon," D'Aubyn said. "Yes, is it a piece of protective equipment, but we are also looking at this as an integral part of the aircraft's weapon system."

Questions remain as to whether the UK will integrate the MBDA-developed Spear 3 small cruise missile onto the Typhoon. It is already destined for the Lockheed Martin F-35. But RAF officials have not definitively said whether the weapon is part of the plans for the Eurofighter, even though it has been tested on the aircraft and further tests are coming. This is despite significant international interest in the Spear 3 and the associated Spear-EW decoy development.

Here France could secure a lead, as it is looking at integrating a similar weapon—the Armement Air Sol Futur—for the Rafale as part of that aircraft's upgrade road map.

BAE Systems has taken delivery of the first prototype Radar 2 and plans to integrate it into a Eurofighter for flight tests starting in 2024.

Despite these challenges, Mezzanatto said the consortium could secure 150-200 additional orders in the next two years, including top-up orders from existing customers as well as from new markets. "We are getting prepared and fully support our partner companies on the export market and in order to meet all these demands," he said.

As reported by Aviation Week, Spain is interested in acquiring some 25 additional Eurofighters for its planned Halcon II fighter requirement to begin replacing the country's EF-18C/Ds (*AW&ST* June 5-18, p. 42).

Other potential new buyers could include Egypt and Poland. Top-up orders could emerge from Oman and Qatar. Saudi Arabia is—at least for now—a less likely buyer, given Germany's reluctance to support a sale there. BAE Systems is leading a campaign to sell the aircraft to Turkey as well, but this depends on whether the U.S. approves deliveries of Block 70 Lockheed Martin F-16s to Turkey.

UK Planning £1 Billion Effort To Secure Hypersonic Weapon Capacity

> WORK TO BE FOCUSED AROUND AUKUS DEFENSE PACT

> U.S.-UK THRESHER PROJECT WILL BE ACCELERATED

Tony Osborne London

The UK wants to secure a seat at the table of the world's hypersonic powers. More than 15 years after the last UK-led hypersonic tests in the Australian desert, the UK Defense Ministry plans to set aside £1 billion ($1.3 billion) over seven years to build a sovereign hypersonic weapon capability that will allow it to produce its own weapons and collaborate in tandem with Australian and U.S. partners as part of the AUKUS defense pact.

In addition to the funding, which comes from the £6.6 billion that the UK Defense Ministry committed in 2021 to research and development, the hypersonic efforts are backed by a "clear political intent," tender documents published in early July state. In short, the goal is to accelerate capability development.

The UK has a history of hypersonic flight research. The most recent trials, about 20 years ago, studied the HyShot dual-mode ramjet/scramjet engine while the ministry provided funding for the Sustained Hypersonic Flight Experiment (SHYFE) to explore technologies for a hypersonic missile. However, with the war in Afghanistan draining resources, interest in SHYFE faded, and the trials were called off.

Nevertheless, hypersonic efforts in China and Russia continued apace, and the emergence of systems such as the Chinese DF-17 and Russian Zircon has forced the UK and its allies to play catch-up. The UK's newly refreshed command paper for structuring its armed services calls for a reprioritization to counter future threats by investing in novel weapons such as hypersonics.

The UK is looking at a three-track approach: buying a strategic Hypersonic Glide Vehicle via AUKUS, collaborating on existing weapon programs and setting up a national program to develop a weapon capability, likely a hypersonic cruise missile.

The newly established Team Hypersonics is leading the efforts, but the collaboration and development strands will be done through a Hypersonic Technologies and Capability Development Framework Agreement with industry.

The effort appears to be entirely separate from the UK's work with France on the Future Cruise/Anti-Ship Weapon program, which aims to produce two weapons—one likely to be a high-speed but not hypersonic anti-ship weapon.

Indeed, France has embarked on its own hypersonic glide vehicle studies by launching a demonstrator, the eXperimental Maneuvering Vehicle (V-MAX) hypersonic glider, over the Atlantic Ocean at the end of June.

The DSTL published this concept of a notional ramjet/scramjet-powered missile to illustrate its hypersonic missile program.

UK DEFENSE SCIENCE AND TECHNOLOGY LABORATORY

The UK's work is focused around AUKUS, with hypersonic weapons added to the scope of the trilateral relationship in April 2022.

"These efforts show the seriousness with which hypersonic technologies are now seen, especially with regard to accelerating efforts to deploy a capability," says James Bosbotinis, a UK-based independent defense and international affairs analyst.

He expects the collaboration work to prioritize UK integration into the Australian and U.S. bilateral Southern Cross Integrated Flight Research Experiment program, which could give the UK a potential hypersonic capability within the accelerated schedule. The sovereign capability would follow.

The tender documents from the UK Defense Ministry state that most of the country's technological capability in hypersonics is at low technology readiness levels. The ministry see the framework as a way to begin bridging the gap by working with industry and academia.

The other routes to a UK hypersonic weapon capability are either to accelerate the joint U.S.-UK Thresher science and technology initiative (*AW&ST* April 6-19, 2020, p. 14), run by the UK Defense Science and Technology Laboratory (DSTL) and the U.S. Air Force Research Laboratory, or to run a technology demonstration program called HyLarc.

Details about HyLarc are scant, however, and the UK Defense Ministry did not address Aviation Week's specific questions about the program. The ministry only provided a statement on the framework saying that the documents were to "stimulate industry interest."

The framework will acquire capability through eight pillars of work: design and integration, modeling, airframe and power generation, propulsion, computing, seekers, lethal packages, and low-technology-readiness-level and academic work packages.

The new UK effort builds on the DSTL's own hypersonic weapons program, running since 2022, which is aimed at delivering a hypersonic cruise missile technology demonstrator by the middle of the decade.

Separately, the DSTL is working with Reaction Engines, Rolls-Royce, the UK Royal Air Force's Rapid Capabilities Office and the UK's National Security Strategic Investment Fund to deliver the Hypersonic Air Vehicle Experimental (HVX) Program—announced at last year's Farnborough Airshow—to explore reusable hypersonic air systems (*AW&ST* July 25-Aug. 7, 2022, p. 26). The HVX team is working on critical high-Mach/hypersonic technologies, including novel air-breathing propulsion architectures, innovative thermal management systems and advanced vehicle concepts.

Airbus A320neos Will Require Earlier Pratt Geared Turbofan Checks

> MANUFACTURING PROBLEM PROMPTED ORIGINAL INSPECTIONS

> ANALYSIS SHOWS CHECKS NEEDED SOONER THAN PRATT THOUGHT

Sean Broderick Washington and **Guy Norris** Colorado Springs

New analysis of an old problem is prompting Pratt & Whitney to revamp inspection protocols on certain PW1100G geared turbofans, potentially pulling hundreds of engines off wing before scheduled shop visits over the next two years.

Inspections have been mandated since late last year of a certain population of high-pressure turbine stage 1 and stage 2 disks produced between 2015 and 2021 that are flying on Pratt-powered Airbus A320neos. Pratt's previous analysis concluded that the checks, which require removal and disassembly of the engine, could wait until scheduled maintenance shop visits. But new analysis from recent inspections has led Pratt to conclude that more frequent checks are needed, the company revealed July 25.

AIRBUS

Engines from hundreds of Pratt-powered A320neo-family aircraft could face unscheduled shop visits over the next year.

"Based on the current assessment, Pratt anticipates by mid-September that approximately 200 PW1100 engines will be removed for enhanced inspection," Chris Calio, president and chief operating officer of Pratt parent RTX, formerly known as Raytheon Technologies, said on a July 25 earnings call.

Results from those checks, which target the highest-time engines, will help determine the next steps. Pratt is anticipating that another 1,000 engines will require inspections by mid-2024, "but the exact number of engines and the timing of those removals is not yet finalized," Calio added.

The affected engines may include one of roughly 2,070 PW1100G disks flagged by Pratt as containing contaminated powder metal (PM) that can reduce a part's service life. The problem was discovered during the probe of a March 2020 engine failure on a Vietnam Airlines Airbus A320ceo. In that case, a contaminated International Aero Engines (IAE) V2500 HPT stage 1 disk failed.

Pratt's initial analysis flagged a small subset of legacy engine parts with the issue. It later broadened its root-cause analysis and found more affected parts, including some on current-generation engines in the PW1000G geared turbofan (GTF) family. Further analysis flagged the 2,070 disk serial numbers listed in a July 2022 service bulletin that recommended inspections. The FAA and other regulators mandated the checks, setting the interval for the next scheduled shop visit.

Every inspection yields new data that Pratt incorporates into its service-life model for the parts.

"Based upon everything that we knew until very recently, we believed the life of the turbine disk was such that we would see these disks in the shop and be able to inspect them before we ever had an issue," said Gregory Hayes, chairman and CEO of RTX. "As we looked at the data again over the last couple of months, our safety risk-assessment [experts] went through their process of updating the data based on all the recent findings. And they said: 'You know what, we're not absolutely positive that the lifing model is accurate. We want to take a look at these disks at a much-accelerated basis.'"

In the long term, the checks will lead to new inspection intervals, which regulators are expected to mandate. However, the near-term ramifications for affected operators are unclear. Some inspections can be done during already scheduled shop visits, while others may lead to slight changes in airline maintenance schedules.

But many are expected to take place well before airlines had planned them, which could lead to significant fleet disruptions. Pratt is developing a "project" shop visit for these cases to minimize the required work and related engine downtime.

"Right now, we've got to work through how we define the work scope and the turnaround time that's required," Calio said. "GTF is going to have a lot of shop visits here in the back half of 2023 and into 2024. We need to figure out how many of those are incremental and what the true impact of the fleet is, but that's ongoing."

Pratt has been adding GTF overhaul capacity to its network as part of a planned ramp-up to meet both scheduled overhauls and address unforeseen problems. Pratt has 13 shops and planned to add six more by 2025. That timeline may change.

"We're going to have to accelerate some of the tooling," Hayes said.

The new wave of inspections will add complexity for some airlines that have seen their GTF fleets plagued with durability issues and premature

engine removals for years. An Aviation Week analysis in April found 11% of all PW1000G-powered aircraft, mostly A320neos and A220s, were either grounded or flying less than once per week (*AW&ST* May 22-June 4, p. 16). In many cases, airlines were waiting for Pratt to provide needed spares or free up slots in engine shops to make repairs.

"We will work through this difficult time," Calio said.

"We've got this," Hayes added. "It's going to be expensive. We're going to make the airlines whole as a result of the disruption we're going to cause them."

Among the few slivers of positive news is that Pratt's inspections have yielded few disks that needed immediate replacement—less than 1% of the more than 3,000 examined from multiple Pratt and IAE engines.

"Of course, if we had to replace the turbines, then we'd factor that into the turnaround time," Calio said. "But our assumption, based on everything that we've seen thus far, is that the fallout rate [on the new inspections] will be very low."

The issue was corrected on the production line in 2021, so recently delivered engines are not affected. The contaminated powder came from HMI Metal Powders—a wholly owned Raytheon subsidiary—and was processed at Pratt's Columbus, Georgia, manufacturing facility.

Clayville, New York-based HMI has been the principal supplier of superalloy powder and billet to Pratt since the mid-1990s. Although nickel-based PM superalloys have been used for many years in the hot sections of engines, Pratt developed a fourth-generation PM for the GTF high-pressure turbine that was designed to allow for operation at higher temperatures. In general, the use of PM superalloys provides improved strength, creep resistance and creep fatigue, as well as better low-cycle fatigue properties at higher temperatures than conventional superalloys.

Pratt has also developed several manufacturing technology innovations for the use of PM, including isothermal forging—sometimes called "gatorizing"—and the use of finer powder. Smaller-gauge powder is designed to reduce vulnerability to fracture initiation and growth, while isothermal forging improves low-cycle fatigue properties compared with conventional processes.

Although the use of PM is not in itself usually the cause of defects in the superalloy, the manufacturing process has to be controlled carefully to prevent contamination of the powder. If contamination occurs, it can alter the fracture mechanics—increasing the potential for defects and faster crack growth. It is not known if contamination is at the root of the process issue identified by Pratt over the 2015-21 batch problem. In most PM manufacturing, issues with contamination are minimized with vacuums or inert gas screening and loading.

Boeing Is Bolstered by Production, Research and Cash Flow Progress

- THE COMPANY REAFFIRMS 737 PRODUCTION RATE INCREASES AND DELIVERIES
- DEFENSE AND SPACE DIVISION CONTINUES TO PILE UP CHARGES

Sean Broderick and **Michael Bruno** Washington and **Guy Norris** Colorado Springs

Boeing stakeholders have become so used to bad quarterly reports from the Arlington, Virginia-based company that they gird themselves every three months. It may be time to start unclenching their fists.

The aircraft-maker is back to generating cash and on the way to meeting key promises made to investors, top managers asserted July 26 as they unveiled financial results for the second quarter of 2023 that exceeded Wall Street expectations in a few meaningful ways.

At the same time, Boeing—citing growing stability throughout its commercial aircraft programs—is on pace to achieve projected production increases and near-term delivery targets. It is further speeding up the resumption of 777-9 production. And there is even serious talk of hitting a monthly production rate of 60 new 737 narrowbodies.

"I would love to get to 60," Boeing CEO and President Dave Calhoun said in a teleconference with financial analysts. "The market is there for it, there's no doubt about it." In the meantime, Boeing is confident in its forecast of 400-450 737 deliveries this year despite the recent tailfin assembly issues (*AW&ST* May 22-June 4, p. 26) and the weeklong strike at Spirit AeroSystems in Wichita (*AW&ST* July 17-30, p. 12).

But before Boeing can contemplate rates beyond the 50-52 per month it has targeted for 2025-26, stabilizing production at the new rate of 38 per month takes priority.

"That is the second half of next year," Calhoun said about the next rate break. "That's when we wind down all our shadow factory efforts and we can apply all the labor to those rate increases."

Boeing said 737-7 and 737-10 certification programs are progressing. While FAA approval of the 737-7 is still expected this year, first deliveries will not take place until 2024, the OEM confirmed separately in its quarterly regulatory filing. This aligns with the fleet planning assumptions of launch customer Southwest Airlines, which has become conservative with 737-7 delivery dates to account for prolonged FAA reviews of new aircraft programs, with the last two 737 MAX variants topping the list.

The 737-10's timeline still envisions FAA type inspection authorization in 2023, with certification and first deliveries in 2024. This is despite significant changes to the model compared with the other 737 MAX-family versions, not to mention more stringent FAA certification requirements.

Meanwhile, as Boeing begins work to adapt a former Delta Air Lines MD-90 into the X-66A Transonic Truss-Braced Wing research aircraft, Calhoun said he remains confident it will pave the way for a 737 replacement. "We are intent on proving this technology, and we are hopeful," he said. "If it matures the way we think it will, and NASA frankly thinks it will as well, I do think it will see service."

The ultimate choice of engines still is some time away, Calhoun said. "For me to pick and choose the variations and powerplants at this stage is probably not smart. We can use exist-

ing power, but we would prefer to have a bigger fan diameter, ultimately, and maybe even open-rotor someday," he said.

Boeing has also formed a sustainability coalition of leading U.S. airlines to advise on the design and testing of the X-66A. The group includes Alaska Airlines, American Airlines, Delta, Southwest and United Airlines—all of which Boeing says will provide input on operational efficiencies, maintenance, handling characteristics and airport compatibility.

In North Charleston, South Carolina, 787 production is steady at four per month and on track to reach five by year-end. Boeing is maintaining its full-year delivery forecast of at least 70 units despite delivering just 31 in the first half and in spite of the discovery of another production quality problem requiring predelivery rework.

The latest issue affects midbody stringers and related shims needed to ensure the structures meet Boeing's design requirements, sources with knowledge of the issue tell Aviation Week. The issue became apparent in late June—787 handovers were paused from June 30 through July 18 but have resumed.

It is not clear how many aircraft are affected. Among the aircraft flagged for rework, the oldest rolled out in April 2020 and the newest was built in January 2022, consultancy Aero Analysis Partners says.

Rework can be done away from the final assembly line, like postproduction join verification that all 787s are going through to address a series of nonconformances flagged in recent years. Boeing says it had 85 undelivered 787s in inventory on June 30 and expects to have most of them in customers' hands by the end of 2024.

The positive production commentary came as Boeing reported what would normally be seen as mixed overall financial results, except that it might have turned a corner on generating free cash flow (FCF), an important metric of financial health for shareholders and debt holders alike.

Boeing reported quarterly revenue of $19.75 billion, up 18% from the second quarter of 2022. It had a net loss of $149 million versus a gain of $160 million for the same quarter last year, with comparable per-share results of a loss of $0.25 against a gain of $0.32.

Yet Boeing reported an FCF of almost $2.6 billion in the latest quarter. Financial analysts had expected a small gain at best or even a small cash burn. Company leaders further reiterated their earlier promise to deliver $3-5 billion in FCF by the end of 2023. With the latest results, Boeing has generated $1.8 billion in FCF in the first half, and executives have already said they expect a stronger second-half performance.

Still, the company is haunted by the Boeing Defense, Space and Security (BDS) division, where charges on several high-profile programs for NASA and the Pentagon have reached $12.2 billion, including new red ink (see chart).

BDS revenue for the second quarter was in line with expectations at $6.2 billion, but the division swung to an operating loss of $527 million for the quarter versus a gain of $71 million year over year. Operating margins plummeted to -8.5% from +1.1%.

The poor results were primarily driven by losses on fixed-price development programs—a long-running specter for legacy primes—as well as continued "labor instability" and supply chain disruption on other BDS programs, Boeing said. The NASA Commercial Crew program recorded a $257 million loss in the latest quarter due to the cascading effects of the previously announced launch delay, Boeing says. The U.S. Air Force T-7A program recorded a $189 million loss resulting from growing estimated costs on production contracts. The Navy MQ-25 program also recorded a $68 million loss from schedule delays.

"I think we said that we're not expecting much at all from the BDS portfolio, just to be clear, because these things aren't going to solve themselves in the near term," Boeing Chief Financial Officer Brian West told analysts on the call. He said overcoming issues in the BDS programs requires managers to achieve a swing of hundreds of millions of dollars in both costs and revenues.

While heartened by the latest FCF and production reports, analysts remain sanguine. "We view the second-quarter performance from Boeing as mixed," Rob Stallard and Karl Oehlschlaeger of Vertical Research Partners say. "On

Airbus Scrutinizes A321XLR Modifications for Performance Effects

- AIRFRAMER ASSESSES HOW TO OFFSET WEIGHT ADDED BY REAR CENTER FUEL TANK FIX
- COMMITMENT TO THE MODEL'S SERVICE ENTRY IN SECOND QUARTER OF 2024 IS CONFIRMED

Jens Flottau Frankfurt

Airbus is conducting performance validation flight tests of the A321XLR to determine the range penalty of added safety measures required by the European Union Aviation Safety Agency.

The OEM and the European Union Aviation Safety Agency (EASA) early this year settled on modifications to and around the rear center fuel tank (RCT) that include the addition of a Kevlar liner inside the tank and some structural reinforcements. The Kevlar liner is to slow the outflow of fuel in case of a tank puncture, thereby increasing safety and fire protection. The RCT has a fuel capacity of around 13,000 liters (3,400 gal.) and is key for Airbus to be able to reach the 4,700-nm range it has promised to customers.

Airbus CEO Guillaume Faury said on a July 26 call with reporters that it has taken some time to "get our arms around the best way" to address issues raised by EASA. The solution that has been found "adds weight on the airplane," Faury confirmed, and performance now needs to be validated in flight testing.

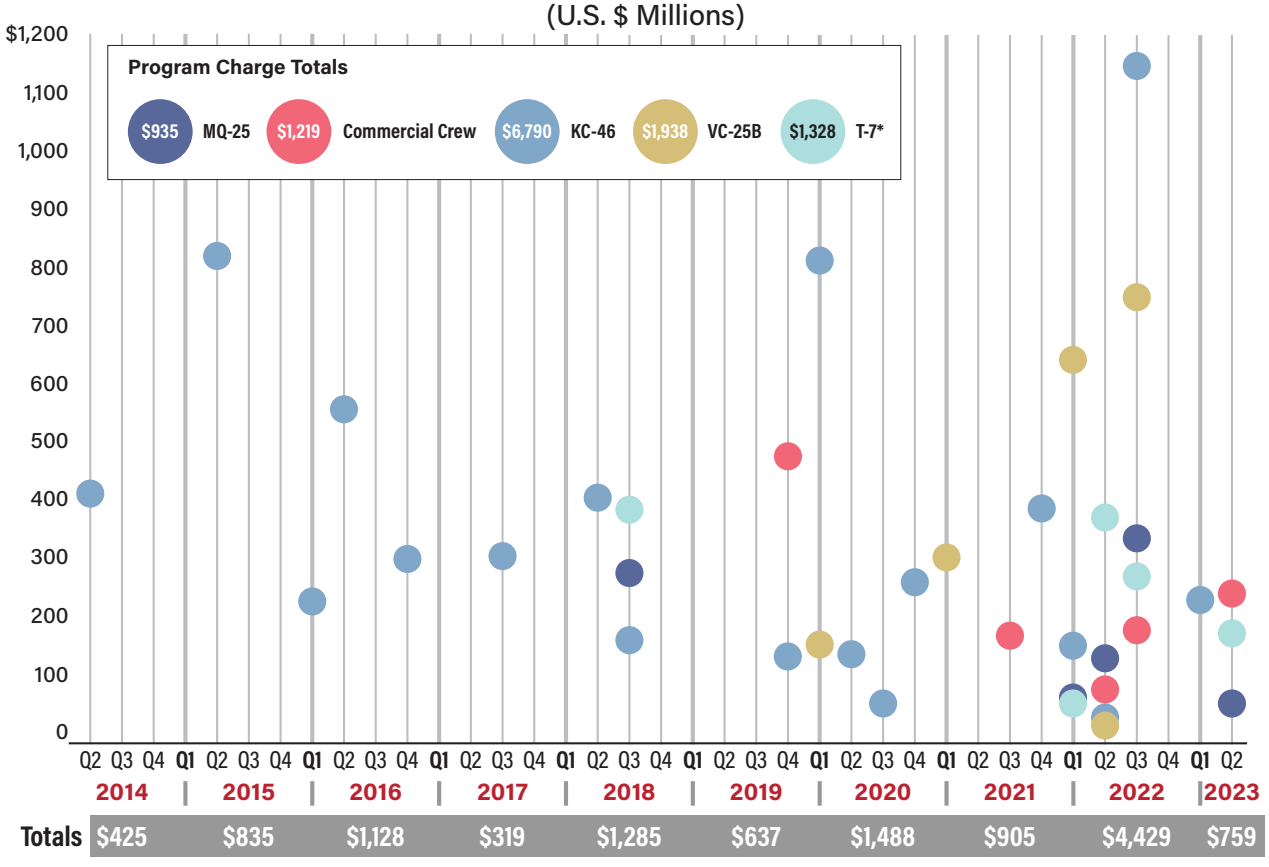
At the same time, Airbus has identified potential areas for weight savings. Faury said Airbus is aiming to "come as close as we can to what we have committed to" and has anticipated that the aircraft will be very close to matching or even surpassing the performance we have promised."

Nonetheless, Faury reconfirmed Airbus' target for the XLR to enter service in the second quarter of 2024.

The latest production quality issue around the Pratt &

Boeing Defense and Space Fixed-Price Contract Charges, 2014-23

(U.S. $ Millions)



*Includes $936 million in forward losses on production aircraft.

Source: Data from Boeing quarterly reports compiled by Steve Trimble/AW&ST

the positive side, there was the Boeing Global Services margin, a steadier production rate at Boeing Commercial Airplanes and, of course, the cash flow (albeit flattered by the timing of deposits). On the flip side, defense continues to bleed money, and supply chain remains a challenge.

"So overall, not bad and a much better performance than what the company has reported in the not-too-distant past," they add. "But investors hardly need reminding that Boeing has been accident-prone, and we see lower-risk/higher-quality alternatives in the aerospace sector."

Whitney PW1100G engines powering the A320neo family is creating a "very critical situation for customers" and "a lot of frustration" as airlines aim for maximum aircraft utilization during the Northern Hemisphere's peak summer season, Faury said. He does not expect a direct or indirect effect on Airbus this year, with Pratt under even more pressure to deliver replacement engines to airlines. "There might be indirect consequences" later based on the new findings, he conceded, but Airbus has yet to receive information from Pratt about 2024 and 2025 engine deliveries.

In response, Pratt is accelerating inspections for more than 1,000 engines—200 alone that have to be removed and checked by September and another 1,000 to be inspected by the middle of 2024 (see page 18). The affected engines have stage 1 and 2 disks flagged by Pratt as containing contaminated powder metal that can reduce a part's service life. The aircraft in question were delivered between the fourth quarter of 2015 and the third quarter of 2021.

Coinciding with the latest Pratt production problem's emergence, Faury said supply chain performance is not improving, and deliveries are still "paced by a few critical suppliers."

On the company's July 26 earnings call, Faury reconfirmed Airbus' ramp-up goal of producing 75 A320neo-family aircraft per month by 2026, but he added that Airbus will no longer announce interim targets. The OEM had previously aimed to reach a rate of 65 by the end of 2024. "I am not withdrawing a target," he said. "There is no change to the plan." As part of it, the A220 is to reach 14 aircraft per month around the middle of the decade, the A330neo four aircraft per month in 2024 and the A350 nine per month by the end of 2025.

Airbus delivered 316 commercial aircraft in the first six months of 2023, among them 25 A220s, 256 A320neo-family aircraft, 14 A330neos and 21 A350s. The company aims to deliver 720 units by year-end, 60 more than in 2022.

The aircraft-maker recorded 1,044 firm orders for the first half of 2023, compared with 259 a year earlier. This was mainly due to large orders placed by IndiGo and Air India. Commercial aircraft revenues were up 16% in the first half at €20.3 billion ($22.3 billion), but operating profit fell 38% to €1.5 billion, partly because Airbus was building up a larger-than-expected inventory as supply chain constraints delayed aircraft deliveries.

French Near-Collision Investigation Highlights Lingering Safety Issues

> REPORTING TECHNICAL MISHAPS IS STILL PROBLEMATIC FOR PILOTS

> DISCREPANCY FOUND IN THE SAFETY EQUIPMENT OF AIRCRAFT SHARING AIRSPACE

Thierry Dubois Lyon

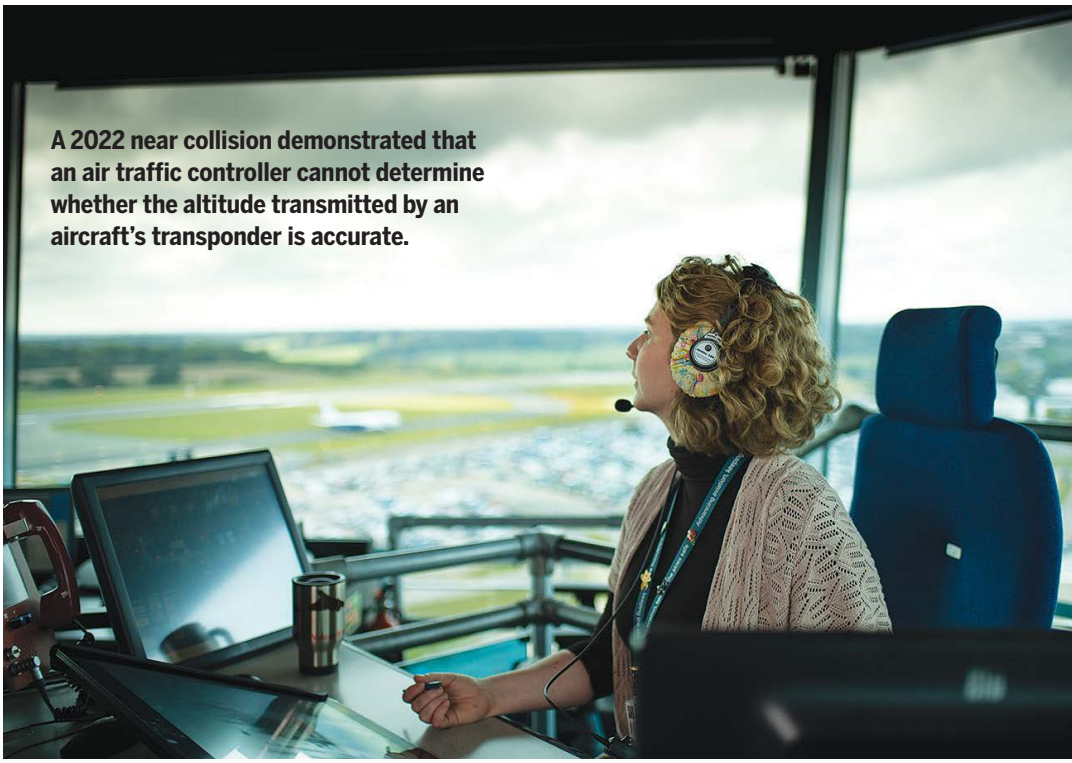
A report by French air accident investigation agency the BEA released July 10 put a spotlight on three safety issues often considered long resolved: critical system redundancy, equipment standard consistency and technical issue reporting. The first two may take years to truly resolve, given the long cycles in rulemaking and fleet retrofit, but technical answers can be found.

The third problem is more concerning because it points to a cultural issue: pilot hesitancy to report mishaps in their aircraft's technical logbooks. What the BEA investigators found substantiates something unions have been warning about for years, though with little prior evidence. The concept of "just culture," under which a pilot feels comfortable reporting a problem without fear of punishment, has yet to become universal.

The loss of separation between an Embraer ERJ170 operated by Air France subsidiary Hop and a Cessna Model 525 CitationJet operated by Valljet in January 2022 near Auxerre, France, was caused by a failure in the Cessna's air data system, investigators say.

Characterized as a serious incident involving a risk of collision, the event resulted in a minimal vertical separation of 665 ft. and a minimal lateral separation of 1.5 nm. The Embraer was equipped with an airborne collision avoidance system (ACAS) designed to alert the crew about approaching traffic. Because it based its calculation on an erroneous altitude received from the Cessna's transponder, the ACAS did not trigger any alarm or resolution advisory.

The CitationJet's air data system relies on two distinct sets. Set No. 1 corresponds to the left seat and No. 2 to the right seat. Each set includes a pitot probe to measure total pressure, two static probes for atmospheric pressure, an altimeter and an airspeed indicator.



A 2022 near collision demonstrated that an air traffic controller cannot determine whether the altitude transmitted by an aircraft's transponder is accurate.

NATS

During the incident, set No. 1 failed, giving false altitude and speed indications to the crew, who noticed the difference between the two sets. The standby altimeter could not help, as it relies on set No. 1's static ports.

Asking air traffic control for an altitude check did not help, either. The controller read the altitude supplied by the transponder, itself using data from set No. 1. Neither the crew nor the controller realized they were relying on flawed data, and the crew continued the climb.

Within a few dozen seconds, the Cessna's crew saw the Embraer as the controller watched the near collision on a radar screen, and the crew decided to switch to set No. 2.

Before the near collision, it was impossible to determine which of the two sets was showing the correct altitude. Large commercial aircraft rely on an additional level of redundancy for altitude measurement. "On the aircraft I fly, the standby altimeter relies on dedicated sensors," says Paul Reuter, professional affairs director at the European Cockpit Association pilot union. "It should not be technically too difficult to retrofit dedicated sensors."

The BEA report went beyond noting the lack of redundancy. Investigators pointed out the difference between the European Union Aviation Safety Agency's (EASA) certification rules for small aircraft (CS 23) and large aircraft (CS 25). The rules do not guarantee the same level of integrity in altitude information. The safety of a CS 25 aircraft therefore actually depends on the equipment of CS 23 aircraft flying in the vicinity, the BEA said.

That point is relevant for ACAS in addition to altimeters. "Any technology that improves safety and affects

someone we share airspace with is a must-have," Reuter says.

After examing the Cessna's air data system, BEA engineers could not find the root cause of the system error. Based on the symptoms the crew reported, they hypothesized the failure took place in a flexible duct. A total or partial obstruction caused by liquid water or ice was likely, they said.

The same problem on set No. 1 had occurred in 2017, 2019 and 2021. And that is where the BEA's report expressed unusual irritation. "The operator seems to persist in requesting that the detection of a technical fault in flight be subject to validation by the managers directly linked to flight operations," the BEA stated. Such a process breaks EASA commercial air transport regulations.

In 2017, the problem was reported in the technical logbook, as required, leading to maintenance action. In 2019, it was partially mentioned, but with no action taken. In 2021, one month before the incident, it was not documented at all.

BEA investigators gathered pilot accounts suggesting that organizational practices of charter operator Valljet, owner of the Cessna, left system malfunctions unreported despite their implications for airworthiness. They allegedly aimed to avoid flight cancellations, which would have affected revenues.

"At some operators, a safety management system is created only to tick a regulatory box. Then, chances are their people will feel under pressure not to report technical problems, such as to avoid aircraft-on-ground situations," Reuter says. "Reporting challenges do not happen only at small operators. Feedback from our members shows it also happens at large carriers. The perception of pressure may be about balancing safety against economic damage to the company. If you feel reporting will hamper your career, then perception is reality."

The pressure does not specifically come in memos asking pilots to avoid reporting technical issues. "It is rather an atmosphere, the result of nonverbal communications," Reuter says. "It is sometimes ambiguous. People may just hear they should get things done. Last year, the CEO of a low-cost carrier said everyone was fatigued and everyone should carry on."

U.S. Airline Pilot Contract Terms Outpace One Another

- PAY COULD STILL CREEP HIGHER IN DELTA, UNITED, AMERICAN AGREEMENTS
- ONGOING SOUTHWEST PILOT NEGOTIATIONS FOCUS ON EFFICIENCY

Christine Boynton Boston

The ability to do more with less is what makes—and has made—Southwest Airlines great, its pilot union says. "Now we're doing less with more," Southwest Airlines Pilots Association (SWAPA) President Capt. Casey Murray tells Aviation Week. As a result, the focus of ongoing contract negotiations "is about efficiency and about maintaining our position in the industry as a low-cost leader," he says.

Southwest is the last of the U.S. Big Four working toward an agreement with its pilots. The contract became amendable in September 2020, approximately one year after those at Delta Air Lines, American Airlines and United Airlines—which have reached, respectively, a deal, a tentative agreement (TA) and an agreement-in-principle (AIP).

Near-unanimous votes to authorize potential strike action from pilots at American and Delta preceded the progress after negotiations lagged through the COVID-19 pandemic years. The United pilots' union unanimously authorized a vote on whether to strike, and in early May, 99% of SWAPA-represented pilots voted to authorize a strike, with 98% taking part.

SWAPA

Southwest Airlines pilots have yet to reach an agreement on a new contract and are calling on airline leadership to take an active role.

Among North American carriers, Calgary, Alberta-based WestJet has come closest to actual strike action, announcing an agreement with hours to spare before a work stoppage was set to begin on May 19. UPS pilots, who signed a two-year contract extension last August, could be next—they are prepared to support a strike by their Teamsters-represented delivery driver and warehouse logistics colleagues. That action could begin Aug. 1 if an agreement is not finalized.

"We're going to honor their lines," Brian Gaudet, director of public affairs at the Independent Pilots Association, told Aviation Week June 30. "If the Teamster picket line is up, we will not be crossing those lines."

In the current high-pressure, demand-rich, capacity-challenged environment, the most recent U.S. airline to achieve contract progress is United. The AIP announced July 15 is a deal the Air Line Pilots Association, International values at $10 billion. It includes significant raises as well as improvements to quality-of-work-life provisions, job security, retirement and benefits.

Quality-of-work-life provisions and pay have been recurring themes during post-pandemic pilot negotiations. For Southwest pilots, that means addressing scheduling—including reassignment practices and the resulting fatigue—and ultimately boils down to improved efficiency.

"I feel confident when I say we're the only labor union in the world that is not trying to work less and get paid more; we're trying to provide efficiency so that we work smarter," Murray says. "That's our main sticking point in negotiations: simply trying to drive some efficiencies in how we are being used."

Emphasizing that focus, SWAPA points to "meltdowns that Southwest has [had] from time to time," including over the Columbus Day holiday in October 2021 and the December 2022 holiday season. Following the December disruption, the Dallas-based carrier began implementing a remediation plan and is budgeted to spend more than $1.3 billion on upgrades and maintenance of information technology (IT) systems this year.

Describing an "operational drift," the union, which represents nearly 10,000 pilots, says the problem is more than IT and infrastructure.

"Yes, $1.3 billion does need to be spent," Murray says. "With the focus on dividends and buybacks over the last decade, there has been a lack of investment in infrastructure and IT, and that does have to be done. But none of that is going to solve the process problems of connecting pilots and airplanes. . . . There has to be a refocusing on efficiency."

In late June, SWAPA requested a release from federal mediation, describing an impasse over several items including pay. In a July 17 message to union members, Murray said a "wasted week of negotiations" had included the take-back of agreements on parental leave that were set to improve language described as being nearly 40 years out of date.

He called on leadership to take an active role. "To date, in over three years, we have yet to see anyone but the company's negotiator and his team in negotiations," Murray says. "That's disconcerting, especially considering where we are in this process. American, Delta and United's CEOs have been involved, and deals have gotten done, and they've gotten through some very difficult issues on their side. Having senior leadership in there to kind of push it along has really helped."

Southwest Airlines in a statement to Aviation Week said it is confident mediation would "continue driving us even closer to a final agreement" that benefits pilots and the business.

The airlines that have struck agreements and deals are not done raising the bar. Thanks to competitive language, pay raises are set to go higher. Within Delta's and United's terms are provisions intended to outpace or match the other on compensation.

Under Delta's, a "me too" clause would increase pay as much as 1% above higher rates set by United or American. Under United's proposed AIP terms, once Delta executes a "snap-up" triggered by either carrier, United pilot pay rates would then increase by 1% to match. The United AIP, fea-

turing cumulative raises of 34.5-40.2% over four years, is now causing American's pilots to reexamine their own TA.

That deal, the Allied Pilots Association (APA) says, has changed the bargaining landscape. "While our pending TA built on some of the gains achieved in the Delta pilots' agreement, it appears that United CEO Scott Kirby has found ways to address pay and quality-of-work-life items for his pilots that American CEO Robert Isom and his team have repeatedly told us were simply impossible to do here," the APA said in a July 16 statement. In American's second-quarter earnings call on July 20, Isom told investors: "We're going to match the wages that United is proposing."

The high-cost contracts are coming during what recent analysis by the Swelbar-Zhong Consultancy—shared with its Research Lab members and seen by Aviation Week—describes as "the second half of the deregulation game," beginning with elements similar to the first half: high fuel costs, economic woes, air traffic control issues and "incumbents with outsized market power."

"Halftime was the pandemic; this was an industry reset," Bill Swelbar, the consultancy's chief industry analyst, tells Aviation Week. "I think what's really interesting here is, people were fearful of the big incumbents at the time of deregulation. Once again, the biggest incumbents seem to have the most market power."

The large pay hikes, Swelbar points out, are an important ingredient in attracting new aviators during what airlines say is a challenging time for pilot supply.

Fares will need to be higher if margins are to be maintained, he says, noting differences compared to the post 9/11 bankruptcy period. Rather than lowering costs to compete, it is now about higher costs and higher fares to slow the growth of lower-cost competitors.

"There have never been increases granted like those being negotiated today, in my memory," Swelbar says. "In the short run, network carriers win. Southwest and the [ultra-low-cost carriers] will have little choice but to raise their fares, too, to compensate for the rapidly increasing costs. If the central theme of the antitrust laws is to promote competition . . . today's labor/management have negotiated agreements that have all but eliminated wage competition among and between sectors. Barriers to entry are being erected and will impact consumers going forward. The competitive intensity will also be less over time."

Going forward, the $10 billion question is whether the deals will be sustainable in the long term. If looking back to history for an answer, one significant factor to note today is cash. "What changes this period is these carriers have balance sheets, and they have liquidity," Swelbar says. "Historically, airlines had no balance sheet, no capacity to borrow, and while their borrowing capacity is less, post-pandemic, they remain very liquid. Time they have."

As Northeast Alliance Wind-Down Begins, American Plans an Appeal

> NEW FILINGS REVEAL THE NEXT STEPS FOR THE NEA

> THE CARRIERS ARE JOINTLY DISMANTLING THE PARTNERSHIP

Christine Boynton Boston

Work on a slot wind-down plan is underway by American Airlines and JetBlue Airways as they dismantle the Northeast Alliance they launched in February 2021, in accordance with a federal ruling this spring.

Through their agreement, JetBlue is leasing nearly 100 slots from American at New York's John F. Kennedy International Airport (JFK) and LaGuardia Airport (LGA) per the ruling, which ultimately found the Northeast Alliance (NEA) to be anticompetitive (*AW&ST* June 5-18, p. 26).

American plans to appeal, although JetBlue has announced it will not contest the decision.

"As we go forward we'll certainly share more, but it's very much our plan and our intention that we continue to see more New York City-originating customers flying with us," American Chief Commercial Officer Vasu Raja said during the carrier's second-quarter earnings call on July 20. "This chapter is closed—another one might open—but we don't expect any material change to our financial outlook."

The two airlines disclosed in filings July 19 that they were "actively working" to submit a slot wind-down plan facilitating the return of American's slots at JFK and LGA—currently under lease to JetBlue—and to end the sharing of other airport infrastructure.

The split between the partners on a decision to appeal was revealed July 5, when JetBlue announced it would end the arrangement and instead turn its focus to the second U.S. Justice Department-initiated suit it faces regarding its potential merger with Spirit Airlines. That case goes to court in October.

"As it relates to the Spirit combination, terminating the NEA renders the Department of Justice's concerns about our partnership with a legacy carrier entirely moot," JetBlue said July 5.

"We, of course, respect JetBlue's decision to focus on its other antitrust and regulatory challenges," American said in response, while reiterating its intent to contest what it called an "erroneous" judicial ruling. "JetBlue's decision and reasoning confirm our belief that the NEA has been highly pro-competitive," the Fort Worth-based carrier added.

Ordering the dissolution of the more than two-year-old alliance, the May 19 federal decision found that it "substantially diminishe[d] competition in the domestic market for air travel."

American has yet to publicly comment further on an appeal, but it could point to the problem it faces at JFK of being unable to build a sufficient short-haul feed system due to the airport's severely inadequate runway capacity, says Craig Jenks of New York-based consultancy Airline/Aircraft Projects.

"An argument focused more on the challenges of operating viably at JFK might highlight how that airport has been losing long-haul connecting mar-

ket share, and consequently long-haul nonstop viability, to other hubs both in the U.S. and elsewhere." Jenks says. "The deal with JetBlue was leading American to a better JFK long-haul outlook. A successful appeal would allow resumption of the deal, assuming JetBlue still wished to go ahead."

While preparing to launch the alliance, American executives in July 2020 pointed to a "unique problem" they faced when looking at their hubs: All the hubs produced unit revenue premiums 10-20% higher than the industry, excluding infrastructure-constrained New York, Boston and the West Coast, where they produced a 10% revenue-per-available-seat-mile deficit compared to the industry.

After the NEA's launch, it did not take long to see the benefits. JetBlue executives noted at the start of 2022 that the alliance had already generated $100 million in codeshare revenue, and in May 2022 Raja noted American's unit revenue improvement in New York had grown sequentially each month.

"We're starting to see signs where it is growing sequentially and even sometimes at a greater rate than the rest of the system, which in our domestic system is no small shakes," Raja said at an investor conference in May 2022. "I've never seen New York unit revenue performance outpace the system."

American certainly saw some traction from the alliance in the New York market, where it had typically struggled. The alliance grew in a phased approach to cover 290 daily departures from JFK by April 2023, with JetBlue operating 190 of those services. At LaGuardia, the partners combined operated 190 flights, with JetBlue handling 52. From Boston, JetBlue operated roughly 150 of the 220 daily departures flown under the NEA.

"Raja said very clearly they needed JetBlue for JFK hub viability," Jenks notes. "In 2016-19, American was building long-haul feed at [Philadelphia International Airport] PHL at the expense of JFK, because that was where it had good feed. However, PHL [origin-and-destination] traffic clearly is way less than JFK's, and the NEA then gave American the feed that slot restraints had prevented it from growing organically. What American now does on East Coast long-hauls remains to be seen."

Initially, in the proposed terms of the final injunction submitted June 9 at the request of the judge, American and JetBlue had sought to keep "pro-competitive" codesharing and frequent-flyer portions of the arrangement intact while the Justice Department asked the court to reject what it dubbed an "NEA Lite." But less than a month after that request, JetBlue announced its decision to end the arrangement. Ahead of the NEA's return to court, the federal judge asked for "joint or separate positions regarding what, if any, impact [JetBlue's] termination [of the NEA] has on the proposed terms of the final injunction and judgment in this case."

JetBlue and American disclosed in July 19 filings they were "actively working" to submit a slot wind-down plan and end sharing of airport infrastructure.

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As a first step, the two said they would end codesharing and loyalty benefits for travel not yet booked on July 21. The July 19 filings next disclosed that work on a slot wind-down plan was underway.

"[The] wind-down process is far enough along that by the time of the hearing on July 26, the key conduct the court found unlawful—specifically capacity coordination and revenue sharing—will have ended or will be within days of ending," the carriers wrote in the filing.

A court order following the July 26 hearing took airline action into consideration, striking down some of the oversight terms proposed by the Justice Department, including appointment of a five-year monitor to broadly oversee an unwinding of the relationship.

The judge also rejected a Justice Department-proposed provision prohibiting each airline from entering any new agreements that are "substantially similar to the NEA" with other domestic carriers—though the defendants did agree to a provision prohibiting such agreements with one another for the next decade, he noted.

Although the two airlines have jointly begun to dismantle the arrangement, American struck an optimistic tone on a July 20 earnings call, stating that some of its past challenges had since improved. "It's unfortunate the NEA is terminated," Raja said. "Our commitment to the customers in the Northeast, and New York specific[ally], hasn't changed. However, the circumstances that gave rise to the NEA have changed."

He pointed to the carrier's slot portfolio, which he said now better matched demand, being less focused on short-haul business-day trips. Operational expenses at JFK had also improved, he said, through the co-location of partners and fleet changes. Additionally, onboard its international flights from New York, roughly 35-40 points of load factor were being generated by American's international partners, he added, describing an intent to grow its New York customer base as "very much our plan."

"Our partnership within the NEA was actually a very small amount of the onboard load factor that's there," Raja said. "That's why when we couple both the expense reduction . . . and some changes that we can make ourselves, we believe that we can go and really replace a lot of the demand, especially now that we've got such a

larger New York City-originating customer base than what we had before."

American has downplayed any impacts on its own balance sheet, but a dissolution of the partnership could mean challenging financial repercussions for JetBlue, already disproportionately affected by a difficult summer season of weather and air traffic control staffing shortage-related delays in the Northeast. Regulatory filings last year warned that an unfavorable ruling could have an "adverse impact" on the New York-based carrier's business and financial results, including operational costs, "which would not be recoverable," the airline said.

A failure to gain approval for its acquisition of Spirit would add more costs. Under the terms of the proposed deal, JetBlue would acquire the Fort Lauderdale, Florida-based ultra-low-cost carrier for $33.50-34.15 per share in cash, depending on the timing of closing. This includes the monthly payments of 10 cents per share it has been making to Spirit shareholders since the start of the year, which it had planned to continue until the transaction is closed or terminated. Should the deal fall through for antitrust reasons, JetBlue has agreed to pay Spirit a "reverse breakup fee" of $70 million, and stockholders would be set to receive $400 million, less any amount paid prior to termination.

Approval of the merger could be a welcome reprieve for JetBlue, which has projected that a combined company with Spirit would have annual revenues of approximately $11.9 billion. JetBlue reported operating revenues of $8.1 billion in 2019 and $9.2 billion in 2022. But should JetBlue fail to win its next antitrust case, what would its future look like, without the NEA and Spirit?

"The industry is in a cyclical upswing, with supply simply unable to meet demand on several critical fronts," Jenks says. "JetBlue will therefore at least benefit from the 'rising tide lifting all boats' upswing effect . . . and may deploy competitive flair beyond that."

A final NEA judgment and permanent injunction incorporating ordered changes and agreements was due from the plaintiffs on July 28 after which the judge was expected to review, sign and enter that injunction.

—With Lori Ranson in Washington

ARCHER AVIATION

AAM Leaders Warn About Proposed Regulations for eVTOL Operations

> ENERGY RESERVE PROPOSAL IS A CRITICAL CONCERN FOR eVTOLs

> PILOT TYPE RATING REQUIREMENTS ARE ALSO IMPORTANT

Graham Warwick and **Ben Goldstein** Washington

Under increasing pressure to act to ensure U.S. leadership in emerging aviation markets including advanced air mobility, the FAA has released a slew of plans and proposed regulations intended to embrace new technologies, including electric propulsion.

But seeing the risk aversion that has gripped the FAA in the wake of the Boeing 737 MAX crisis, industry and Congress alike question whether the regulator can be sufficiently forward-looking and fast-moving to enable U.S. leadership in the face of growing competition from Europe and China.

On June 14, the FAA published the notice of proposed rulemaking (NPRM) for the Special Federal Aviation Regulation (SFAR) establishing the pilot certification and operating rules for powered-lift electric vertical-takeoff-and-landing (eVTOL) vehicles.

On July 18, the regulator issued its plans for near-term implementation of advanced air mobility (AAM), called Innovate28 (I28), aimed at enabling eVTOL operations at scale at key locations in the U.S. by 2028. The priority is ensuring their use at a significant scale at the Los Angeles 2028 Summer Olympics.

And on July 24, the FAA published the NPRM for revamped rules for the manufacture, certification and operation of light sport aircraft. Developed under the Modernization of Special Airworthiness Certification (Mosaic) initiative, this will allow aircraft with electric propulsion systems and simplified flight controls, a move intended to increase their suitability for flight training and personal flying (see page 62).

Amid this flurry of activity, the U.S. House of Representatives on July 20 passed its version of the 2023 FAA reauthorization bill, focusing on reorganizing the regulator in a bid to reassert U.S. leadership in aviation. While the Senate has not passed its own version, the House bill includes new provisions for AAM and innovation and directs the FAA to meet its rulemaking deadlines.

Industry leaders have expressed concerns about key provisions in the FAA's proposed SFAR for powered-lift pilot certification and operations. "Getting the SFAR out is an amazing accomplishment, but there are rules in there that are instant industry-killers," Adam Goldstein, founder and CEO of eVTOL developer Archer Aviation, said on July 18 at a Honeywell AAM summit in Washington.

The FAA must meet its rulemaking deadlines if the U.S. is to lead the AAM market, say industry and Congress.

"There are some showstoppers in there," Jim Viola, president of Helicopter Association International, said at the event. "I went through the document and put a green check on paragraphs that enable us or a big red X on those that would kill the industry. There at least five of those."

Release of the NPRM follows the FAA's U-turn on eVTOL type certification in May 2021, when it decided to treat them as a special class of powered-lift aircraft for which certification standards and operating rules did not exist. "We objected as an industry but said, 'OK, you're the regulator, we're going to go down this path,'" Pete Bunce, president and CEO of the General Aviation Manufacturers Association (GAMA), said at the summit.

"Now they go and publish the SFAR and . . . there are a lot of problems with it," he continued. "It's like [FAA] specialists just started throwing stuff against the wall and said, 'This is the way we've done it all the time,' without thinking about what we really want to do." Viola concurred, noting that parts of the SFAR read like the opinions of individual inspectors and not the considered judgment of the FAA.

Industry concerns with the SFAR include the energy reserve requirement. Contending that it lacks operational data on powered-lift aircraft, the FAA is proposing to apply existing visual flight rules reserve requirements for fixed-wing aircraft to eVTOLs: 30 min. for daytime operations, 45 min. for nighttime.

But for short-range eVTOL air taxis, a 45-min. energy reserve can double the size of the battery. "They are putting an old requirement for airplanes onto vehicles that cannot handle it," Goldstein said. Industry wants a performance-based require-

ment. "We have to work to show what makes sense," he said.

"We have been saying for years we want performance-based rulemaking, not prescriptive," Viola said. "What has happened in this SFAR is you'll see stuff that is very prescriptive. So it's not performance-based and therefore it limits the capability of these vehicles and what they can do for society."

Other industry concerns with the SFAR include the requirements for pilot training to obtain a type rating for an eVTOL. These call for powered-lift aircraft with dual controls when most OEMs are developing eVTOLs with single-pilot cockpits, as well as full-flight simulators certified to Level C or higher.

"They want a rule to certify the simulator," Bunce said. "But we know how long it takes. It's years and years. It's not going to work. We need leadership within the FAA to talk to the specialists and say, 'No, these machines are different.' In our crawl and walk phases we can take pilots and give them a type rating in a simulator. They don't need dual-control aircraft, which is another showstopper that is in there."

GAMA is working on a coordinated industry response to the proposed SFAR, in addition to individual comments. "We have to apply the right rules to the right aircraft," Bunce said. "And this is such a critical time. If the FAA will listen to industry, take the comments that we are all putting together, I think they can get this right. If they don't, it's going to be problematic and it's going to put the U.S. behind."

Some industry leaders urge caution. "It's great that the SFAR is out. But we need to listen to the FAA's concerns," said Rob Scholl, president and CEO of Textron eAviation. "We have to be sure as an industry of what we ask for. The FAA has responded to industry's requirements for timing. We must be very careful not to get ahead of ourselves. There is work still to do on the technology."

The FAA's goal is to finalize the powered-lift SFAR by the end of 2024, enabling commercial air taxi operations to begin in the U.S. in 2025 as planned by Archer and Joby Aviation. Concerns that the 2028 target of the FAA's AAM implementation plan might shift the agency's focus later are being downplayed.

"The Los Angeles Olympics in 2028 is a forcing function, an opportunity for the U.S. to show leadership in this area with hundreds of aircraft at the Olympics," Archer's Goldstein said. "But we need to get operational in 2025 and start laying out the infrastructure."

That 2028 target does not mean the agency has budged from its original middecade target for type-certifying aircraft, says former FAA acting administrator Billy Nolen, now chief safety officer with Archer. "The FAA hasn't shifted its target at all. What they're saying is they expect initial services in 2025 and then for those operations to be at scale by 2028."

The initial services offered by Archer and Joby are planned to be lower-frequency airport shuttle flights concentrated in large cities such as Chicago and New York. By 2028, the FAA envisions there will be at least one—and possibly several—fairly dense markets with eVTOL vehicles operating at a higher tempo alongside drones and commercial aircraft.

The number of air taxis in commercial service will steadily multiply from as few as 10 in 2025 to perhaps as many as 1,000 by 2028, Nolen predicts. "Innovate28 is that key event that coalesces all of the FAA's different workstreams into a holistic plan of action with clearly replicable steps, milestones and accountability," he says. "So the industry knows where they stand, what the deliverables are and the pathway to getting there."

While the FAA's Mosaic NPRM is not directly connected to the eVTOL SFAR, it would allow sport pilots to fly larger and more capable aircraft as well as designs with electric propulsion systems and simplified flight controls. This is expected to improve safety and reduce the cost of flight training. The proposed rule would not allow sport pilots to fly powered-lift aircraft such as eVTOLs, "given the complexity and ongoing development of those aircraft designs," the FAA says.

On Short Final?

- VOLOCOPTER PREPARES FOR FIRST FLIGHT OF PRODUCTION-STANDARD AIRCRAFT
- IT TARGETS AN INTRACITY NETWORK SHOWCASE AT PARIS 2024 OLYMPICS

Volocopter flew its VoloCity 2X demonstrator at the recent Paris Air Show.

VOLOCOPTER

Jens Flottau Bruchsal, Germany

Volocopter is making the last preparations for the start of flight tests that it hopes will lead to certification of its VoloCity multicopter ahead of the 2024 Paris Olympics. The company plans to fly the production-standard prototype in the coming weeks at its main facility here.

If successful, Volocopter would be the first of a series of advanced air mobility (AAM) startups to receive regulatory clearance for commercial flights that are planned to accompany the Olympic Games next July. Once the Paris project is completed, Volocopter has ambitious plans for more commercial services in other cities, a larger version of the VoloCity, a steep production ramp-up and the introduction of its VoloRegion aircraft that is expected to complement the intracity missions of its first product.

Volocopter has started work on a larger, piloted version of its air taxi that would seat four or five people. "We will have at least three, maybe four paying passengers and a range of 40 km [25 mi.] operationally," Volocopter CEO Dirk Hoke says, adding that that would make the aircraft commercially viable. "We are not looking at maximum range with new batteries, but everyday operations. We believe the batteries we are testing allow for more, but we are conservative, and 40 km is enough to connect almost all airports with downtown."

The larger version would still be a multicopter by design, but limiting its speed and range helps make it easier to maneuver inside city centers. Hoke expects the aircraft to be certified in 2026 ahead of its next big project, the longer-range VoloRegion—an early version of which made its first flight in June 2022.

"We could have gone for a four- or six-seater right away, but then we would not be flying next year," Hoke says. "The batteries just don't deliver that. Battery development has not progressed as fast as hoped."

As part of its cautious, step-by-step approach, Volocopter decided to aim for European Union Aviation Safety Agency approval of its two-seater as fast as possible. "It is not a great business case," Hoke says. In fact, Volocopter decided to subsidize operations in the first two years. For the company, the process is more a case of "gaining experience."

"And it is a big success anyway because helicopters are not allowed where we fly, and we want to show the population our technology," Hoke adds. "Initial reactions will be key."

The flight-test campaign will begin here, but Volocopter is searching for a site more suitable for testing in the winter. Fellow German startup Lilium has moved flight tests

of its uncrewed Phoenix demonstrator to a test facility near Ubeda, Spain. A decision on where to test in the winter is expected shortly—and it is crucial to facilitate certification before July 2024.

Volocopter plans to operate several aircraft on five routes in Paris during the Olympics. Among them: a connection between Charles de Gaulle and Le Bourget airports, a service from Le Bourget to the Austerlitz train station and one from Austerlitz to nearby Versailles. Hoke says it took him 2 hr. by car to get from Charles de Gaulle to Le Bourget during the recent Paris Air Show, "a perfect example of why you need something like a [VoloCity]," he adds.

VoloCity flights from Charles de Gaulle to Le Bourget will cost up to €180 ($200) based on a €10-15 per-kilometer charge; the Austerlitz flight from Le Bourget will cost up to €300. The next-generation, larger VoloCity and volume production are expected to bring costs down to a level closer to taxi standards, at around €5 per kilometer.

For Hoke, the Paris trial is all about introducing the AAM concept to the public and gauging reactions to operations. "We want to wait for the first wave of reactions from the general public before entering the next phase," Hoke says. "We have talked with our partners about scaling up the operation and adding routes that are commercially viable."

The Paris showcase is intended to be followed by ones in Rome and at the 2025 World Exhibition in Osaka, Japan. Flights are also planned in Neom, Saudi Arabia.

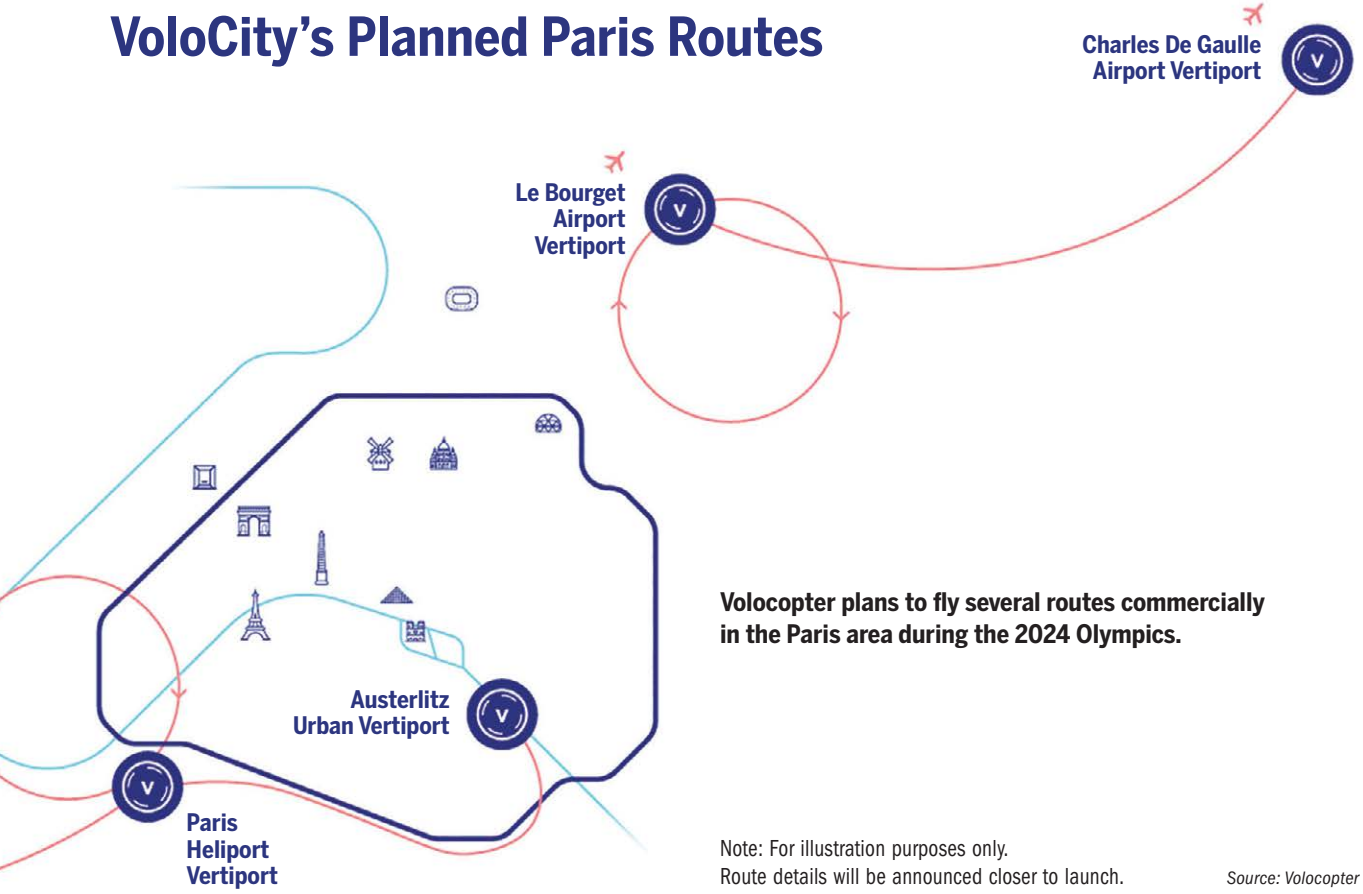
Volocopter has financing in place that will last until the beginning of 2024 and is in the process of securing up to €500 million more to fund it through 2025, including certification and the start of commercial operations in Paris and Rome. "It would be a good basis for a further financing round and eventually an initial public offering," Hoke says.

Looking ahead, Hoke—who joined Volocopter as CEO in September 2022, after serving as CEO of Airbus Defense and Space—sees strong consolidation in the AAM sector kicking in over the next three years. He estimates that the listed AAM startups alone have a combined €4 billion capital need annually, and that total is much greater when other projects are included. "It is challenging to find that capital," Hoke says. "A lot of the promises have not been kept."

Volocopter's projects that the intracity traffic will comprise around 60% of the AAM market initially, with other segments growing later, given what the company's views as a slower-than-expected improvement in battery energy density. Ultimately, Hoke argues that most market forecasts are too conservative in terms of absolute numbers of aircraft deployed but too optimistic about the expected timelines.

Initial production is to take place here with annual capacity for around 50 aircraft. In 2027 or 2028, Hoke expects Volocopter to produce "hundreds" of aircraft per year and estimates around 5,000 Volocopter vehicles of different types will fly in the early 2030s. How production will be distributed is not clear yet. Hoke does not rule out putting more work in Germany, but he notes that France is a key market for Volocopter, too.

VoloCity's Planned Paris Routes



Volocopter plans to fly several routes commercially in the Paris area during the 2024 Olympics.

Note: For illustration purposes only.
Route details will be announced closer to launch.

Source: Volocopter

DEFENDING NATO'S

- GERMANY AND U.S. AIR NATIONAL GUARD LEAD 200-AIRCRAFT AIR DEFENDER EXERCISE
- NATO NATIONS LOOK TO INCREASE OVERALL DEFENSE SPENDING
- GERMANY'S AIR FORCE IS STARTING A NEW MODERNIZATION PLEDGE

Brian Everstine Schleswig-Jagel Air Base, Germany

As NATO leaders prepared for one of the most anticipated meetings in the organization's recent history, 25 member nations wrapped up the alliance's largest air exercise ever—one that represented a dramatic shift in the status of host nation Germany.

A German Air Force Panavia Tornado was painted in a special scheme for the event.

The brainchild of leaders in the German Air Force and U.S. National Guard, NATO's Air Defender 2023 ran from 26 operating locations through most of June—about one year after the German government pledged a large increase in defense spending amid Russia's invasion of Ukraine.

"They see the war in our neighborhood, Russia against Ukraine. They are concerned and they think it's a strong signal of the ability to defend our territory, of deterrence," Lt. Gen. Gunter Katz, commanding general of Germany's Air Forces Command, tells Aviation Week. "And that's why, because they are concerned, some of them are afraid, [so] . . . it's a good thing to [send] such a strong signal."

The subsequent NATO summit in Vilnius, Lithuania, in July saw member nations commit to spending at least 2% of their GDP on defense—a figure that was previously a goal but is now considered a budget floor. Additionally, 20% of that spending is planned to be focused on procuring major weapons systems, including new research and development, according to the communique issued at the close of the event.

NATO Secretary General Jens Stoltenberg said at the summit's end that although Ukraine will not immediately become part of NATO because of the ongoing war, there will be a path for it to join afterward as a broader message to Russia. Member nations also pledged to send more cruise missiles to Ukraine and to begin training of Ukrainian F-16 pilots within Romania.

"What we do know is that the more military support we provide to Ukraine, the more land they are able to liberate, the stronger their hand will be at the negotiating table," Stoltenberg said.

During the Air Defender event, Russia took notice. U.S. Air National Guard Director Lt. Gen. Michael Loh says participating aircraft saw Russia watching from the air on the eastern edge of the exercise, prompting the NATO nations to adjust how they flew to avoid showing all their capabilities.

"Any time we come together to practice and do that stuff, if [there are] real-world assets out there that are monitoring, we're not going to show all our capabilities—nobody would," Loh says. "It's [a question of] how do we conceal our capabilities? . . . We also had some fighters from other countries [around] that were not anticipated, but it's great training for our folks."

He compared it to interactions Russian fighters had with U.S. aircraft in Syria, which prompted the Pentagon to deploy Lockheed Martin F-22s to the region. "So we've seen those same things out there before," Loh says. "Russia was watching."

About 200 aircraft operated together across Europe for more than

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BRIAN EVERSTINE/AW&ST PHOTOS

two weeks during Air Defender. The scenarios were designed to practice all phases of a potential conflict, starting with large-scale deployments from the U.S. It featured the largest airlift from the U.S. since the beginning of the Iraq War.

Aircraft practiced establishing air superiority with the destruction of long- and medium-range surface-to-air missiles (SAM). U.S. participating aircraft included A-10s, Lockheed C-130s, Boeing F-15s, Lockheed Martin F-16s and F-35s, Boeing KC-135s and KC-46s and General Atomics MQ-9s. German participants included Eurofighter Typhoons, Panavia Tornados and Airbus A400Ms. Hungarian Saab Gripens, Greek F-16s, Finnish Boeing F/A-18s, Spanish F-18s and Turkish F-16s also participated, among others.

During a visit by senior-level NATO military members in the later days of the exercise, Aviation Week observed a briefing of a specific scenario. Friendly "blue" forces of F-35s and Eurofighter Typhoons targeted SAMs from afar over the North Sea. Follow-on fighters—including F-16s, Gripens and A-10s—then came in to target smaller, mobile SAMs. Joint terminal attack controllers and special operations forces on the ground located and followed the mobile SAMs, providing new targeting information for the aircraft.

"Red" enemy aircraft played the roles of Sukhoi Su-24s and Su-30s, with simulated SA-11s and SA-15 SAMs on the ground. Additionally, aircraft defended against a simulated long-range bomber strike, with a Typhoon dropping to a low level to mimic a cruise missile, Loh says.

The exercise gave Germany a chance to train closely with F-35As—in this case, Joint Strike Fighters of the Vermont Air National Guard. The F-35 presence in Europe is increasing as the U.S. contingent at RAF Lakenheath, England, continues to take on aircraft. Berlin has finalized an €8.3 billion ($9.3 billion) plan to buy 35 of the aircraft,

Air National Guard pilots practiced multiple phases of an air war, including targeting surface-to-air missiles, as part of NATO's Air Defender.

A U.S. Air National Guard F-16 taxied by a line of other F-16s and A-10s before taking off as part of the June exercise.

which are set to be based at Buchel air base. The German Air Force plans to begin training with the aircraft in 2026, with deliveries to start in 2027. German Air Force Commander Lt. Gen. Ingo Gerhartz, who was a leader in planning the NATO exercise, says his service is in the "learning phase" with the aircraft.

The massive deployment of Air National Guard aircraft comes as the U.S. Air Force and Capitol Hill debate the future of the fleet. The service is continuing a "divest to invest" plan, aiming to fully retire A-10s, F-15C/Ds and about half of the F-15E fleet. Most of the A-10s and F-15s are flown by the Air National Guard.

Loh says he is concerned about the future of his fleet, pointing out that any additional funding the guard receives would need to go directly to fighter modernization. This would mean the guard should be given aircraft fresh off the production line, he says, likely more F-15EXs.

"You can see that capacity's an issue when you put together a large force package to go out there and execute. Numbers matter," he says. "So the ability to put fifth-gen, fourth-gen—the F-15EX is a lot closer to a fifth-gen fighter with its capabilities than it is a fourth-gen—the ability to put those modern assets on the battlefield will definitely pay huge dividends."

The Air Force is in the early stages of bringing F-15EXs on board. The planned buy changed with each budget request during the previous few years. The latest request calls for purchasing 104 of the aircraft. The service plans to combine F-15E and F-15EX training after the Air National Guard closes down the F-15C/D schoolhouse training unit in Klamath Falls, Oregon. Loh says this puts the guard in a bit of a bind, since the F-15E training focuses largely on the Strike Eagle's ground strike role while the guard needs its F-15EX fleet to focus on air superiority for homeland defense.

"The pilots here in the National Guard, will be focused on air-to-air [and] air superiority," he said during the guard's largest air exercise in Germany, which included aging F-15Cs set to be replaced by -EXs. "That's what I really need them to focus on."

The Air Defender exercises in Germany came more than a year after Chancellor Olaf Scholz announced plans for a large increase in the country's defense spending beyond NATO's 2% goal. Before the announcement, Germany was spending approximately 1.5% of its GDP on defense. Much of the promised increase has yet to come to fruition, with major plans announced but not appropriated. This includes the F-35 buy and a new Berlin-led air defense effort called the European Sky Shield Initiative.

In February, Scholz said Germany had been neglecting the German Armed Forces and that he wanted to reverse that with a special fund of €100 billion for the military spurred by a change in the country's constitution. Critics have said the government has been moving too slowly on that plan. Among them is Michael Schoellhorn, CEO of Airbus Defense and Space, who says the company has not received any orders and that its A400M is being held back by export restrictions.

In addition to F-35s, the fund is expected to support procurement of more helicopters and maritime patrol aircraft.

At the close of the exercise, Katz said the new defense fund is part of a broad change in the nation's perception of the military, which was largely unpopular due to Germany's history. "Nowadays people are, I would say, proud of the military, proud of having us, and they thank us for what we are doing," he says. "It's good to see the mindset of the people changed. They accept the huge amount of money we are getting; they accept that we're doing such an exercise."

With the unprecedented amount of military aircraft operating in busy European airspace, Katz said they expected a large number of flight disruptions and public complaints about delays and noise. But he said they received "hardly anything." "People accept it's their price for peace and stability, and they accept that their flight is delayed for 15 min.," he noted.

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'TYRANNY OF DIST

Brian Everstine Clark Air Base, Philippines

The Boeing C-17 with call sign Reach 105 was packed full of U.S. Marines, tons of fuel equipment and vehicles plus a commander's entourage as it touched down at this Philippine air base in a moment that exemplified U.S. and allied plans for—and readiness in—the Pacific.

The Globemaster III deployed from South Carolina to the Asia-Pacific region for the U.S. Air Force's Mobility Guardian 2023 exercise, the largest of its kind in the service's history, designed to practice airlift and refueling across the region and into the first island chain near China. The Philippine base already had U.S. A-10 attack jets, Lockheed Martin F-22 fighters, U.S. Marine Corps helicopters and a U.S. Navy Boeing P-8 on the flight line for a separate exercise, which kicked off just as U.S. Defense Secretary Lloyd Austin reached an agreement with the Philippines' new defense minister, Gilberto Teodoro, to increase U.S. and allied deployments to other locations in the country.

This series of exercises and new basing agreements showcases how the U.S. and its partners are preparing to fight a new type of war in the Pacific and are working to identify capability gaps they want to address quickly.

"We cannot figure this out on the run. We have to do it now," says U.S. Air Force Gen. Mike Minihan, commander of Air Mobility Command (AMC) and an outspoken advocate for preparing for a potential conflict as soon as possible. "There's no doubt in my mind that we will, and there's no doubt in my mind that we would be successful tomorrow. But the point is not to be comfortable with where we are. The point is to keep driving improvements so that we adopt that deterrence model. We have that deterrence, [and] we need to maintain it so that any potential adversary wakes up and looks at us and says, 'I don't want a piece of that.'"

The U.S. and its allies have been fighting for decades in environments in Middle East where surveillance assets could loiter above targets on land before tracking and striking at them. They relied on large, fixed bases that for the most part did not require heavy defenses. Airlifters and refuelers could fly wherever they wanted and did not need increased situational awareness. None of that would be the case in a potential Pacific conflict, and this series of exercises is showcasing what the Pentagon must do to be prepared.

Minihan, who made headlines by predicting in a leaked memo that the U.S. could go to war with China in 2025, warned the Air Force early in his tenure that it is not ready for a fight in the region. The joint force cannot operate in the first island chain, but it would be ready by a self-imposed deadline of August 2023, he contended. Mobility Guardian was the test of that readiness, and Aviation Week embedded with Minihan and AMC for a week of the gigantic exercise.

About 70 aircraft from the U.S., Australia, France, Japan and the UK operated from dozens of bases ranging from Australia to Alaska for Mobility Guardian. Participants focused on deploying aircraft, materiel and personnel over long ranges as well as command and control, refueling, aeromedical evacuation and operating from austere locations. The tankers connected with fighters operating as part of the Cope Thunder exercise in the Philippines and Northern Edge in Alaska, along with other real-world events. All told, more than 200 aircraft from at least six nations trained together in the series of events.

Minihan says the first challenge is also the most obvious for any operation in the Pacific: distance. The vastness of the ocean poses problems in every mission—referred to by a phrase that has become cliche, "the tyranny of distance." This challenge was seen in his own 24-hr. direct deployment from Virginia to Japan on a C-17, while another C-130J was cleared for a 44-hr. nonstop mission to the Philippines, unprecedented for the type. Mobility Guardian spanned several time zones over the international dateline.

A critical mission that needs to change in the Pacific is aeromedical evacuation (AE). For decades, AE has focused on groups of highly specialized medical teams working on a small number of aircraft—flying hospitals with a full cadre of doctors and nurses and high-tech operating rooms—to bring

'TANCE'

> MASSIVE EXERCISES AND NEW INVESTMENTS SPEED THE PENTAGON'S PACIFIC SHIFT

> AEROMEDICAL EVACUATION WILL NEED AN OVERHAUL

> MARITIME TARGETING AND STRIKE CAPACITY ARE CONCERNS

relatively small numbers of injured troops back to higher echelons of care quickly. That would not happen in a fight in this region, Minihan says. There would be far more casualties spread across a far larger area, meaning dispersed care at several locations and quick-reacting aircraft outfitted with improved communications systems are required.

"AE is a contract. It's a nonnegotiable part of our mission, and the way it will be executed will be much different than the last three decades in the desert," he says. "I view that as one of our greatest challenges: How do I take something that was a few airplanes with a lot of expertise and make it a lot of airplanes with less expertise?"

The command currently has 11 people on a team doing AE on one aircraft. Mobility Guardian looked at bringing on smaller groups of medical personnel onto more aircraft. U.S. and New Zealand crews flew on a UK Airbus A400M in Hawaii to see how they could work together, in one observed example.

"In a peer-to-peer conflict, you are not going to be able to do that same level of care," says Maj. Gen. Darren Cole, AMC director of operations. "It is going to be massive here, and what we are figuring out is what level of care we can provide and what capacity and how we can make more capacity."

The headquarters for most of the mobility forces was Andersen AFB in Guam—a sprawling, fortified location that hosts strategic bombers along with scores of other aircraft. The base is a critical piece of the military's presence in the Pacific and hosts large amounts of war reserve materiel in addition to aircraft and personnel. The island has become so important that the defense of Guam has become a top priority for U.S. Indo-Pacific Command, which has received billions of dollars of additional funding from Congress for things such as Aegis Ashore missile defenses.

U.S. aircraft have increased operations in the Philippines under a new agreement between the nations.

BRIAN EVERSTINE/AW&ST PHOTOS

The location is vulnerable, as evidenced by a May super typhoon that damaged the entire island and the base. The storm severely altered planning for the exercise, and Minihan's orders were to treat it like an attack. Aircraft needed to be based elsewhere and play into operations differently to provide space for the island to recover.

This dispersal to other operating locations is the main goal of the Air Force's Agile Combat Employment doctrine, using small groups of aircraft and personnel moving quickly to complicate an enemy's targeting plans. The Marine Corps is undergoing a similar shift to expeditionary advanced base operations, and the Army is experimenting with multidomain task forces.

Protecting these austere locations is compelling the Air Force to reconsider its defenses and call for a broader doctrine change. Current U.S. doctrine is for the Army to provide air base defense at a hub, but the Army will not protect aircraft that move out to protect maneuvering forces, says Col. Richard Tanner, deputy director of air operations for Pacific Air Forces.

"We put very scarce, hard-to-come-by and, at the speed of war, irreplaceable assets out into all of these little airfields," he says. "And so we, the Air Force, are also recognizing a need to invest in modest integrated air and missile defense capabilities."

Potential enemies have large arsenals and can target anything, "but they cannot persistently target everything," so the Air Force needs to be able to move to avoid big barrages and

French and UK Airbus A330 Multi-Role Tanker Transports (right) joined U.S. Air Force C-17s in Guam for a large-scale mobility exercise across the Pacific.

be prepared to recover operating bases, he says.

Targeting is also a persistent problem for offensive operations, one that is growing more acute as exercises continue. At Northern Edge, more than 160 fighters and bombers came together in Alaska, bolstered by Mobility Guardian's refuelers, to focus on this issue. "That's one of the things we'll have to do better as an Air Force. . . . We do not currently have a lot of abilities to prosecute maritime targets," Tanner says.

An emerging problem in a China scenario is that Beijing's ample fleet of destroyers can both target aircraft and protect themselves. In the Pacific, the Air Force cannot rely on having intelligence, surveillance and reconnaissance aircraft up and ready to track these targets for fighters and bombers. This would mean more tactical reconnaissance from space providing targeting information. And in a Taiwan Strait scenario, aircraft would need to move beyond the destroyers and hit amphibious ships that could be part of an invasion force.

In addition, the Air Force needs more munitions capacity to strike these targets, due to the limited magazine depth of systems such as the AGM-158C Long-Range Anti-Ship Missile and Kongsberg Joint Strike Missile, which the service is buying.

"We're trying to look at what the next generation of those capabilities is going to look like," Tanner says. "How are we going to get the platforms that can deliver those capabilities into an area where they can actually engage? How do you get them escorted, refueled to those engagement locations?"

With mobility aircraft required to connect these fighters and bombers to targets across the region, Mobility Guardian's leaders say their exercise showed that change needs to come, and progress is being made.

"We have a stark recognition that you have to change the way you operate. Anytime you build a plan, it's built on certain facts and assumptions," Cole says. "Those facts and assumptions don't apply in this future fight. So it is absolutely critical that you practice what we think our new facts and assumptions are . . . and get ready for it as quickly as you possibly can."

The U.S. Air Force Has a Wish List for Next-Gen Tankers and Airlifters

> THE SERVICE IS SPEEDING UP ITS MOBILITY RECAPITALIZATION

> IT COULD PURSUE AN MQ-25-LIKE REFUELER

Brian Everstine Joint Base Pearl Harbor-Hickam, Hawaii

As the U.S. Air Force accelerates studies for its future aerial refueling and cargo fleets, one key point is becoming clear: The service will need to buy multiple aircraft to replace each type.

The Air Force has started an analysis of alternatives for what it calls the Next-Generation Air Refueling System (NGAS) to come online in the 2030s following the acquisition of Boeing KC-46s and to replace the remainder of its Boeing KC-135s. Subsequent to that will be the Next-Generation Airlift (NGAL) program to replace Boeing C-17s and Lockheed Martin C-5s.

Gen. Mike Minihan, commander of Air Mobility Command, says these studies show the need for a series of aircraft—from the small and exquisite to the large and simple. "I think there's an absolute, mandatory need to look at the problem in terms of a system as opposed to just one thing that has to do everything," Minihan says.

Within the past year, the Air Force has overhauled its refueling fleet modernization plans. Instead of the KC-Y "bridge tanker" program originally planned to follow the acquisition of 179 KC-46s, the service aims to extend the KC-46 procurement by a few dozen and field the NGAS earlier.

"These future mobility concepts may be very different than our traditional ones," Air Force Secretary Frank Kendall said last fall. "We need capabilities that can survive the threat of long-range air-to-air missiles. You must be able to bring mobility assets into a contested environment."

Amid the command's massive Mobility Guardian exercise in the Pacific, Minihan laid out for Aviation Week his vision for the NGAS. He sees three roles for refuelers. The first, and the bulk of the refueling mission, would be done in very permissive environments such as exercises at home and refueling fighters off the coast of California. This could be performed by a typical commercial-based tanker such as the KC-135 or KC-46.

The second would be closer to a fight in the Pacific. These aircraft would need to be more survivable and have improved connectivity to communicate with the combat fleet. They would be similar to the upgraded KC-46s, following block upgrades and other enhancements, Minihan says.

Third would be an entirely new type of tanker that is small, survivable and able to operate in the same areas as fighters. "For the high-end stuff that needs to go into the scariest part of the weapon engagement zones, that doesn't need to be everything," Minihan says. "That can be a small fleet of very capable aircraft that can be a bucket brigade—that can be the exquisite gas that needs to be [sent] forward so the kinetic team can be successful."

For this, Minihan wants the mobility forces to take advantage of the Air Force work on its Next-Generation Air Dominance (NGAD) fighter, the Northrop Grumman B-21 bomber and the new plan for uncrewed Collaborative Combat Aircraft. Given the money spent on these, Minihan asks: "What of that can I bring into my fleet now and take advantage of?"

Additionally, Minihan points to the carrier-based MQ-25 Stingray tanker Boeing is developing for the U.S. Navy to take on the Boeing F/A-18s' refueling mission.

"It's not hard for me to imagine that the MQ could get gas, give gas," he says. "I could put it on station 2 mi. off my right wing, put it on a holding pattern 50 mi. behind me, or I could send it forward 200 mi. into a highly contested environment and have the automation for a person in the loop to make an orchestra of all that."

The NGAL, which is likely to be renamed the Next-Generation Airlift System, should have a similar ap-

proach. The Air Force needs new ways to deliver cargo in a high-threat environment where traditional airlifters such as the Lockheed C-130 and C-17 would not survive.

It is a question of not only "'Can I get cargo forward into a high-threat environment?'" Minihan says, "but also: 'Can I get cargo forward to a maneuvering unit that doesn't have a runway from which I can operate?'" He adds: "Does it have to be manned? Can it be unmanned? Does it have to be 10,000 lb. or 5,000 lb.? Can I do vertical lift? Can I do it on an airship [or] a slow-moving low-altitude blimp? There's a lot of opportunity when it comes to how you approach that."

Minihan says the command is closely following ongoing experiments such as the Defense Innovation Unit's blended wing body demonstrator program and DARPA's Speed and Runway Independent Technologies and Liberty Lifter demonstrator. He says he also has been meeting with the Air Force Research Laboratory on designs that have not been announced. Technology from the B-21 and NGAD should be adopted, he says.

"I want to develop a headquarters that thinks about the next generation of systems, not just when the current generation is failing," he says. "We need to create a muscle memory and a capability that survives the actual acquisition of the airplane."

For the current fleet, experiments and exercises such as Mobility Guardian have revealed a critical need for improved connectivity. Tankers and airlifters require better situational awareness and instant communication with combat aircraft and command and control.

"This pounding drum of connectivity in the mobility fleet is paramount," he says. "If I have to key my mic to know what's going on, then we are condemned to an old architecture of employing airpower, especially when it comes to cargo and, most important, when it comes to aerial refueling. The Vietnam planners could come in and lay out our scheme if I'm condemned to having to key a mic to know what's going on or relying on a brief I received 6 hr., 10 hr. or 12 hr. ago."

During Mobility Guardian, Air Mobility Command aircraft experimented with a series of new connectivity systems. These included the Sierra Nevada Corp. Airlift and Tanker Open Missions System, which uses a small antenna to provide multiple data links and other secure communications with limited modification to the aircraft, Minihan says. Additionally, the Air Force is expanding the Collins Aerospace Real-Time Information in the Cockpit data link modification, originally for KC-135s, to other mobility aircraft including C-130s and C-17s.

STAFF SGT. HEATHER FEJERANG/U.S. AIR FORCE

A KC-135 refueled a KC-46 as part of the Air Force's Mobility Guardian exercise in the Indo-Pacific.

Lt. Col. Matthew Novotney, the experiment lead for Mobility Guardian, says the overarching goal for these experiments is to move beyond airlifters and refuelers just receiving data. Existing systems such as the Roll-On Beyond-Line-of-Sight Enhancement for KC-135s help the tankers improve their situational awareness, but that does not go both ways.

During the exercise, a major experiment with the Tanker Intelligent Gateway (TIG) system was conducted using a payload similar to that in the E-11A Battlefield Airborne Communications Node. The TIG, installed in a KC-135's limited cargo bay, sent and received data over several data links, including beyond line of sight, to "tap into the full picture" of the airspace. Novotney says the system is capable enough that an air battle manager could fly on the KC-135 to perform some of the mission traditionally done by aircraft such as a Boeing E-3 AWACS.

Mobility Guardian is the third exercise in which the system was used; it is currently installed on just one KC-135 with the Utah Air National Guard and Air Force Reserve Command Test Center. Congress provided more funding for TIG to help it become a full program.

In addition to data, the Air Force used a new, alternate navigation system called MagNav designed as a collaboration with the Air Force Research Laboratory and the Massachusetts Institute of Technology's Lincoln Lab. The system, flown on a C-17, navigates Earth's magnetic field using artificial intelligence to "zero out" the C-17's interference. The aim is to tap magnetic fields to help an aircraft navigate in an environment without GPS.

These promising experiments are just the latest in a series of similar systems being evaluated by Air Mobility Command with no real program of record to show for it yet. Minihan says he wants Mobility Guardian to show gaps in capability that can be closed relatively cheaply by outfitting the fleet with proven, available technology. In turn, it would be mandatory to define the requirements for next-generation aircraft.

"I think we can get there; this is going to be a thing I want to close. I intend to get it at scale," Minihan says, adding that he would be happy to see similar systems installed in about 10% of the fleet at first, depending on funding. "We have got to infuse this across the fleet. It has got to be there, and I'll take that as a personal challenge as one to close," he says.

U.S.-Thai Military Alliance Is at a Crossroads

> AMERICAN ARMS EXPORTS FACE CHALLENGES IN THE INDO-PACIFIC REGION

> DESPITE THAILAND'S BURGEONING TIES WITH CHINA, THE U.S. MILITARY IS MAKING PROGRESS

Matthew Fulco Washington and **Chen Chuanren** Singapore

In late May, the Royal Thai Air Force said the U.S. had denied its request for Lockheed Martin F-35A Lightning II fighters, an outcome that unfolded as China looms ever larger in Asia's regional security picture—and in Thailand's orbit.

The U.S. denial of Thailand's request for the F-35 speaks to underlying problems in bilateral defense ties.

PATRICK BARRON/ALAMY STOCK PHOTO

The U.S. said it rejected the request because current production rates and orders meant it could not deliver the F-35 to new buyers for at least 10 years—and because Thailand lacks the readiness to receive the F-35. Thailand would need to improve everything from the quality of its airfields and air base security to maintenance and pilot capabilities, according to the U.S.

That was just part of the story. "From a U.S. government standpoint, [Thailand's request for the F-35] was never seriously considered," Trey Meeks, managing principal at consultancy Asia Group in Washington and former colonel in the U.S. Air Force, tells Aviation Week. "They do not have a good record with tech security."

These events illustrate the challenges the U.S. must manage in balancing security alliances in the Indo-Pacific region with arms sales as it faces the most precarious geopolitical environment since the Cold War.

As a U.S. treaty ally, Thailand understandably would seek the F-35, the most advanced fighter jet of the world's premier military power. In the Indo-Pacific, the U.S.' other treaty allies, save the Philippines, all have the F-35.

That said, "the F-35 is perhaps overkill for Thailand's defense needs," says Drew Thompson, a visiting senior research fellow at the Lee Kuan Yew School of Public Policy at the National University of Singapore (NUS) and a former Pentagon official. "For a continental country, it is pretty secure in its geography."

The U.S. has closely guarded the F-35's technical security, holding back the United Arab Emirates' purchase of the advanced fighter jet because of concerns about a Chinese telecommunications network. Turkey was an original partner in the development of the Lockheed Martin fighter, but its deal was scuttled after Turkish President Recep Tayyip Erdogan purchased the Russian S-400 air defense system. The U.S. has reportedly offered to sell Thailand its Lockheed Martin F-16 Block 70 and Boeing F-15EX Eagle II fighters instead of the F-35, although the Royal Thai Air Force (RTAF) may opt instead for another fleet of Saab Gripen fighters.

Meeks suggests that Thailand show the U.S. it can appropriately safeguard the F-16's active, electronically scanned array radar technology. "Then you can have an actual honest conversation about the F-35," he says.

In addition to specific technology-related risks, the U.S. is concerned about the broader deepening security relationship between Thailand and China. In the past decade, the Thai and Chinese militaries have begun training together regularly, and the countries signed 10 major arms deals between 2014 and 2019, among them a $1.3 billion package including three diesel-electric submarines and 48 battle tanks comprising Thailand's largest arms purchase to date.

"China didn't have as much to offer in the 1990s when it was still busy ripping off Soviet tech and reverse engineering," Thompson says. "But as China's defense industry has moved up the quality ladder and the innovation ladder, it has a better menu to offer its customers."

Although Chinese defense equipment has some shortcomings compared to equipment produced in the U.S., "when you factor in affordability and potential financial shenanigans that may appeal to a client, then yes, China is a good option," Thompson says.

The Thai military continues to have close ties with the People's Liberation Army (PLA), from which it has acquired surface-to-air missiles, ships and submarines. The RTAF and People's Liberation Army Air Force (PLAAF) have conducted a joint exercise known as Falcon Strike

five times since 2015 during which Thailand deployed Saab Gripen Cs against advanced Chinese Chengdu J-10s and Shaanxi KJ-500 airborne early warning aircraft. In 2022, Thailand also used German-made Dassault/Dornier Alpha Jet light attack aircraft.

Under an agreement between the Thai and U.S. air forces, the RTAF's F-16 and F-5 fighters are barred from participating in a joint exercise with China, presumably to prevent the PLAAF from gathering technical insights about those aircraft.

Thailand and China kicked off the 2023 Falcon Strike exercise on July 10 at Udorn Royal Thai Air Force Base. The exercise included Chinese fighter jets, bombers, airborne early warning aircraft and ground-to-air missile installations and is intended to "strengthen military cooperation between the two countries and maintain regional peace and stability," Chinese state news agency Xinhua said.

Boripat Ratchaneepun, an officer with the RTAF directorate of operations, said the drill is intended to improve "mutual trust and friendship" between the RTAF and PLA, Xinhua reported.

Meanwhile, Thailand and China are slated to hold joint army exercises Aug. 16-Sept. 2 and joint naval exercises Sept. 3-10, according to *The Bangkok Post*.

"Thailand is broadly diversifying its security policy," says Benjamin Zawacki, a Bangkok-based expert on Southeast Asian security and author of *Thailand: Shifting Ground Between the U.S. and a Rising China*. While "the Thais would still prefer American weaponry," they can obtain more from China at a lower price and receive delivery much more quickly, he notes.

Thitinan Pongsudhirak, a professor of international relations and political science at Chulalongkorn University in Bangkok, traces the deepening Sino-Thai military ties to changes in Thailand's political system that began nearly a decade ago. "The Thai military had to seek support from China as Thai politics turned more authoritarian after the May 2014 coup, including arms procurement and high-level visits," he tells Aviation Week.

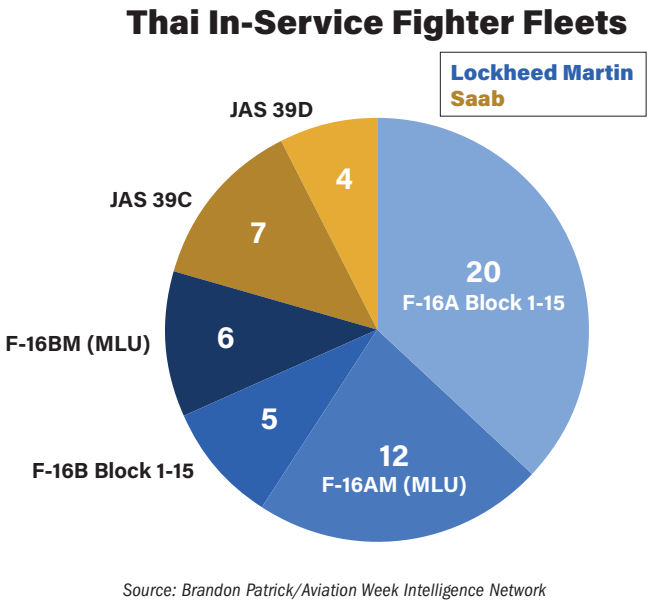
The Obama administration responded strongly to the coup, suspending roughly $4.7 million in military aid, canceling small-scale military exercises and halting an officer exchange program. In addition, then-Secretary of State John Kerry warned: "This act will have negative implications for the U.S.-Thai relationship, especially for our relationship with the Thai military."

"The U.S. has not always treated Thailand as a respected ally," NUS' Thompson says.

For its part, the Pentagon has not sought to distance itself from the Thai military. U.S. military commanders value their access to the U-Tapao Royal Thai Navy Airfield on the Gulf of Thailand, which has one of Asia's longest runways. During the Vietnam War, U-Tapao served as a staging center for U.S. Boeing B-52 bombing runs into Cambodia and Vietnam.

In exchange for its support of the U.S. in Vietnam, Thailand received $1.1 billion in economic and military aid and an additional $530 million from the U.S. Agency for International Development, according to research by Richard Ruth, a professor at the U.S. Naval Academy. Foreign investment poured in, and the tourism industry boomed in the decades after the war ended, helping Thailand become an upper-middle-income economy by 2011.

Given this history, it is not surprising that Thailand has high expectations of its treaty alliance with the U.S. and would feel justified in requesting the F-35, Zawacki says. Yet he acknowledges that the treaty-ally paradigm creates unrealistic expectations on both sides. While Washington's other Indo-Pacific treaty allies generally see China in a similar light to the U.S., he says that in Thailand's case, "it is like trying to fit a square peg in a round hole."



Source: Brandon Patrick/Aviation Week Intelligence Network

At the same time, the U.S.-Thai alliance does appear to have staying power. Thailand has remained a major buyer of U.S. arms exports, with more than $3 billion in active Foreign Military Sales, according to the U.S. State Department. In fiscal 2019-21, Washington authorized the permanent export of more than $605.9 million in defense articles to Bangkok via Direct Commercial Sales.

Among what the State Department describes as "significant implemented sales" are the Boeing AH-6i Little Bird, Sikorsky UH-60M Black Hawk and Eurocopter (now Airbus Helicopters) UH-72A Lakota helicopters; F-16A/B Block 15 aircraft Midlife Upgrades; and RGM-84L Harpoon Block II and Evolved SeaSparrow missiles.

A source with knowledge of U.S.-Thai ties tells Aviation Week that bilateral military exchanges have increased 180% since 2018.

"The military-military component of the Thai-U.S. alliance remains robust," Chulalongkorn University's Pongsudhirak notes. Both the U.S. and China have boosted their exchanges with Thailand's military. "But the increase with China attracts more attention because it's new and because of U.S.-China competition," he adds.

In light of the ruling junta's major setback in the May election, Pongsudhirak says: "I anticipate that Thailand's new post-election and relatively more democratic government will reorient and recalibrate to aim for a more balanced approach, as Bangkok will not need China's support as much because Western democracies will view the poll and post-poll government favorably."

New Systems Aim To Shield Battlefield Assets From Jamming

> RECONCILING CONFLICTING POSITIONING DATA POSES CHALLENGES

> GERMANY IS PURCHASING COLLINS' NAVHUB RECEIVERS

Angus Batey RAF Fairford, England

One of the more common laments throughout the history of warfare is that too many military planners, defense ministry officials and equipment suppliers assume the next conflict will resemble the last. Yet the opposite appears to be happening with resilient precision navigation and timing.

RTX

An engineer prepared equipment in an anechoic chamber at RTX's Harlow, England, facility before electromagnetic interference tests on the Landshield anti-jamming antenna system.

The Landshield system, developed and built by RTX in Scotland, is a low-SWAP (size, weight and power requirement) anti-jamming antenna. It helps the platforms on which it is installed continue to receive space-based precision navigation and timing (PNT) signals while an adversary is using high-powered jammers.

The sensor division's head of strategy, Toby Marshall, notes that while Landshield has been in service for about six years, some of its capabilities are only now becoming routinely required. Marshall says the company is not seeing changes to customer requirements, "[but they] are seeing things they thought might happen actually happen." These include PNT spoofing—a form of jamming where the genuine signal is prevented from reaching the device and a fake position and/or time signal is received instead.

During a briefing at the Royal International Air Tattoo here, after the company announced a contract extension with the UK Defense Ministry, which has ordered more than 1,000 Landshields, Marshall explained some of the ways in which the technology has adapted to changing requirements and battlefield realities. For spoofing, these include validating that the signal being received is the one expected and rejecting data from unauthorized sources, as well as improvements to the anti-jamming capability.

"The software's been updated to take into account different jamming scenarios, adding things in like direction-finding," he says. "The next stage is to work out how we can start to characterize the jammers."

In an almost contemporary program, RTX subsidiary Collins Aerospace developed the NavHub anti-jamming receiver. The two companies collaborated on joint pitches of the complementary products prior to their 2020 merger. Graham Davenport, Collins' mission systems marketing director, says one European customer is buying a combined Landshield/NavHub system.

The German military has bought a large number of NavHub units for use on "almost all their vehicles," he says. Integrating inertial systems—such as those built at Collins' Plymouth, England, site—alongside the anti-jamming antenna and receiver can provide further resilience.

Neither Collins nor RTX will say whether their technology is deployed on platforms being used in Ukraine, or how they are pulling any insights from that conflict into ongoing development. However, in announcing the July 18 refresh of the UK Defense Command Paper, Defense Secretary Ben Wallace told the BBC that Ukraine has "tragically become a battle lab," and he singled out "the power of electronic warfare" emerging as of critical importance.

Moreover, a defense industry source tells Aviation Week that "a massive amount has been learned about what the Russians are doing and are capable of doing."

An issue that needs to be addressed is ensuring that a platform-based anti-jamming capability can both enable and prevent conflict with components integrated into other subsystems. Various systems rely to some degree on space-based navigation and timing—and so many systems already include some form of resilient PNT receiver technology. If multiple subsystems each report their own version of the vehicle's position, how will any differences be reconciled?

"There are ways around it," Marshall says. "You can create a [radio frequency] network in the vehicle. But it all requires someone to think it through and come up with a solution design. We could do that, but obviously that's now no longer just buying a relatively low-cost antenna or a NavHub and putting in a system. Now you've got to do more work to integrate. But the alternative is that you buy a Landshield antenna for every single GPS receiver you've got."

RTX developed Landshield initially for land platforms, but Marshall says the system has also been installed on larger uncrewed aircraft.

Thales Advances Secure Satcom With Cobham AeroComms Acquisition

> EASIER FLIGHT PLAN UPDATES COULD RESULT IN MORE FUEL-EFFICIENT ROUTES

> INMARSAT AND IRIDIUM CONNECTIONS SHOULD ADD REDUNDANCY

Thierry Dubois Lyon

Since the late 2010s, Thales has endeavored to connect electronic flight bags—with their user-friendly interface and faster internet service capability—to the flight management system, a certified piece of equipment that can be likened to the brain of the aircraft.

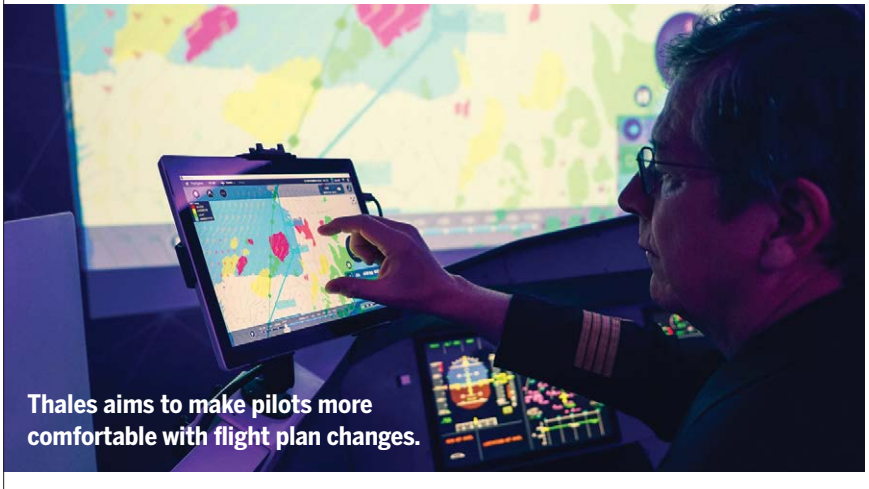
In Thales' vision, flight management systems (FMS) can benefit from large amounts of up-to-date data in flight. A feature of its concept is the use of "open-world" data, such as weather updates from internet sources. To keep the avionics segregated from a potential threat in the open world, data is retrieved at the electronic flight bag (EFB) level. The flight crew would use the EFB to devise or alter the flight plan, and elements of that preparation would be sent to the FMS, which would then compute the trajectory with the required integrity.

The aim is to make pilots more comfortable with plan changes, increase safety through information updates in flight and ultimately improve route fuel efficiency.

Thales' proposed acquisition of Cobham Aerospace Communications (also called AeroComms), a specialist in cockpit communication systems, would add a powerful technology brick to the offering: secure broadband satellite communications. It would also advance a second aspect of Thales' future avionics concept: more autonomous flight. "Our intention is to progress faster toward secure communications between the cockpit and the ground, via satellites, at higher data speeds," says Yannick Assouad, executive vice president for avionics at Thales.

She says both applications are being addressed. "First, modifying flight plans with up-to-date, cybersecured data in flight, aiming at optimized operations," Assouad says. "Second, progressing toward more autonomous flight. Some tasks may be automated while one of the pilots takes a rest on a long-haul flight. The overarching idea is to avoid human error and transition to task monitoring from task execution."

Airbus has selected Thales' PureFlyt FMS for the A320, A330 and A350, so the concepts can be expected to crystallize within the next few years. "For the A320, we plan to start linefit installations in 2026," Assouad says. "Retrofit will follow from 2027."



THALES

Thales aims to make pilots more comfortable with flight plan changes.

The unit includes a securely connected FMS and a pilot assistant capable of working out a new flight plan. "It needs connectivity to update data in flight, and that is what AeroComms' technology will provide," Assouad says.

Among AeroComms' products is a secure satellite communications terminal that uses Inmarsat L-band connectivity. To rely on satellite connectivity, however, redundancy is required. "Both AeroComms and Thales had begun the development of an L-Band solution with Iridium," Assouad notes. "Upon closure of the [AeroComms] deal, we will be merging the two Iridium developments, and the terminal will link to both Inmarsat and Iridium."

The adoption of secure broadband satellite communications in the cockpit is expected to grow quickly. A new aircraft entering service in 2035 will be delivered with secure broadband cockpit communications as standard equipment, Assouad predicts.

AeroComms' L-Band system is installed on 20% of the A320neo-family aircraft Airbus delivers, Assouad says. The company has won a series of contracts this year, CEO Nicolas Bonleux reports. In June, it announced the delivery of its Light Cockpit Satellite Communications System (LCS) on China Eastern Airlines' Airbus A320neos.

Compared with previous hardware, it offers two separate aircraft communication network domains and up to 80 times the data transfer capacity. In addition, the LCS offers approved secure internet-protocol-based aircraft an Aircraft Communication Addressing and Reporting System and voice services when connected to Inmarsat's SwiftBroadband-Safety satellites.

Thales is negotiating to acquire AeroComms from Advent International. The $1.1 billion deal is expected to close in the first half of 2024, after regulatory approvals. Employee representative bodies of both Thales and Cobham Aerospace Communications will be consulted.

Based in Rungis, France, near Paris-Orly Airport, Cobham Aerospace Communications employs 690 staff in France, Canada, Denmark, South Africa and the U.S. The company is the product of a number of previous mergers and became an autonomous entity when Advent took over the Cobham group. Cobham Aerospace Communications anticipates revenues of $200 million this year.

The company usually derives 70% of its revenues from civil work and 30% from defense projects, while research and development spending stands at 15% of its revenues—a high level, comparable to Thales' 20%.

ULA Revamps Plan for Vulcan Debut

> DELAY BUMPS NATIONAL SECURITY SPACE LAUNCH MISSION TO SECOND QUARTER OF 2024

> U.S. SPACE FORCE STICKING WITH TWO-FLIGHT CERTIFICATION PLAN

Irene Klotz Cape Canaveral

After a decade of development, it is not the all-new, methane-fueled BE-4 main engine—manufactured by startup Blue Origin—that is delaying the debut flight of the United Launch Alliance Vulcan rocket. Instead, the postponement is due to an unexpected modification of the Centaur upper stage, a vehicle with more than 60 years of flight heritage.

The latest Centaur design, known as the Centaur V, is nearly twice the size of the current Centaur III that flies on United Launch Alliance (ULA) Atlas rockets. Designed for high-energy, long-duration missions, the Centaur V is a 40-ft.-long, 18-ft.-dia. vehicle built from stainless steel sheets thinner than a dime. The metal is welded to form a cylinder with domes at the top and bottom. The vehicle is propelled by liquid hydrogen and liquid oxygen.

ULA was about halfway through its 15th Centaur V structural test at NASA Marshall Space Flight Center on March 29 when a hydrogen leak developed from a crack near the vehicle's forward dome. The leak continued for about 4.5 min., growing in size and gathering above the stage.

"It reached a flammable concentration, found an ignition source and caught fire because it's in an enclosed space," ULA CEO Tory Bruno told reporters on July 13. "It overpressured, and that damaged the test stand and also severely damaged the test article."

It took a while to access the stand, as the Centaur V's liquid-oxygen tank had been filled with 100,000 lb. of liquid nitrogen for the test that took several days to boil off. Then all the test equipment that had fallen on top of the damaged vehicle had to be removed—including a mass simulator, a mechanical loading structure and platforms.

ULA retrieved the remains of the damaged forward dome, which had caved in and been torn into fragments, to determine the cause of the leak—it turned out to have originated adjacent to a door at the top of the dome.

"The door is a very thick, stiff stainless-steel structure," Bruno said. "Between that, the milled regions and the long-seam welds which radiate outward from the center to the outer periphery where it connects to the cylinder, we have a very complicated load- and stress-state.

"We discovered there was a stress-riser, or a load intensification, right at that spot," Bruno said. "We would expect to have a certain load profile across that dome, but right in that narrow region the loads went way up because of this complicated geometry.

"The coarser analysis we did several years ago to determine the load design to design to did not catch that," Bruno added. "And that particular phenomenon was not present on Centaur III because of its smaller scale and slightly different geometry."

UNITED LAUNCH ALLIANCE

This Centaur V, pictured being hoisted atop the Vulcan Cert-1 booster in the Vertical Integration Facility at Cape Canaveral SFS Launch Complex-41 in February, was previously assigned to fly the first Vulcan mission. It will be retrofitted and reassigned.

The unanticipated higher load was not the only problem. ULA had switched from a gas tungsten arc welding process for the seams on the Centaur III tanks to finer-detailed laser welding for the Centaur V. Those laser welds turned out to be less strong than samples, Bruno said.

"The higher loads and somewhat lower strength on the welds are what caused the crack to begin," he added.

ULA had already decided to return to arc welding on the Centaur V's 12-ft. seams because the precision of the positioning needed to set up the robotic laser welding technique was not saving production time as anticipated, Bruno said.

Fixing the Centaur V is relatively simple: ULA is making the top of the dome a little bit thicker. "The corrective action is a pretty low-tech thing," Bruno said. "We will simply put in another layer of stainless steel . . . a ring doubler on top of the welds around that door and weld that on. Then add strips of stainless steel from there outboard down the dome about 2 ft. to cover that much of the weld. After that, the stresses are so low that you have no concerns."

ULA began the work well before its accident investigation concluded, and it expects to have the first modified Centaur V ready for testing to support a Vulcan Centaur launch before

year-end. ULA plans to use the flight article to complete structural testing, Bruno noted.

The mission, known as Cert-1, is the first of two required before ULA will be allowed to fly U.S. national security satellites on the new booster. Cert-1 will carry a commercial lunar lander for Astrobotic, two demonstration satellites for Amazon's planned high-speed-internet Kuiper network and other secondary payloads. Cert-2, targeted for early 2024, would launch Sierra Space's first Dream Chaser cargo ship to the International Space Station for NASA.

Meanwhile, ULA plans to use the Centaur assigned to the Cert-2 mission to complete certification testing.

The Centaur V earmarked for the first National Security Space Launch (NSSL) mission, which is expected to be Vulcan's third flight—and the first to undergo the modification—will be used for Cert-1.

The upper stage previously planned for Cert-1 will be retrofitted and most likely flown on Vulcan's third flight, the NSSL mission now targeted for the second quarter of 2024.

U.S. Space Force Stirs Up Competition for Launch Services

Irene Klotz Cape Canaveral

WITH THE DEMAND FOR NATIONAL SECURITY SPACE Launch services expected to surge, the U.S. Space Force plans to add a third provider to its list of contractors capable of handling the full range of its mission requirements.

Previously, two companies were expected to be selected in the full-service Lane 2 portion of the upcoming National Security Space Launch (NSSL) Phase 3 competition, with approximately 39 missions split 60-40. The arrangement echoes the Space Force's current NSSL Phase 2 program, which has contracts with United Launch Alliance and SpaceX.

But with the number of missions in Lane 2 expected to reach 58, the Space Force plans to solicit three companies in a follow-on draft request for proposals, Col. Douglas Pentecost, deputy program executive officer for the Assured Access to Space program at U.S. Space System Command, told reporters during a July 19 conference call.

Competing companies would be required to be able to execute the entire range of NSSL missions, including the most challenging deliveries into cislunar orbit and direct placement into geostationary (GEO) orbit. However, the third-place awardee—determined by best value—would receive just seven missions, including five GPS and two direct-inject-to-GEO launches.

SPACE SYSTEMS COMMAND

The U.S. Space Force is preparing for a wide array of launch service offerings as part of its upcoming National Space Security Launch Phase 3 program, which features on-ramps for new contenders.

"It's going to challenge that provider to be able to meet our full requirement set, but it does limit it to those seven [missions] so we're not having to do multiple integration studies," Pentecost said.

The five GPS missions previously were to be awarded among the Lane 1 vendors, which are expected to lure companies such as Rocket Lab and Firefly Aerospace that currently do not provide heavy-lift launch services.

Lane 2 contenders would not know in advance whether they might win the 60% award, the 40% award or the third, "best-value" slot—with just seven missions guaranteed. The company awarded the 60% share of the NSSL Phase 3 program can expect to win 30-31 missions during the five-year ordering period beginning in fiscal 2025; the company awarded 40% would receive about 20 missions.

Lane 1 service providers can expect to compete for another 30 missions, Pentecost added.

Companies competing for Lane 2 awards with a new launch vehicle could win a contract, provided they have a plan for certification of the new boosters by 2027. Actual flight assignments would be made after a launcher's successful debut.

Non-U.S. vehicles such as Arianespace's upcoming Ariane 6 are not eligible to compete in the NSSL Phase 3 program.

Formation Flyers

- NASA'S STARLING CUBESATS TO DEMONSTRATE AUTONOMOUS FORMATION FLYING
- ABILITY TO TRAVEL AS A MESH NETWORK COULD EXPAND COMMUNICATIONS
- AUTONOMOUS MANEUVERS COULD HELP AVOID COLLISIONS ON ORBIT

Garrett Reim Los Angeles

NASA is seeking ways for satellites to cooperate autonomously—without real-time commands from mission control on Earth—to enhance scientific data collection on deep-space missions and pave the way for orbiting spacecraft to avoid collisions automatically.

In pursuit of this, the agency in mid-July launched four Starling cubesats, small satellites designed to fly in formation autonomously as they orbit Earth. The six-unit cubesats, launched from Mahia, New Zealand, on a Rocket Lab Electron rocket, will be placed in sun-synchronous orbit about 355 mi. above Earth for six months while flying about 40 mi. apart.

NASA Ames Research Center at Moffett Field, California, is leading the Starling mission. Blue Canyon Technologies designed and manufactured the spacecraft buses.

Each Starling will use a commercial star tracker—a device to help satellites navigate and orient themselves by measuring the position of the stars—to locate its fellow travelers and stay in a relatively tight formation. The Starling Formation-Flying Optical Experiment portion of the mission will use the star trackers to pick up light from companion spacecraft and will tap specialized software to coordinate swarming.

NASA intends to test that software's ability to plan and complete spacecraft maneuvers without direct input from humans as part of the Reconfiguration and Orbit Maintenance Experiments Onboard phase of the mission. In the autonomous maneuvering program developed by Emergent Space Technologies, the spacecraft would plan as well as execute their trajectories.

NASA also wants to see if the spacecraft can reconstitute themselves into a traveling mesh network, a communications system through which information can be routed via different paths depending on the strongest signal. NASA will test its Mobile Ad-hoc Network using all four Starling

NASA plans to test satellites flying in passive safety ellipses in low Earth orbit.

satellites, each communicating through two-way S-band crosslink radios provided by CesiumAstro.

The space agency also wants to test the ability of the satellites to collect and analyze scientific data as a swarm. During the Distributed Spacecraft Autonomy experiment, the Starling satellites are planned to work together to optimize data collection about Earth's ionosphere. Autonomous data collection is expected to improve NASA's ability to make scientific observations in deep space, where the distance from Earth makes communications with spacecraft difficult and slow.

Over the course of the mission, Starling spacecraft will fly in two formations. Initially, the satellites will travel in line in a "string of pearls" formation. Then the cubesats will continue to fly one after another but swirl in what NASA calls passive safety ellipses.

"In the 'string of pearls' formation, all four spacecraft will be in line one behind the other, approximately 40 mi. apart," says Howard Cannon, project manager for Starling. "In the passive safety ellipse formation, the four spacecraft still follow each other with the same spacing, but they rotate in an ellipse around the centerline of the average velocity vector. Since they will be at different distances from the velocity vector, the ellipses are safe in that even if they begin to get closer, they remain safe from the standpoint of [not] running into each other."

NASA sees multiple applications for small, swarming satellites. For instance, groups of cubesats could provide navigation services or be communication nodes for deep-space missions. The ability of multiple satellites to gather data from different positions could allow the spacecraft to act like one large instrument, potentially helping to find resources on the Moon. Telescopes mounted on multiple small spacecraft observing an object could create a larger field of view than is possible with a single big space telescope.

The autonomous swarm technology also might be useful for commercial satellites orbiting Earth. After its primary mission is complete, NASA will attempt Starling 1.5—a demonstration in which the cubesats are to test advanced space traffic management techniques in coordination with SpaceX's Starlink communications satellites.

The Starling and Starlink satellites would communicate their future trajectories to their ground stations, and that data would be forwarded to a space traffic management hub, which would analyze the data for potential collisions and relay that information to operators.

"The methods and technologies developed for this may be utilized by the Department of Commerce as they develop plans for traffic management services in low Earth orbit," Cannon says.

Check 6 *Aviation Week editors discuss the small satellite market and new technologies:* **AviationWeek.com/Check6**

NASA

Neuromorphic Camera Promises High-Speed Performance for Smallsats

- EVENT-BASED CAMERAS RECORD CHANGES ONLY AT PIXEL LEVEL
- THE CAMERA SENSOR HOLDS POTENTIAL FOR VARIED MISSIONS, INCLUDING MISSILE DEFENSE

Garrett Reim Los Angeles

When a dragonfly hunts a mosquito, it does not chase the insect; the four-winged arthropod calculates where the bloodsucker is going and intercepts it. Dragonflies have a catch rate of more than 95%—one of the highest in the animal kingdom.

"It does that with a tiny brain, terrible visual system and a microwatt of power," says Gregory Cohen, deputy director of the International Center for Neuromorphic Systems at Western Sydney University (WSU) in Australia. "That's a problem we really struggled to deal with using full supercomputers, graphics processing units and all this stuff we have right now. So clearly, the dragonfly is doing it the easy way."

Dragonflies and other living organisms, including humans, are the inspiration for the U.S. Air Force Research Laboratory's (AFRL) Falcon Neuro, a pair of experimental neuromorphic cameras that have been flying mounted on the outside of the International Space Station (ISS) since 2022. The laboratory calls the mission the first demonstration of neuromorphic cameras in space.

Whereas a conventional video camera continuously records video using all its pixels, a neuromorphic camera—also known as an event camera—records data only from pixels that sense a change in light. The method echoes how human eyes transmit more signals to the brain in response to changes but fewer for static scenery.

"If you see something weird, you tend to [look at] that directly and then you deal with that information," Cohen says. "We work on novelty, and these cameras are essentially doing the same thing."

The AFRL sees neuromorphic cameras as promising for small satellites, the performance of which is constrained by size, weight and power.

Falcon Neuro's cameras are based on Inivation's Davis 240C, customized by WSU and controlled by electronics developed by U.S. Air Force Academy cadets. From their perch on the ISS, the neuromorphic cameras' primary mission has been recording lightning and sprites streaking across the planet's atmosphere.

"If you happen to have a normal camera that takes frames, you have to be really lucky to catch [a photo of lightning]," Cohen says. "Our camera sensor can be really fast, [with] really low power and a really low data rate."

The Falcon Neuro cameras capture events that occur in fractions of a second, such as a lightning flash, across relatively long periods of time.

"Exactly how fast you can render the data depends on how much contrast there is between the target and the background," says Matthew McHarg, principal investigator

for Falcon Neuro and director of the Air Force Academy's Space Physics and Atmospheric Research Center. "Lightning has a lot of contrast, allowing Neuro to render at 1,000 [frames per second]."

A comparable high-speed camera might capture only seconds of footage before running out of memory and could cost hundreds of thousands of dollars, Cohen says. "You get the benefit of a high-speed camera without all the costs," he explains.

Because a neuromorphic camera uses a sensor that records only changes, there is less data to be processed, stored or transmitted.

"When nothing's happening, you get no data," Cohen says. "The sensor itself does the heavy lifting. That's really where you save so much power because you don't have to search through millions of pixels for what you care about."

In addition to capturing lightning, Falcon Neuro has detected orbiting satellites and spotted stars, as well as tracked ships on Earth, Cohen says. A follow-on, higher-definition neuromorphic camera, Falcon ODIN (Optical Defense and Intelligence through Neuromorphics), is planned for launch in 2025.

NASA

Phase Four Says Its RF Thruster Matches Hall-Effect Performance

> RADIO-FREQUENCY THRUSTER CAN USE A VARIETY OF PROPELLANTS

> PROPULSION TYPE MIGHT ENABLE VERY-LOW-ORBIT SPACEFLIGHT

Garrett Reim Hawthorne, California

Phase Four says it has built and tested a next-generation radio-frequency thruster for spacecraft that equals the performance of a Hall-effect thruster.

The achievement, demonstrated over several weeks of testing in a vacuum chamber, is an important milestone in the Hawthorne, California-based company's attempt to push the propulsion type into the mainstream of the small satellite industry.

"We've decided to develop a new technology in a conservative field—in aerospace—which is a hard thing to go into business for," says Umair Siddiqui, Phase Four chief technology officer. "A lot of people say: 'Oh, this technology will never work.' The point of [this testing] is to basically prove to the world that, yes, a cathodeless thruster can meet or exceed these targets."

The company's next-generation radio-frequency (RF) thruster, the Maxwell Block 3, has shown performance using krypton propellant in the range of a typical Hall-effect thruster, Siddiqui says. Phase Four defines that comparable range as 250-800 watts of operating power, specific impulse of 600-1,300 sec. and thrust levels of 8-18 millinewtons. The company declines to give specific performance metrics but says it plans to post more detailed figures soon, when it anticipates exceeding the performance of a Hall-effect thruster.

A type of electric propulsion that has been used for decades for satellite orbital station-keeping and deep-space exploration, Hall-effect thrusters are a trusted technology among satellite operators. They ionize a propellant, such as xenon, to create an ionized plasma, which is then accelerated using an electric field to create thrust.

Phase Four says its radio-frequency system not only will have higher performance, but it will also be less expensive than a Hall-effect thruster—ideal for operators of low-Earth-orbit (LEO) constellations such as the U.S. Space Development Agency and OneWeb. The company's thruster uses radio-frequency energy to heat a propellant into ionized plasma that is then ejected away from a spacecraft by a permanent magnet, creating thrust.

Phase Four has on orbit eight examples of its current product, the Maxwell radio-frequency thruster. Collectively, those have logged more than 5,000 days in space since 2021. Capella Space, an operator of satellite-based synthetic aperture radar, is one customer. Other customers have not been disclosed but tend to be "Earth-facing" LEO satellite operators, Siddiqui says. The thrusters were developed with small satellites weighing 110-1,100 lb. in mind.

Because a radio-frequency thruster system uses a permanent magnet instead of an electromagnet, as a typical Hall-effect thruster does, it is a simpler system, Phase Four says.

"There's no cathode. There's no heater. There's no igniter. There's no separate power supply for the anode and the cathode," Siddiqui says. "There's physically significantly fewer power electronics that go into the [power processing unit]. Our bill of materials is a lot simpler. The time to build is a lot [shorter]. All of those cascade and add up to a competitive price point."

Phase Four says it has higher profit margins on its thrusters. Simplicity also means a 75% reduction in lead time, it says. The company's new facility in Hawthorne should be able to produce 130 units per year. The first examples of the Maxwell Block 3 are anticipated to be ready for delivery in early 2024.

Because radio-frequency thrusters can be used with a variety of propellants—including xenon, krypton,

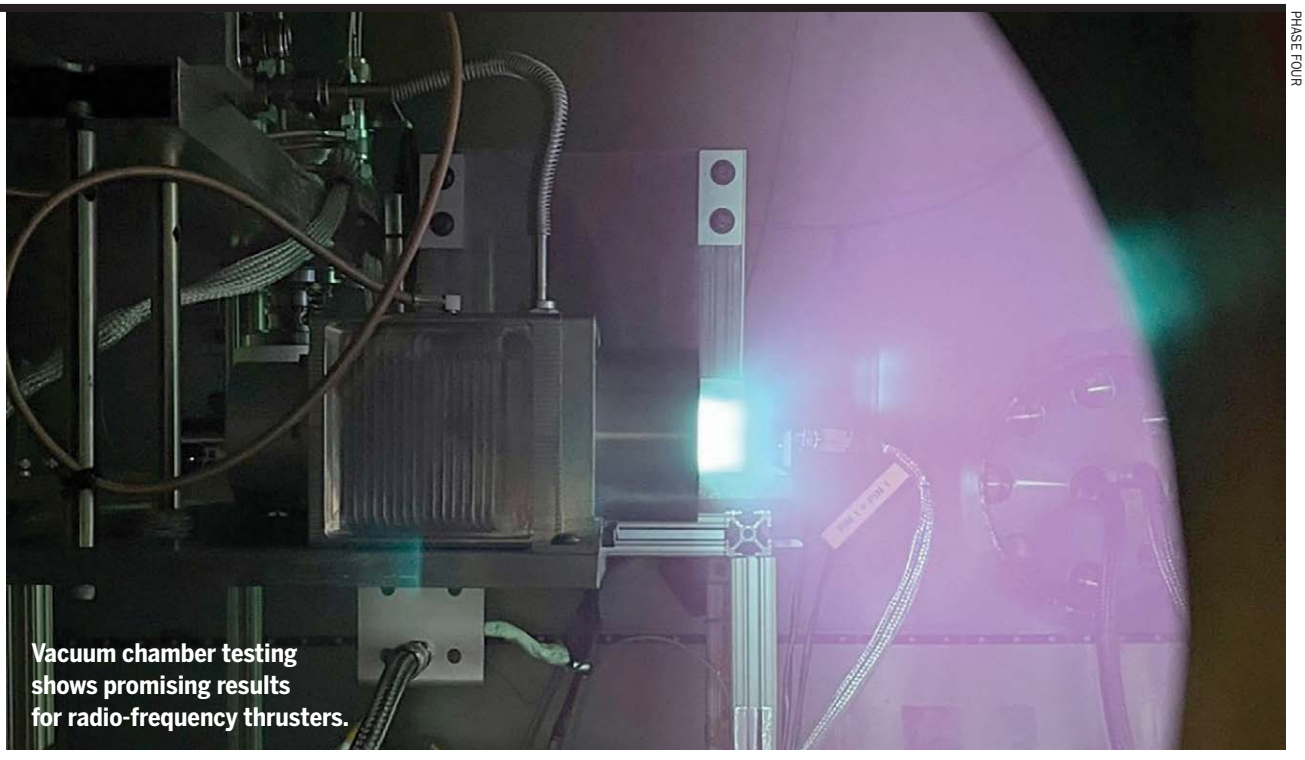
Falcon Neuro is fast enough to capture flashes of lightning.

The AFRL sees a variety of potential military missions for neuromorphic cameras, including detecting hypersonic reentry vehicles or fast-moving aircraft.

Neuromorphic cameras fit into the U.S. Space Force's plans to launch hundreds of small satellites for roles previously handled only by its biggest spacecraft. The Space Force has tasked multiple military agencies with shrinking payloads, including missile-tracking sensors, to fit that vision.

For example, in 2020, The Aerospace Corp. demonstrated a three-unit cubesat carrying an off-the-shelf, uncooled, commercial infrared camera that spotted and tracked several rocket launches. Because the experimental satellite was so small—with limited power generation and storage capacity—it had to be preprogrammed to record scheduled rocket launches. That is not practical for wartime missile defense.

Cohen says infrared neuromorphic cameras are a next step for research. "When you look at the infrared spectrum, all you care about is change," he says. "These cameras are extremely well-suited to that."



PHASE FOUR

Vacuum chamber testing shows promising results for radio-frequency thrusters.

iodine, water vapor, nitrogen and oxygen—Phase Four says the system could ingest propellant in situ.

"If you're able to achieve high [specific impulse] with water vapor, then all of a sudden you can go to the Moon, mine water vapor and come back," Siddiqui says. "Water vapor is abundant, especially in the outer Solar System, and so now suddenly you have natural gas stations."

A radio-frequency thruster also could power spacecraft flying in very low Earth orbit (VLEO), a region roughly 125-186 mi. above the surface of Earth. There, atmospheric density creates friction and makes long-duration flight difficult for conventional spacecraft. However, a radio-frequency thruster could harvest gases from the atmosphere, such as nitrogen, oxygen and atomic oxygen, and then use them as propellant to stay aloft. Phase Four is designing a two-stage radio-frequency propulsion system for that purpose and is testing it using nitrogen in a vacuum chamber.

"It's designed to resonantly accelerate gases of a certain molecular weight," Siddiqui says. "Nitrogen, oxygen and even water vapor are roughly in the same mass range."

The potential for VLEO spacecraft to carry electro-optical, infrared or radar sensors closer to a target has made the technology interesting to the U.S. Defense Department.

"There are a lot of intelligence applications," Siddiqui says. "Whoever can get into the VLEO environment first has a national advantage over their peer adversaries."

Viasat and Inmarsat Pursue Joint Vision as One Company

> VIASAT AIMS TO BUILD A MULTIORBIT NETWORK

> MALFUNCTION OF VIASAT-3 AMERICAS COULD ALTER PLANS

Bill Carey Carlsbad, California

With the belated approval of their combination now confirmed, geostationary-orbit-satellite operators Viasat and Inmarsat can pursue the vision of a multiorbit, multiband network they each had before becoming a satellite communications powerhouse.

BILL CAREY/AW&ST PHOTOS

Viasat supplies dual, hybrid K_u-/K_a-band satellite communications terminals, like the one pictured, on the Boeing 747 that serves as Air Force One.

Inmarsat's concept, Orchestra, was intended to be an interconnected "dynamic mesh network" combining the company's L-band and K_a-band geostationary orbit (GEO) satellites with a new low-Earth-orbit (LEO) constellation and terrestrial 5G communications. Viasat also envisioned a multiorbit system but has not named it.

"I don't know what subbrands we will continue to use," says James Person, director of business development and strategy for Viasat's business aviation unit. "The only brand decision we have made is that the future company is called Viasat."

But as the saying goes, space is hard. On July 12, Viasat disclosed that its recently launched ViaSat-3 Americas K_a-band satellite had experienced "an unexpected event" during deployment of a reflector antenna that may affect its performance. The company did not name the reflector supplier, although website Ars Technica identified it as Northrop Grumman's Astro Aerospace business, quoting a past interview with a Viasat executive. During launch, the reflector folds up against the Boeing-manufactured 702MP+ satellite bus.

Viasat has described the mesh-like reflector antenna, which is tethered to a boom in space, as exceptionally large for a commercial broadband satellite. ViaSat-3 Americas is expected to vastly increase Viasat's coverage and capacity over the Americas for airlines and other aviation users. Its possible malfunction caused the company's share price on the Nasdaq exchange to plummet and led to media speculation of a mid-nine-figure insurance payout if the satellite is a total loss.

The company says it will provide an update on the status of ViaSat-3 Americas and any necessary contingency plans during an earnings call scheduled for Aug. 9.

Announced in November 2021, Viasat's acquisition of London-based Inmarsat was slowed from its planned closing date in the second half of 2022 when the UK Competition and Markets Authority and the European Commission (EC) launched antitrust investigations. Once the authority signed off on the acquisition in early May, approvals by the U.S. Federal Communications Commission and EC soon followed.

Viasat announced the completion of the transaction on May 31, uniting two companies with a combined annual revenue of more than $4 billion and over 8,000 employees. The anticipated merger of Luxembourg-based satellite operator SES and U.S.-based Intelsat would have created a company of similar scale, but it has been called off, SES confirmed in June.

Aviation Week visited Viasat's Carlsbad campus near San Diego soon after it passed a 30-day internal integration milestone with Inmarsat. New colleagues had recently socialized in the same courtyard where Viasat employees gathered April 30 to watch the launch of ViaSat-3 Americas, the first terabit-class communications satellite, from Kennedy Space Center in Florida.

Six months before the launch of ViaSat-3 Americas, President Joe Biden touted the CHIPS and Science Act from a stage outside the company cafeteria. During his remarks, Biden recognized Viasat's provision of dual, hybrid K_u-/K_a-band terminals on the VC-25 (Boeing 747) that serves as Air Force One, identified by two radomes atop its fuselage.

Inmarsat and Viasat both have defense and government customers, and each provides satellite connectivity to other markets such as the maritime industry. Where their verticals closely align is in supplying broadband, K_a-band service to airlines and business aviation aircraft.

Combined, Inmarsat and Viasat deliver inflight connectivity to 60 airlines, including 3,100 in-service aircraft and 2,000 more under contract, as well as 1,650 business jets. Under an agreement announced in May 2022, new Southwest Airlines Boeing 737 MAX 7/8 airliners come factory-equipped with Viasat antennas, modems, wireless access points and other enabling hardware and software.

Culturally, the Inmarsat-Viasat union joins a British company established in 1979 as an intergovernmental organization—later privatized—to develop a satcom network for ships with a Southern California startup formed in 1986 by alumni of Linkabit, a technology company that led to the creation of Qualcomm as well as Viasat.

The combined companies have 19 in-service satellites, with eight GEO satellites planned for launch in the next three years. Inmarsat brings to the table flight-deck-oriented,

Viasat's base in Carlsbad, California, near San Diego is set to be the headquarters of the combined business, while Inmarsat's London offices are to be the international headquarters.

narrowband L-band connectivity, with seven total L-band or combined L-/K_a-band satellites in space. Inmarsat also operates an S-band satellite for the European Aviation Network, a broadband service for domestic European airspace that integrates terrestrial 4G LTE connectivity from Deutsche Telekom. Through a partnership with Space Norway, it plans to operate K_a-band payloads on two highly-elliptical-orbit satellites that are to provide coverage of the Arctic region at latitudes beyond the reach of GEO satellites.

While Inmarsat service and hardware is provided through partner resellers and manufacturers, Viasat builds much of its own equipment. The company manufactures the antennas used in its satcom terminals for business and air transport aircraft at a facility in Duluth, Georgia. It builds ViaSat-3 satellite payloads in Tempe, Arizona, along with components including radio-frequency integrated circuits used in transmit/receive assemblies.

The acquisition should not affect Inmarsat's relationships with its value-added resellers, which include SITA, Collins Aerospace and Thales for commercial aviation, Viasat executives say. "Those relationships are valued with the resellers," notes spokesperson Scott Goryl. "At this point, there is no intention to make any changes there or ride the contracts out or whatever the case may be."

Honeywell, Satcom Direct and Israel's Orbit Communication Systems build Inmarsat K_a-band terminals for business aircraft. To operate on Viasat's network, the terminals would have to incorporate Viasat's waveform, which could be done by inserting an additional modem card, Person says.

The two companies are in harmony on development of a communications network based on a multiorbit, multiband architecture. That would entail launching new LEO satellites or leasing capacity from existing constellations such as SpaceX's Starlink. Inmarsat referenced "a small, targeted constellation" of 150-175 LEO satellites when it unveiled Orchestra in July 2021. More recently, executives of both companies have been quoted as saying they are open to partnering on LEO capacity.

"We don't have the answer for what we're going to call it yet, but we are very much aligned on the philosophy," Person says. "On Day One, our legacy Inmarsat friends said, 'Here's our vision for what Orchestra delivers and here's our filings for those satellites,' and the Viasat team said, 'Here's what our vision was for multiorbit and here's our filings.' We're going through that very [integration] process right now because clearly it doesn't make sense to do both plans independently—we're one company now. We haven't announced that, frankly, because we haven't figured out which one we're going to go with yet."

AIMING FOR THE MOON

> INDIA'S CHANDRAYAAN-3 WILL ATTEMPT A SOFT LANDING

> MISSION SHOULD ENTER SECOND LUNAR TRANSFER PHASE SOON

> CHANDRAYAAN-2 ORBITER'S CAMERA IS SLATED TO WATCH OVER THE LANDING

Apurva Mahajan Washington

The Indian Space Research Organization's Chandrayaan-3 is heading to the lunar south pole on a quest to make India the fourth country to land a spacecraft on the Moon. The nation's last attempt at a soft landing crashed into the surface. This time, the space agency has designed the new lander, Vikram, to withstand failure.

The 6.1 billion rupee ($74 million) 3,900-kg (8,600-lb.) mission, which includes a companion 26-kg rover, is targeted to touch down near the Moon's little-explored south pole around Aug. 23. If successful, India would join the former Soviet Union, the U.S. and China on the short list of countries that have accomplished a lunar landing.

As many as four more Moon missions are poised to launch this year, including:

- Luna 25, which is set to be Russia's first foray to the Moon since the 1976 Soviet-era Luna 24 returned with 170 grams (6 oz.) of lunar soil. Launch is planned for Aug. 11.
- Japan's Smart Lander for Investigating Moon, which aims to demonstrate the pinpoint landing technology necessary for future lunar probes. Launch is targeted for Aug. 26.
- Commercially developed and operated landers owned by U.S.-based Intuitive Machines and Astrobotic, which are set to attempt missions for NASA and other customers (*AW&ST* July 17-30, p. 32). Launches onboard a SpaceX Falcon 9 and United Launch Alliance's first Vulcan rocket are planned for the third and fourth quarters, respectively.

Two previous private efforts to land spacecraft on the Moon failed—one by Israel's SpaceIL in 2019 and the other by Japan's Ispace in April 2023.

The Indian Space Research Organization (ISRO) Launch Vehicle Mk. 3 rocket (LMV3)—previously called the Geosynchronous Satellite Launch Vehicle Mk. 3—launched the Chandrayaan-3 mission on schedule at

Following a partly successful second foray to the Moon, India launched the Chandrayaan-3 mission on July 14, aiming to put a lander and a small rover on the lunar south pole.

INDIAN SPACE RESEARCH ORGANIZATION

MISSIONS TO THE MOON

With Chandrayaan-3, India is aiming to join the elite club of nations that have landed spacecraft on the lunar surface. Its journey began about 15 years ago, with the successful insertion of Chandrayaan-1 into the Moon's orbit. Here is a look back at international missions to the Moon since then.

2022 Dec. 11 | Ispace Hakuto-R Mission 1
This private Japanese mission is scheduled for a soft landing on the Moon's near side on April 25, 2023, but communication is lost during the final moments before landing as the spacecraft runs out of fuel and crashes onto the Moon's surface.

Nov. 16 | NASA Artemis I
The mission sends NASA's uncrewed Orion capsule spacecraft into lunar orbit as a test to prepare for future crewed Artemis flights. Orion circles the Moon twice before reentering Earth's atmosphere and splashing down in the Pacific Ocean on Dec. 11, 2022.

2019 Feb. 22 | SpaceIL Beresheet
The first private attempt to land on the Moon and Israel's first lunar mission, funded by Israeli nonprofit organization SpaceIL, aims to measure the magnetic field and anomalies at Mare Serenitatis. It ends when the team loses communication with the spacecraft right before the touchdown attempt, resulting in a crash landing on April 11, 2019.

2018 Dec. 7 | Chinese National Space Administration (CNSA) Chang'e 4
The mission results in the first successful soft landing on the far side of the Moon on Jan. 3, 2019. Chang'e 4 comprises a lander and rover, Yutu 2, each containing scientific payloads to study the geophysics of the area.

2013 Sept. 7 | NASA LADEE (Lunar Atmosphere and Dust Environment Explorer)
The mission is designed to collect measurements pertaining to the lunar atmosphere, lunar dust and conditions near the lunar surface. LADEE does not have the fuel needed to maintain a long-term orbit, so the spacecraft is intentionally crashed into the Moon on April 8, 2014.

Dec. 1 | CNSA Chang'e 3
China becomes the third country to soft-land on the Moon, following the U.S. and Soviet Union. The mission sends a lander and rover, Yutu, to the lunar surface. Yutu continues to operate until Aug. 3, 2016.

2011 Sept. 10 | NASA GRAIL (Gravity Recovery and Interior Laboratory)
The mission sends two nearly identical washing-machine-size spacecraft (Ebb and Flow) into low lunar orbit to measure the Moon's internal structures and create a map of its gravitational field. Ebb and Flow are decommissioned before a deliberate impact on the Moon on Dec. 17, 2012.

2010 Oct. 1 | CNSA Chang'e 2
China's second mission to the Moon, originally designed as a backup satellite for its predecessor mission, Chang'e 1, is a technical test satellite for future missions. The other main objective is to take high resolution pictures of the Moon's surface to choose a landing satellite for Chang'e 3.

2009 June 18 | NASA LCross (Lunar Crater Observation and Sensing Satellite)
The satellite is launched alongside NASA's Lunar Reconnaissance Orbiter right after ISRO's Chandrayaan-1 discovered water on the Moon. The spacecraft deliberately crashes into the Moon on Oct. 9, 2009, while sending real-time data back to Earth to support the identification of water in the lunar regolith.

2008 Oct. 22 | ISRO Chandrayaan-1
India's first deep space mission, consisting of an orbiter and a Moon Impact Probe, achieves lunar orbit and discovers water molecules on the lunar surface. The probe goes into freefall and crashes onto the lunar surface at the lunar south pole on Nov. 14, 2008.

5:05 a.m. EDT (2:35 p.m. local time) from the Satish Dhawan Space Center in Sriharikota, India, on July 14. It was the rocket's fourth operational mission.

"All of our spacecraft parameters are normal, including the power generation in both propulsion module and lander module," Chandrayaan-3 Project Director P. Veeramuthuvel said after the launch.

"Wishing you safe travels to the Moon," NASA Administrator Bill Nelson commented on X, formerly known as Twitter. "We look forward to the scientific results to come from the mission."

The planned 40-day trip to the Moon is divided into three phases. In Phase 1, the Earth-bound maneuver phase, the spacecraft orbits Earth while periodically increasing its distance from the planet. So far, it has performed five orbit-raising maneuvers.

The first firing on July 15—the day after launch—left Chandrayaan-3 in an elliptical orbit that stretched as far as 41,762 km (26,000 mi.) and came as close as 173 km from Earth. The second, third and fourth firings occurred on July 17, 18 and 20. The fifth maneuver occurred on July 25 and was expected to place Chandrayaan-3 into a 127,609 X 236-km orbit, ISRO says.

After the Earth-bound maneuvers are complete, the mission is to transition to Phase 2: the lunar transfer phase. The TransLunar Injection burn, scheduled for Aug. 1, is intended to send the spacecraft toward the Moon and into lunar orbit.

When Chandrayaan-3 reaches lunar orbit, targeted for Aug. 5, Phase 3 is planned to begin. The spacecraft is slated to orbit the Moon multiple times, gradually approaching the surface with each pass. Once it reaches a 100-km orbit above the lunar surface, the lander and rover are planned to detach and attempt to touch down.

Chandrayaan-3, which does not include an orbiter, is designed to use the Chandrayaan-2 orbiter as a data relay spacecraft, the ISRO said. The 2019 Chandrayaan-2 mission's orbiter placed itself around the Moon and remains operational, surpassing its expected one-year design life. The Chandrayaan-2 program ended with its lander and rover crashing into the Moon's surface during the final descent phase.

Chandrayaan-1—the first Indian lunar mission, launched by a Polar Satellite Launch Vehicle in October 2008—completed more than 3,400 orbits around the Moon until communications were lost in August 2009. That orbiter made the first discovery of water molecules on the lunar surface, specifically in the polar regions.

Building upon its predecessors' capabilities, the new Vikram lander has a higher landing velocity tolerance, ISRO Chairman S. Somanath told *The Times of India* in a June 29 interview. This means it should not break or crash at a vertical velocity of 3 m/sec. (10 ft./sec.)—an increase from Chandrayaan-2, which was designed for a 2-m/sec. touchdown velocity.

Since the lander's mass was increased by around 200 kg, it requires a minimum of two engines to land, Somanath said in the interview. Vikram also carries more fuel this time, he said.

The lander is equipped with improved technology as well, such as a laser doppler velocimeter sensor, which examines lunar terrain and provides three velocity vector components, and lander horizontal velocity cameras to hedge against failures.

"Instead of a success-based design, the ISRO has this time opted for a failure-based design," Somanath said at the Space Economy Leaders Meeting in Bengaluru, India, in early July. "We looked at sensor failure, engine failure, algorithm failure, calculation failure. There are different failure scenarios calculated and programmed inside."

ISRO is targeting a larger landing ellipse this time, aiming for a 4.2 X 2.5-km region near the Moon's south pole. The agency expects to have a clear view of the landing site ahead of touchdown via Chandrayaan-2's camera, so it will not rely solely on pictures from the lander itself, Somanath said.

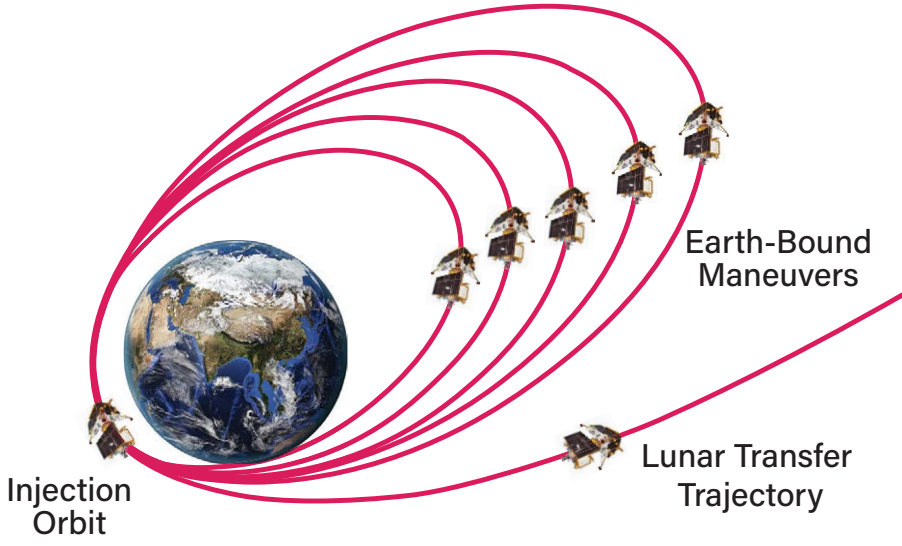
The lander and rover are designed to last for one lunar day, the equivalent of about 14 Earth days. They carry an array of scientific payloads that are to perform experiments on the lunar surface.

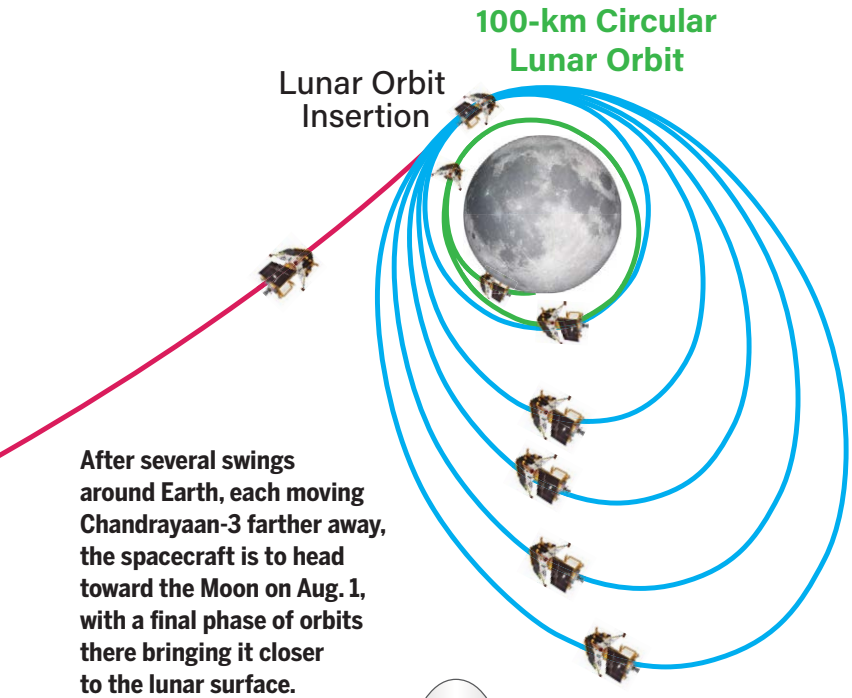
Vikram carries Chandra's Surface Thermophysical Experiment, designed to measure the thermal properties of the lunar surface near the polar region; the Radio Anatomy of Moon-Bound Hypersensitive Ionosphere and Atmosphere Langmuir probe to measure changes in the near-surface plasma ions and electron density over time; and the Instrument for Lunar Seismic Activity to measure seismic activity in the area surrounding the landing site as well as analyze the lunar crust and mantle structures.

In addition to the ISRO payloads, the lander carries a NASA-provided Laser Retroreflector Array. This passive instrument can provide lunar ranging by reflecting laser light from other spacecraft, enabling it to measure the distance between the two.

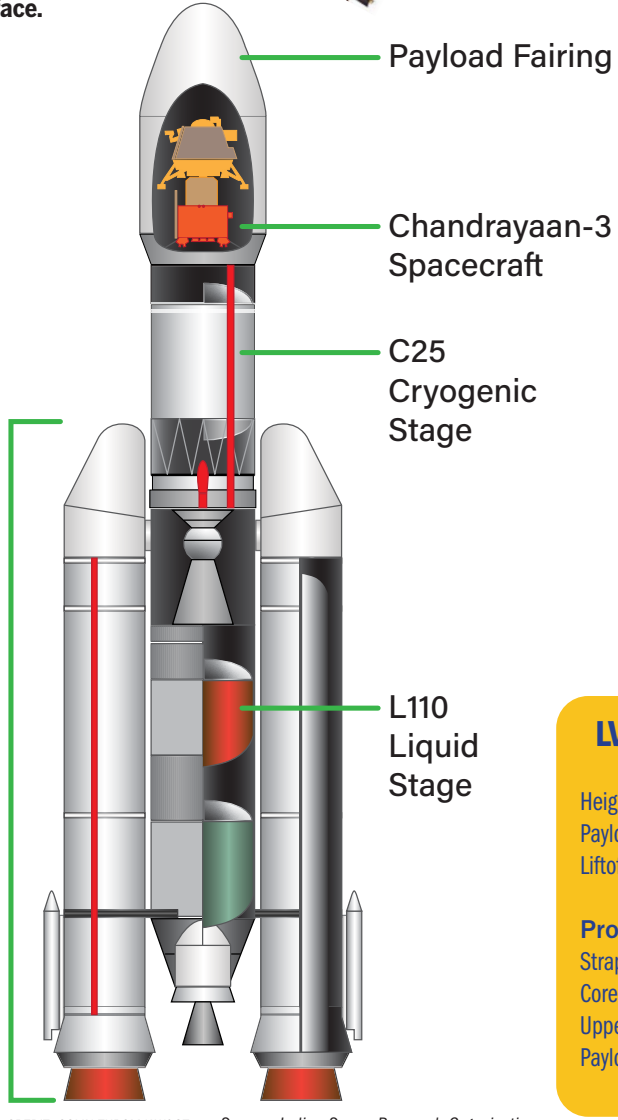
On the rover, Pragyan, an Alpha Particle X-Ray Spectrometer is planned

Chandrayaan-3's Path to the Moon





After several swings around Earth, each moving Chandrayaan-3 farther away, the spacecraft is to head toward the Moon on Aug. 1, with a final phase of orbits there bringing it closer to the lunar surface.



CREDIT: COLIN THROM/AW&ST *Source: Indian Space Research Organization*

to infer the mineral and chemical composition of the lunar surface and a Laser-Induced Breakdown Spectroscope is slated to determine the elemental composition of the lunar soil and rocks near the landing site.

The propulsion module has an experimental payload of its own, the Spectro-Polarimetry of Habitable Planet Earth, intended to study the signatures of the polarization of light on Earth in the near-infrared range.

Standing 43.5 m (140 ft.) tall, the LMV3 is a three-stage rocket that includes a pair of solid S200 strap-on motors. With 204 tons of solid propellant, the S200s are among the largest solid boosters in the world.

The rocket's L110 liquid-fuel core stage is powered by two Vikas engines fueled by 115 tons of unsymmetrical dimethylhydrazine and water. The rocket is designed to take off with the simultaneous ignition of the S200 boosters. The core stage ignites at 113 sec. after liftoff, and booster burnout occurs 21 sec. later. The L110 is designed to continue firing until 313 sec., at which point it separates, leaving the rest of the ascent to a high-thrust C25 upper stage fueled by 28 tons of liquid oxygen and liquid hydrogen.

The LMV3 can carry up to 4,000 kg to geostationary transfer orbit and 8,000 kg into low Earth orbit. In March, an LMV3 launched 36 OneWeb satellites. ISRO is developing a human-rated version of the rocket to carry astronauts. "We are in the process of increasing the launch frequency of this vehicle, considering national requirements as well as satellite demand," noted Chandrayaan-3 Mission Director S. Mohan Kumar.

—With Irene Klotz in Cape Canaveral

LVM3-M4 Vehicle Characteristics

Height (m [ft.])	43.5 (143)
Payload Mass (kg [lb.])	3,895 (8,587)
Liftoff Mass	642 tons

Propulsion Stages

Strap-On Motors	2 X S200 (Solid)
Core Stage	L110 (Liquid)
Upper Stage	C25 (Cryo)
Payload Fairing Diameter (m [ft.])	5 (16.4)

Source: ISRO

Hydrogen Propulsion Progress Puts Infrastructure in the Spotlight

> AIRBUS IS GATHERING CLEARER IDEAS ON AIRPORT NEEDS

> FUNDING HAS YET TO GROW BEYOND NASCENT STAGE

Thierry Dubois Lyon

RESEARCH AND TECHnology programs aiming to power aircraft with hydrogen are well underway. Despite the ambitious nature of Airbus' goal of putting the first hydrogen-powered commercial aircraft in service in 2035, the funding and skills behind those programs give reasonable hope it can be met.

LHYFE

In the Sealhyfe demonstration project, green hydrogen is being produced offshore.

While ensuring enough hydrogen is available at airports is another matter, it has climbed higher on the agendas of airport operators, and production projects abound. A snowball effect has started, and the question is how large the effort will grow.

"More people are talking about infrastructure," says Robin Riedel, co-leader of the McKinsey Center for Future Mobility. "Not just geeks—airport CEOs are talking about it."

But there are still major uncertainties about the timing and degree of investment. "We are not seeing massive investment," Riedel notes. "And 90% of it is outside the airport sector, according to the World Economic Forum."

Would-be manufacturers of hydrogen-powered aircraft have yet to answer this question effectively. "When will they produce aircraft so airports know when they have to care?" Riedel says. Startup companies plan to have hydrogen-powered aircraft in service well before Airbus—Universal Hydrogen, for one, is targeting 2025-26.

Airbus sees itself as a catalyst. "We launched the hydrogen hub at airports concept in 2020," says Christophe Arnold, head of hydrogen infrastructure at Airbus. To make hydrogen propulsion economically viable in aviation, airports will have to be hydrogen hubs, producing and using as much of the fuel as possible.

Airbus also is betting on other industries, such as road and rail transportation, to help realize that vision. "In 2035, we will have a mature hydrogen ecosystem, thanks to other sectors," Arnold says. "The production of decarbonized hydrogen is growing fast everywhere in the world."

Sakowin, a French startup participating in Paris airport operator Groupe ADP's H2 Hub Airport project, has made progress toward producing hydrogen from methane. It is targeting green generation of hydrogen, with solid carbon as a byproduct.

"Our strong point is the ability to produce large volumes of hydrogen on site," says Sakowin President Gerard Gatt. "For Paris [Charles de Gaulle] Airport, ADP has set a target of 500 metric tons of hydrogen per day.

"Despite many European countries' desire to get rid of natural gas imports, gas will remain indispensable in the short term," Gatt says. "Transitioning to renewable or nuclear energies calls for long construction cycles. Our solution is more pragmatic; it can accelerate the energy transition."

Sakowin's process, methane plasmalysis, is adapted from methane pyrolysis. "In our reactor, plasma is as homogeneous as possible so energy can be distributed evenly," Gatt says. "As a result, we maximize the production of hydrogen (as opposed to carbon) in the reaction. What is special about our technology is that it will be competitive, whatever the market price of solid carbon as a byproduct."

Solid carbon could be valuable in industrial agriculture, which tends to consume the soil's carbon, reducing its water retention capacity, Gatt says. Returning carbon to the soil would help plants grow.

Compared with water electrolysis, Sakowin's technology cuts electric power needs by a calculated factor of 5:1. A methane molecule requires much less energy to dissociate than a water molecule. And the surface Sakowin's production units require is compatible with an airport, which is not the case for water electrolysis powered by a photovoltaic farm.

Sakowin's process is designed to decarbonize natural gas. "If we use biomethane, our technology becomes a sink for CO_2," Gatt adds.

With ADP, Sakowin is considering a pilot production unit of 100 kW, which corresponds to 200 kg (440 lb.) per day from local biomethane. The accompanying gas station will be able to deliver biomethane, hydrogen and electricity. Designed with Groupe ADF and Karrgreen, it will fuel ground vehicles. "In 2025, the pilot unit at an ADP airport will be part of the total 15 pilot units in operation by then," Gatt says.

Since 2021, the process' technology readiness level (TRL) has grown to TRL 5 from TRL 4, meaning it has been validated in a relevant environment as opposed to a laboratory. In 2022, Sakowin delivered a 3-kW prototype.

This year, delivering a 6-kW unit will grow maturity to TRL 6, an advanced stage that usually allows the launch of a product. "With the 6-kW prototype, we have built a system that works continuously, without any overheat phenomenon or unexpected stop," Gatt says.

In 2024, a beta test 100-kW unit is

LOGO: ARTHOBBIT/UNDEFINED UNDEFINED/WASTESOUL/MARYLOO/GETTY IMAGES

planned to start operations, bringing the TRL to 7 before the 2025 delivery to ADP.

Public investment fund Bpifrance has provided Sakowin €9 million ($10 million) in 2022-23. Four industrial companies are in the investors pool: Ponticelli, Groupe ADF, Saint-Gobain and Aes Dana.

Larger quantities of green hydrogen may come from offshore. "Producing hydrogen at a competitive cost will be even more possible with offshore installations," says Thomas Creach, chief technical officer at green hydrogen producer Lhyfe. "The idea is to get the energy from where it is cheap and stable." Transporting hydrogen to shore is more cost-effective than conveying electric power over long distances.

The Sealhyfe demonstrator aims to prove hydrogen can be produced at an industrial scale at sea. The production unit is situated 23 km (14 mi.) off the coast of Le Croisic, France. "We chose a location with an existing floating wind turbine," Creach explains. "We integrated our production unit—1 megawatt, creating 400 kg of hydrogen per day—on a floating platform. We made it compact and worked to reduce maintenance needs. We also designed software tools to operate it remotely."

The production unit was inaugurated in September 2022 and remained docked in the port of Saint-Nazaire, France, until May. During the period, tests validated the developments and a few modifications were made. Then the platform was towed to the current location to show it can withstand tough conditions, such as 10-m-high (33-ft.) swells.

In June, the anchored production unit was connected to the wind turbine and has since been producing up to 400 kg of hydrogen per day. Hydrogen is released into the atmosphere, however, as a pipeline would have taken two or three years to be authorized, Creach says.

"There is no business case for 400 kg per day," he emphasizes. "Business cases can be found for producing 100 or 200 times more. We are going to bid in the Netherlands for a 500-megawatt project involving wind turbines and hydrogen production units and in Germany for a 1-GW project along the same lines."

In the meantime, Lhyfe's Hydrogen Offshore Production for Europe project is planned to be 10 times the size of Sealhyfe and produce 4 metric tons of hydrogen per day. Located off the coast of Ostend, Belgium, it is designed to be a semi-floating installation and jacked up instead of anchored. A pipeline would deliver hydrogen to local customers. The effort has received €20 million under an EU research and technology project, and production is planned to start in 2026.

How can hydrogen coming from afar be delivered? "Road tankers feeding the airport are a nice solution," Airbus' Arnold says. "You can scale it up easily. However, there is a limit to the number of such trucks you can put on the road. Another valid option is an underground pipeline of gaseous hydrogen."

Airbus has created partnerships with several airports in France, South Korea, New Zealand and Singapore to study hydrogen ecosystems. "We have learned a lot," Arnold says. "We have identified two major challenges. First, a liquid hydrogen refueling truck must ensure a fast turnaround to maintain flight connections. Second, in the long term, access to the energy grid must be created for the airport. If you want to produce and/or liquefy hydrogen on site, you need a large amount of electric power or access to gaseous hydrogen pipelines."

An underlying question, McKinsey's Riedel notes, is whether electrons will come from a sustainable source. "We have not decarbonized the grid," he says. "The assumption is we will have plenty of electricity and treat it as a commodity. And yet we have to create that capacity; it is not a trivial question. As for nuclear energy, its environmental relevance is a philosophical matter."

With Air New Zealand, Airbus has studied how to equip a minimal number of airports and cover an entire domestic network, Arnold adds.

Safety procedures will need to be adapted from those created for Jet-A1. "Hydrogen posing a far greater safety challenge is a myth," Arnold says.

Air Transport Sector Braces for Increased Climate Change Impact

> UNITED AIRLINES TO PLAN BUFFERS FOR EXTREME WEATHER

> EUROCONTROL WARNS OF EFFECT ON INFRASTRUCTURE

Thierry Dubois Lyon and **Christine Boynton** Boston

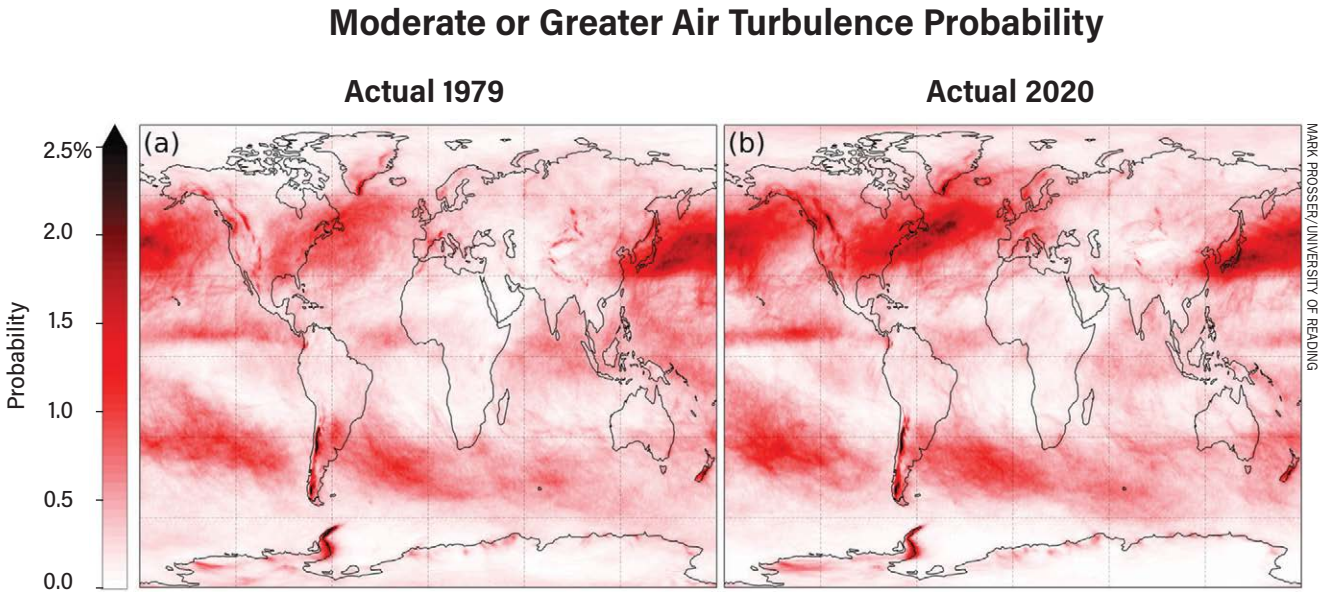
Signs are converging that climate change has begun to affect commercial air transport, with more frequent storms, higher summer temperatures and increasing turbulence as just a few examples of the phenomenon. As such, aviation should prepare for structural changes—as opposed to incremental adaptation—and accompanying costs. That realization is all the more urgent for the sector as global warming appears to be happening even more quickly than projected.

The weekend of June 24 will be remembered as the stormy start of the official summer season in the U.S. northeast. Some of the most intense difficulties occurred with United Airlines at Newark Liberty International Airport (EWR) in New Jersey.

"Airlines can plan for things like hurricanes, subzero temperatures and snowstorms, but United has never seen an extended limited operating environment like the one we saw this past week at Newark," CEO Scott Kirby wrote in a July 1 message to staff. Pointing to "truly unprecedented severe weather" at EWR, he added, "severe restrictions" on June 24-27 had reduced the total number of aircraft able to depart EWR by 60-75% for an average 6-8 hr. each day.

"Airlines, including United, simply aren't designed to have their largest hub have its capacity severely limited for four straight days and still operate successfully," he wrote.

The event revealed room for improvement, including investments in crew technology and changes to sched-



The probability of encountering moderate-or-greater clear-air turbulence has increased over the last four decades.

uling at EWR. Being better prepared to recover quickly from disruptions will be key to confront future challenges, he noted. "We're heating the atmosphere—thermodynamics 101, we're going to have more thunderstorms," Kirby said at a July 11 event in Washington. "Dealing with climate change is a business imperative." (*AW&ST* July 17-30, p. 19)

Eurocontrol, the organization in charge of air traffic management in Europe, is again warning the aviation industry about the risks climate change is posing to flight operations.

The organization sounded the alarm in 2021 and is this time presenting new, striking cases in point. "The industry needs to mitigate the very real impacts climate change has on its own operations," Rachel Burbidge, environmental policy officer in Eurocontrol's aviation sustainability unit, said during a recent episode of Eurocontrol's "Raising the Bar" podcast.

Among the most significant threats are much higher temperatures, which affect aircraft performance. Typically, hot weather translates into longer takeoff distances, so a consequence of climate change may be a requirement to extend runways.

Extreme temperatures may also affect employee and passenger health, Burbidge said, and stronger storms may damage infrastructure. Due to sea level rise, airport capacity may be reduced, she added—falling short of acknowledging some airports may simply become unusable.

As seen last summer, heat waves may degrade materials on runways and other surfaces. Other extreme weather events include heavy rainfall that increases flooding risk. At the opposite end of the spectrum of hazards, droughts could cause water shortages that could affect every human activity, including airport operations.

Those disruptions will also have financial outcomes. Delays due to a major storm, flying additional distances and burning extra fuel to avoid a stormy area will add to costs. In 2019, storm-induced costs in the Eurocontrol area (all of Europe, extending to Turkey) amounted to €2.2 billion ($2.4 billion), Burbidge says. That total comprises inefficiencies, extra fuel burn and lost passengers.

What if an airport closes due to a major weather event? "We found that the cost of diverted and canceled flights in the case of a one-day closure in a large airport—100,000 aircraft movements per year—could be around €18 million," Burbidge says.

"It is really important to start adapting and building resilience now to reduce those costs and damages further along the line," she adds.

Moreover, in just a few years, tourism may be reshaped. Some countries may become unsuitable for tourism in the summer due to prolonged heat waves. Some other places may turn attractive in more seasons, such as spring and fall, in addition to summer.

"The most important thing for any organization is to carry out a risk assessment," Burbidge says. Such an analysis shall identify specific risks, suitable adaptation and resilience measures.

A warmer climate means more energy in the atmosphere. Therefore, turbulence can be expected to grow both in occurrences and strength. Recently published research by Mark Prosser, a graduate student at the University of Reading in England, shows clear-air turbulence—a phenomenon that is challenging to forecast or detect—increased between 1979 and 2020.

For example, at an average point over the North Atlantic between 1979 and 2020, the total annual duration of moderate or greater clear-air turbulence increased by 37%, to 96.1 hr.

Moderate turbulence is defined as the point at which unsecured objects begin to move and at which people find it difficult to move around inside the cabin. Strong turbulence (at the upper end of the moderate-or-greater category) can injure those inside the cabin. And additional airframe fatigue caused by turbulence requires more maintenance. Again, such changes will call for aviation to adapt.

Battle Lines

- NEXT-GENERATION SINGLE-AISLE ENGINE TECHNOLOGY PLANS FIRM UP
- TESTS SHOW THE OPEN FAN IS QUIETER THAN THE LEAP
- SWITCH PROGRAM'S EARLY FOCUS IS AIRFRAME INTEGRATION

Guy Norris Colorado Springs

In the two years since the GE Aerospace-Safran CFM International joint venture revealed plans to target development of an open fan concept for its next-generation, single-aisle airliner engine, the program has been kept under wraps and technological progress has gone largely unreported.

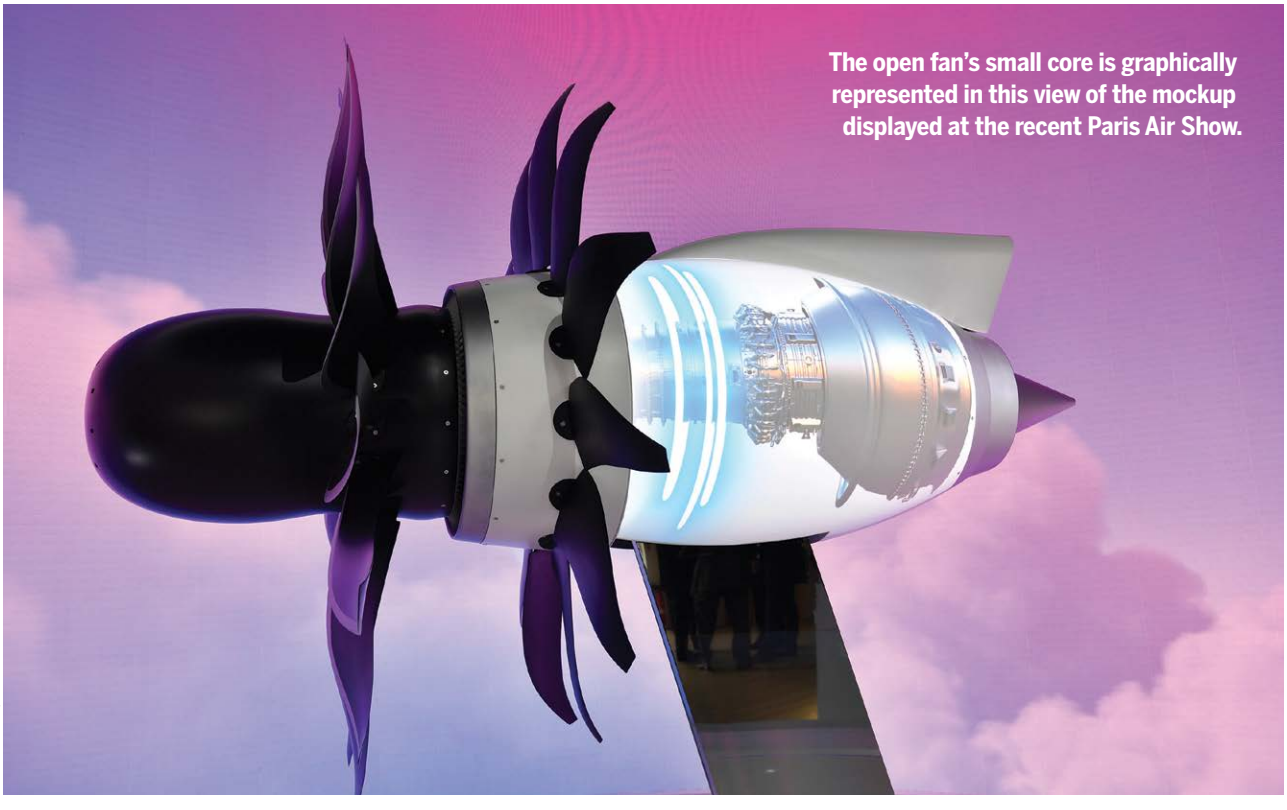
Now this—and the competitive landscape—is changing. CFM is providing new testing detail about its Revolutionary Innovation for Sustainable Engines (RISE) technology initiative, while a potential challenger in the form of the MTU Aero Engines-led Sustainable Water-Injecting Turbofan Comprising Hybrid-Electrics (Switch) program is quickly taking shape based on Pratt & Whitney's baseline PW1000G geared turbofan (GTF) architecture.

"RISE isn't anymore just on paper—it's for real," says Mohamed Ali, vice president and general manager for engineering at GE Aerospace. More than 100 components, systems, subsystems and module tests have been conducted at GE and Safran so far as part of technology maturation work aimed at proving aspects of the concept ahead of full-up integrated engine tests around the middle of the decade.

Tests have included the use of supercomputers to analyze the engine design. Other advanced computing tests are ongoing to assess areas including the high-pressure (HP) turbine design and, along with Airbus, modeling of the open-fan noise and installation characteristics. The tests with Airbus, conducted at the company's facility in Hamburg, Germany, indicate that noise levels of the open fan will be lower than those of the Leap, Ali says. "So these are very encouraging results," he adds. "It keeps us saying we'll keep moving with the program, and it's quite exciting for us to be working with all the airframers."

CFM has been using Frontier, a recently commissioned supercomputer at the U.S. Energy Department's Oak Ridge National Laboratory in Tennessee, to model the performance and noise levels of the open fan. With the processing power of around 37,000 graphics processing units, GE says the Energy Department's Frontier supercomputer can model the vastly complex unsteady-flow characteristics of the open fan in fine detail and at full scale.

The 13-ft.-dia., single-stage fan and stator design is a key element of the configuration, which is targeting a 20% reduction in fuel consumption and CO_2 emissions compared with current single-aisle engines. However, as the first open fan design of this type, scale and puller configuration, there are many unknowns about how the interaction between the rotating fan stage, static stator stage, nacelle and installa-



The open fan's small core is graphically represented in this view of the mockup displayed at the recent Paris Air Show.

MARK WAGNER/AVIATION-IMAGES

CFM

Tests of the RISE high-speed, low-pressure turbine are underway in an F110 at GE's facility in Evendale, Ohio.

tion might affect the performance and noise levels. GE worked with the laboratory to develop computational fluid dynamics software for Frontier that could simulate air movement of a full-scale open-fan design.

Frontier, which is a Hewlett Packard Enterprise-made Cray EX supercomputer with more than 9,400 nodes, can analyze data at more than exascale speed, or over a quintillion calculations per second. Exascale computers are digital computers roughly similar to earlier-generation supercomputers but with much more powerful hardware. By running full-scale fan flow simulations, GE says it has been able to identify interaction areas and make design changes where appropriate ahead of testing with full-scale hardware.

"The open fan obviously steals quite a bit of the show because it's the most visible part of the program, but there's quite a lot going on behind it," Ali says, referring to other new design areas including a high-power gear system and a compact, high-pressure core to boost thermodynamic efficiency. RISE will also include a recuperating system to preheat combustion air with waste heat from the exhaust. The demonstrator will feature a broad range of advanced materials, such as ceramic matrix composites, in the hot section and resin-transfer-molded composite fan blades.

Both GE and Safran have also made and demonstrated new additively manufactured heat exchangers designed to handle the thermal challenges of the compact core. Meanwhile, related work on small core technology is underway by GE for the Turbofan Engine Power Extraction Demonstration under NASA's Hybrid Thermally Efficient Core project. "They're showing us superior results because of the geometries that you can never achieve using anything other than additive manufacturing," Ali says, referring to the heat exchangers.

"We have designed new turbine blades and nozzles using our supercomputing capability, and we got fascinating, revolutionary results in terms of fuel-burn improvements as well as durability," Ali says. Tests of the first full high-speed, low-pressure (LP) turbine stage have also begun at GE's Evendale, Ohio, facility using an F110 military donor engine—a high-performance gas generator with the closest available configuration to the F101, which formed the original core of the CFM56. The work, which began in June, is focused on the aerodynamic performance of the blades as well as demonstrating the advanced cooling system of the new design. High-speed LP turbine tests are also underway at Safran's site in Villaroche, France, alongside static and vibration tests.

"Now we have also started to procure material for the engine demonstrator, including forgings. So it's real parts for a real engine," CFM President and CEO Gael Meheust says.

The Switch program, which is pursuing a 25% reduction in fuel burn compared with current engines, is also gathering momentum. Led by MTU with partners Airbus, Collins Aerospace, GKN Aerospace and Pratt & Whitney, the research and technology program is being conducted under the European Union's Clean Aviation public-private partnership initiative and combines a complex water-enhanced turbofan (WET) concept with a hybrid-electric architecture.

The WET cycle incorporates a condenser to collect water from the engine exhaust gas and a heat exchanger to vaporize it into steam. The steam is then injected into the combustor, increasing the mass being accelerated out of the engine and boosting thrust. The process also serves to cool the turbine inlet temperature, thus improving fuel efficiency. Under the concept, the reduced temperature profile also eliminates most of the combustor hot spots where nitrogen oxides form.

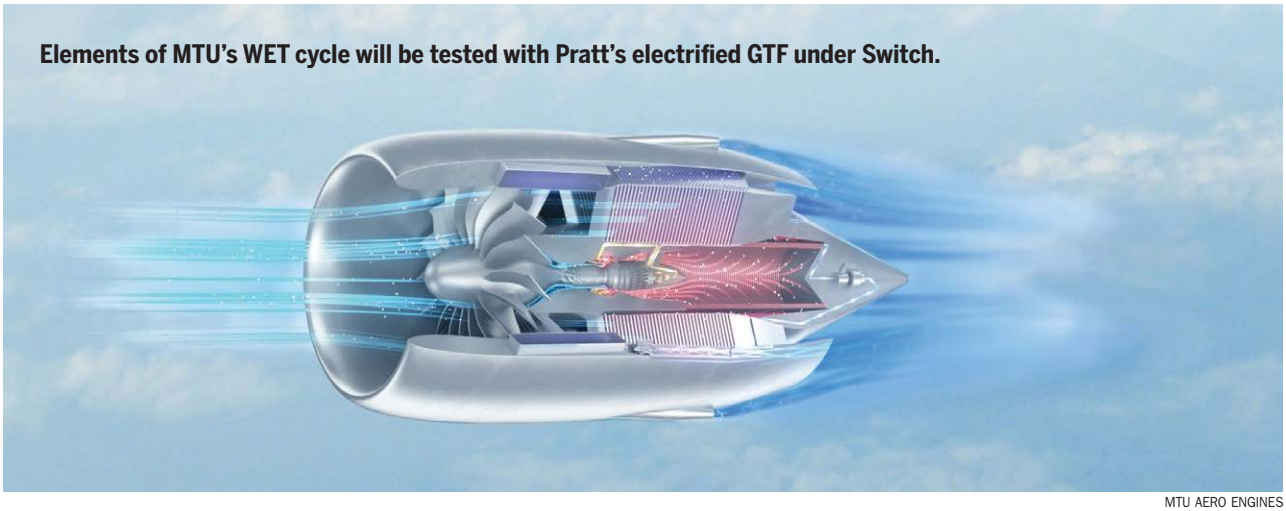
"We're putting a lot of focus right now on the integration part of the engine concept into the aircraft and working very intensely with Airbus on that," says Claus Riegler, MTU's senior vice president of technology and engineering for advanced programs. "The WET concept features two significant heat exchangers, which come obviously with volume, size and weight. And therefore, smart integration is vital and that's what we are currently focusing on.

"We're also starting to look into special operating cases aside from typical cases like takeoff, climb and cruise," Riegler adds. "And we will learn a lot about how this hybrid engine configuration reacts potentially differently to more traditional engine configurations."

For the hybrid-electric system, which will be initially tested separately from the WET cycle in a modified PW1100G, Collins Aerospace is supplying a 500-kW motor generator for the HP spool and a 1-megawatt motor generator on the LP shaft. The electric system will be used for taxiing and boosting power for takeoff, as well as other transient phases.

"We are currently developing requirements, plugging those into the system and working very closely with Airbus to understand the requirements for the electrical components," says Marc Holme, senior director of engineering at Collins Aerospace. "We are also working with Pratt & Whitney to look at how those will integrate within the engine to make the necessary interfaces."

In addition, Pratt is "working closely with Collins in terms of the integration of the electrical motors into the engine



Elements of MTU's WET cycle will be tested with Pratt's electrified GTF under Switch.

MTU AERO ENGINES

and continuing the overall definition of requirements that are necessary for this engine," adds Graham Webb, Pratt's chief sustainability officer.

On a related front, GKN is working on the structural integration of the electric motor while also providing a new, high-voltage wiring system. "We are working heavily with Collins on that," says Henrik Runnemalm, vice president of the Global Technology Center at GKN Aerospace. "And then on the WET side of the program, we are preparing a number of technology bricks in order to prove that this concept will work and we understand fully what's going on with the different technologies."

As with the RISE effort, Switch is targeted at maturing propulsion technology for possible entry into service around the mid-2030s. The hybrid-electric element of the program will be ground-tested in a complete engine, while components and subsystems of the WET cycle will be tested under Phase 1 of the program, which runs through 2025. A second phase, set to run from 2025 to 2030, would likely culminate in flight tests of the fully integrated Switch to mature it sufficiently to a level at which it could be ready for full-scale development by the 2035 time frame.

TECH TAKE

By **Graham Warwick**

For the latest, go to **AVIATIONWEEK.COM**

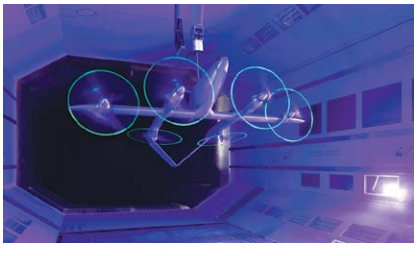
Textron's Nexus eVTOL Tested in Wind Tunnel

Textron eAviation has begun wind tunnel testing of its Nexus electric vertical-takeoff-and-landing vehicle as it works toward flying a full-scale demonstrator by the end of 2024.

The 23%-scale powered model is being tested in the RUAG wind tunnel in Emmen, Switzerland, to validate the performance, stability and control of the design and confirm the speed and range estimate for the preliminary design.

The piloted, three-passenger Nexus is designed to fly 100 nm at 120 kt. on all-electric propulsion. The winged electric vertical-takeoff-and-landing (eVTOL) aircraft has six tilting propellers for vertical and forward flight, plus two lift rotors.

TEXTRON eAVIATION



The Nexus eVTOL has six tilting propellers for lift and thrust plus two lift rotors for vertical flight.

Wind tunnel testing will evaluate the propellers at the full range of conversion angles and power levels and will provide data related to tail size, engine power requirements, transition strategies, hover net thrust and aerodynamic drag, Textron eAviation says.

The Nexus program is one of two divisions within Textron eAviation. The other is Slovenia-based Pipistrel, which produces the Velis Electro electric trainer and is developing the Nuuva V300 eVTOL large, uncrewed cargo aircraft.

The Nexus was started within Textron company Bell but transferred to the new eAviation business unit after it was established in March 2022 following the agreement to purchase Pipistrel. The eVTOL vehicle is being developed with the help of Bell and Pipistrel as well as Textron's Beechcraft and McCauley propeller business units.

Bell is developing the composite airframe, flight control system and lift rotors, Pipistrel the batteries and McCauley the propellers, while Beechcraft has responsibility for testing, eAviation President and CEO Rob Scholl told a Honeywell advanced air mobility summit in Washington in July 18.

Development of the Nexus is taking advantage of Bell's expertise with helicopters and tiltrotors as well as Textron Aviation's experience certifying a large number of Cessna and Beechcraft fixed-wing aircraft, he said. The company is aiming for service entry around the end of the decade.

FAA Rule Would Clear Path for Electric Aviation

The FAA is proposing changes to the regulations for light sport aircraft (LSA) that would allow electric propulsion systems and simplified flight controls in a move aimed at increasing their suitability for flight training and personal flying (see page 28).

Intended to enable deployment of a new class of lower-performance aircraft that would be less expensive to produce and operate than general aviation aircraft certified under Part 23, the LSA rules introduced in 2004 set a weight limit of 1,320 lb., or 1,430 lb. for operation on water.

The rule also established a sport pilot certificate that enables pilots to fly certified LSAs with less training than a private pilot license. As of January, almost 4,460 airplanes had been manufactured and 7,000 sport pilots certified since the rule was finalized.

Now the FAA is proposing to remove the LSA definition and establish a new regulation that would set performance limitations and design requirements for the aircraft that sport pilots can operate. Limits on amateur-built, experimental and restricted-category aircraft also would be updated.

The rule would not allow sport pilots to fly powered-lift aircraft, including eVTOL vehicles, "given the complexity and ongoing development of those aircraft designs," says the FAA, which expects that future rulemaking may consider these aircraft.

PIPISTREL

The revamp of FAA light sport rules would open the U.S. market to electric trainers like Pipistrel's Velis Electro.

The proposed rule removes the weight limit on LSAs but also increases the limit on stall speed to 54 kt., indirectly limiting maximum weight to around 3,000 lb. Maximum speed is raised to 250 kt. and seating capacity to four, allowing more capable aircraft.

The proposed rule would "remove prescriptive weight limits that hinder incorporation of safety-enhancing designs and equipage; enable more robust aircraft for the pilot training environment; enable increased capacities for passengers, fuel and cargo; enable electric propulsion; and enable faster, higher-performing aircraft more suitable for personal travel," the FAA says.

Developed with industry collaboration under the Modernization of Special Airworthiness Certificates (Mosaic) initiative, the notice of proposed rulemaking for the new regulation was published July 24 as the Experimental Aircraft Association AirVenture 2023 show opened in Oshkosh, Wisconsin.

In addition to allowing more complex aircraft with retractable landing gear and variable-pitch propellers, a key provision of the proposed rule is a change in language to "powered aircraft" from "engine-driven." This removes the existing barrier to using electric propulsion in LSAs.

Makers of electric light aircraft including Textron-owned Pipistrel are waiting for the Mosaic rule to unlock the U.S. market for electric trainers that can dramatically reduce the costs of flight training. While sport pilots will be able to fly four-seat aircraft, they will be allowed only one passenger.

Another key provision of the rule would permit aircraft with simplified flight controls instead of traditional primary flight controls. These would be required to enable the pilot to control the aircraft without direct manip-

ulation of the control surfaces (i.e., fly-by-wire), prevent loss of control and enable the pilot to discontinue the flight quickly and safely.

Heart Plans ES-30 Ground Demonstrator

Swedish startup Heart Aerospace is to build a full-scale nonflying demonstrator of its planned ES-30 electric regional aircraft for charging and taxiing tests at Malmo Airport in southern Sweden.

The demonstrator is to be built under Phase 3 of the Electric Aviation in Sweden (ELISE) program, supported by 20 million krona ($1.9 million) in funding from government innovation agency Vinnova.

The project will run until the spring of 2025. In addition to Heart and Swedish airport operator Swedavia, the charging and taxiing tests will involve Swedish carriers Braathens Regional Airlines and SAS as well as Swedish battery-maker Northvolt. The 30-passenger ES-30 is planned to fly in 2026 and is aimed at service entry in 2028.

Gothenburg-based Heart emerged from the ELISE project, which was launched in 2018 to promote electric aviation in Sweden. The 9.2 million krona second phase of the project, which ran from January 2020-July 2022, resulted in the design of the 19-seat ES-19 electric regional airliner.

Heart subsequently decided to develop a larger aircraft, the ES-30, based on input from initial customers including United Airlines and Mesa Airlines, which together have placed preorders for 200 aircraft. The ES-30 has an all-electric range of 200 km (124 mi.), increasing to 400 km with a hybrid-electric reserve system.

HEART AEROSPACE

A full-scale nonflying ES-30 demonstrator will be used for taxiing and battery charging tests.

Running from May 2023-April 2025, ELISE Phase 3 is planned to produce a full-scale demonstrator and rechargeable battery pack for testing. Malmo's proximity to the European mainland and its focus on international operations "make the airport an ideal test arena for the continued development of Swedish electric aviation," says Karin Ohrstrom, Malmo Airport director.

Supporting the ELISE Phase 3 project is an advisory board including: Swedish regional airport operator SRF, RISE (Research Institutes of Sweden), Bromma Air Maintenance and Swedish air navigation service provider LFV, as well as the Swedish Transport Agency and Swedish Transport Administration.

BAE UAV Flies in the Stratosphere

BAE Systems' PHASA-35 solar-powered uncrewed aircraft system has lofted into the stratosphere for the first time.

On the 24-hr. flight, which took place in late June from Spaceport America over the White Sands Missile Range in New Mexico, the high-altitude pseudo-satellite (HAPS) reached an altitude of more than 66,000 ft., BAE says.

The short stratospheric flight allowed engineers to assess the performance of the aircraft at high altitudes and was the first in a series of trials planned to confirm the PHASA-35's system performance.

BAE joins a small list of companies including Airbus that have successfully flown a solar-powered, long-endurance uncrewed aircraft system (UAS) in the stratosphere.

The PHASA-35, which was developed by Alton, England-based subsidiary Prismatic, made its first flight in February 2020 at Woomera in Australia and completed cold soaks in a simulated stratospheric environment to prove its mettle before the flight.

Like Airbus' Zephyr, the PHASA-35 uses solar cells covering the upper surface of the wing and horizontal stabilizer to provide power to the electric motors and onboard systems. The cells also recharge the aircraft's lithium-ion batteries to provide power at night.

The PHASA-35 uses U.S. startup Amprius Technologies' high-energy-density silicon-anode lithium-ion battery cells. In October 2022, Amprius

BAE SYSTEMS

BAE Systems' PHASA-35 solar-powered uncrewed aircraft exceeded 66,000 ft. altitude during the flight.

entered into a three-year cooperation agreement with BAE to investigate business opportunities for the batteries in electric products being developed by the UK company. Airbus, which is an investor in Amprius, also is using the company's silicon-anode cells in its Zephyr HAPS.

"The aircraft performs exactly as we expected, and in many areas exceeded expectations," says Phil Varty, BAE Systems business manager for UAS.

Named for its 35-m (115-ft.) wingspan, the PHASA-35 weighs 150 kg (330 lb.) and can carry a payload of 15 kg. With expected improvements in battery technology and motor efficiency, the PHASA-35 could potentially stay airborne for up to a year, but Varty says there will be an incremental approach to increasing the endurance of flights.

BAE sees defense as a primary customer, namely for missions such as communications relay and surveillance. But with civil certification, PHASA-35 could also provide 4G and 5G wireless connectivity to the ground as well as support disaster relief missions and border protection tasks.

The first flight trial was sponsored by the U.S. Army's Space and Missile Defense Command Technical Center, and the next flight is to be supported by the UK Defense Ministry and carry a payload.

"PHASA-35's first stratospheric flight demonstrates that this vehicle is on track to become the go-to system for long-endurance, high-altitude and communications applications in the future," says Prismatic CEO Dave Corfield.

The PHASA-35 program sits within BAE's newly established FalconWorks business for advanced research and development and is part of the company's Air sector. BAE purchased Prismatic in September 2019.

—Tony Osborne in London

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Aviation Week & Space Technology
July 31-Aug. 13, 2023
VOL. 185, NO. 15 (ISSN 0005-2175)

Aerospace Calendar

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Aug. 1-Oct. 24—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations. See rtca.org/content/upcoming-committee-meetings

Aug. 15-16—Counter-UAS Summit 2023. Westin, Old Town Alexandria. Alexandria, Virginia. See idga.org/events-counteruas-usa

Aug. 23-24—39th China Helicopter Academic Exchange Conference/7th Civil Helicopter Industry International Forum. Guanghan Civil Aviation Flight Academy of China. Deyang, China. See my.31huiyi.com/pc/page/e7c40000-5ba9-4ec4-96dd-08db61bc86e3

Aug. 28-31—International Civil Aviation Organization (ICAO) Air Navigation World. ICAO Headquarters. Montreal. See icao.int/Meetings/anw2023

Sept. 5-6—2023 Aviation Digital Operation Congress. Venue TBD. Haikou, China. See my.31huiyi.com/m/e7c40000-5ba9-4ec4-a927-08db624a8dd1

Sept. 5-7—Commercial UAV Expo. Caesars Forum. Las Vegas. See expouav.com

Sept. 9-10—Air & Space Forces Association 2023 National Convention. Gaylord National Resort and Convention Center. National Harbor, Maryland. See afa.org/events/afa-national-convention

Sept. 11-13—2023 Air, Space & Cyber Conference. Gaylord National Resort and Convention Center. National Harbor, Maryland. See afa.org/2023-air-space-cyber-conference

Sept. 12-14—2023 ICAO TRIP (Traveller Identification Programme) Symposium. ICAO Headquarters. Montreal. See icao.int/Meetings/TRIP-Symposium-2023

Sept. 12-15—Defence and Security Equipment International (DSEI 2023). ExCeL London. London. See dsei.co.uk

Sept. 13-14—Aviation Africa 2023. International Convention Center. Abuja, Nigeria. See aviationafrica.aero

Sept. 14-16—Taipei Aerospace and Defense Technology Exhibition. Taipei Nangang Exhibition Center. Taipei, Taiwan. See tadte.com.tw/en/index.html

Sept. 14-17—China Helicopter Exposition. Free Trade Zone of Tianjin Port (Airport Economic Zone). Tianjin, China. See helicopter-china-expo.com

Sept. 19-20—Hypersonic Weapon Systems. Sheraton. Pentagon City, Virginia. See idga.org/events-hypersonicweaponssystems

Sept. 19-21—Future Travel Experience Global. Long Beach Convention Center. Long Beach, California. See futuretravelexperience.com/fte-global

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Aug. 31-Sept. 1—CAPA Latin America Aviation & LCCs Summit. Queretaro, Mexico.

Sept. 13-14—Aero-Engines Europe. Madrid.

Sept. 14-15—CAPA Australia Pacific Aviation Summit. Brisbane, Australia.

Sept. 20-21—A&D SupplyChain Europe. London.

Sept. 26-28—MRO Asia-Pacific. Singapore.

Oct. 3-4—Digital Transformation Summit. Seattle.

Oct. 15-17—Routes World 2023. Istanbul.

Oct. 17-19—MRO Europe. Amsterdam.

Oct. 26—CTC Shanghai Corporate Travel Summit 2023. Shanghai.

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VIEWPOINT

Aviation Education for the AAM Future

By **P. Barry Butler**

Audience interest in the slate of advanced air mobility prototypes unveiled at the 2023 Paris Air Show made clear that the sector has reached a breakthrough moment.

But preparing for this new mode of air travel—which cannot rely entirely on legacy industry technologies, processes, training, certifications or infrastructure—involves inherent difficulties, according to a government accountability report published last year. Bridging that gap was the focus of an Aviation Week panel at the air show. It was an honor to join panelists from CAE, the Vertical Flight Society, Archer, Volocopter and the Aerospace Industries Association. My role was to share the aviation education perspective.

MARK WAGNER/AVIATION-IMAGES

From that vantage point, Embry-Riddle Aeronautical University faculty are in constant discussion about the ways in which advanced air mobility (AAM) is ushering in a new era in flight, one that requires reconsideration of engineering, operations, maintenance, the global airspace system and other core components of aviation. Among the voices in this discussion are leading electric vertical-takeoff-and-landing aircraft manufacturers, industry advisory board members and academics.

Embry-Riddle's Unmanned Aircraft Systems (UAS) degree programs offer coursework that introduces AAM concepts, including infrastructure development, such as vertiports and modifications to the airspace to accommodate these systems. A suite of courses in AAM is under development and will constitute a minor course of study for students wanting to pursue this field.

As venture capital and research and development are directed toward building and certifying the first generation of these new aircraft, engineering programs are adapting. For example, Embry-Riddle's Eagle Flight Research Center draws students from diverse disciplines—electrical, aerospace and mechanical engineering—to develop electrified and hybrid-propulsion aircraft. We have also introduced a course for engineers on the fundamentals of electrified propulsion, battery technology and variable-pitch rotors.

And thanks to a $1.4 million grant from NASA, researchers with Embry-Riddle, Boston University, Virginia Tech, Tuskegee University and Joby Aviation are studying how air taxis can take off and land quietly at vertiports in dense urban environments where winds are unpredictable.

Air traffic management is another main operational concern. Our students recently used sophisticated virtual simulators at the air traffic control (ATC) laboratory at our Prescott, Arizona, campus to test Reliable Robotics' new communication system for remotely piloted, highly autonomous aircraft. Chad Healy, senior human factors engineer at Reliable Robotics, which specializes in safety-enhancing aircraft automation systems, said that having access to highly trained students and a robust ATC simulation environment is providing valuable data "that will help us refine our system."

Thanks in part to FAA regulation changes, aviation maintenance programs are providing more relevant coursework and higher-level training for the complex designs, electronics, avionics, communication and navigation systems in aircraft today. This positive trend has opened the door for maintenance programs to include AAM subject matter such as electricity and composite structures.

"THOUGH AAM AIRCRAFT WILL USE INCREASING LEVELS OF AUTOMATION, COCKPIT SKILLS WILL STILL BE CRUCIAL."

Stephen Ley, associate professor in the School of Aviation Sciences at Utah Valley University, and Zackary Nicklin, UAS program manager at Northland Community and Technical College in Minnesota, recently told Aviation Week that they are collaborating on EVPro+ training at their institutions (*Inside MRO* July, p. MRO13).

Preparing pilots for AAM aircraft—which often employ vertical and horizontal flight modes and different flight controls—is a significant hurdle, and training standards are just beginning to be defined. In June, the FAA proposed a comprehensive rule for certifying pilots of powered-lift aircraft.

Companies are developing training for their proprietary AAM aircraft, but aviation schools will be critical to developing a training pipeline for pilots skilled in the control logic and autonomous systems used in AAM. Our experience with augmented reality, virtual reality and simulation will also prove helpful in validating training methods.

These new aircraft will collect vast amounts of flight data. Leveraging this data and conducting predictive analysis will be critical to providing a safe way for them to enter an already congested airspace.

Though AAM aircraft will use increasing levels of automation, cockpit skills will still be crucial as this new aviation environment emerges. Broadly known as "headwork," these skills include situational awareness, decision-making, teamwork, communication, anticipation and continuous learning. When AAM enters the airspace, unexpected hazards are likely to arise, and strong headwork will be needed to mitigate them.

As rulemaking and certification continue to advance, and industry rolls out its innovative and exciting prototypes for AAM, one goal must remain above all: safety.

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

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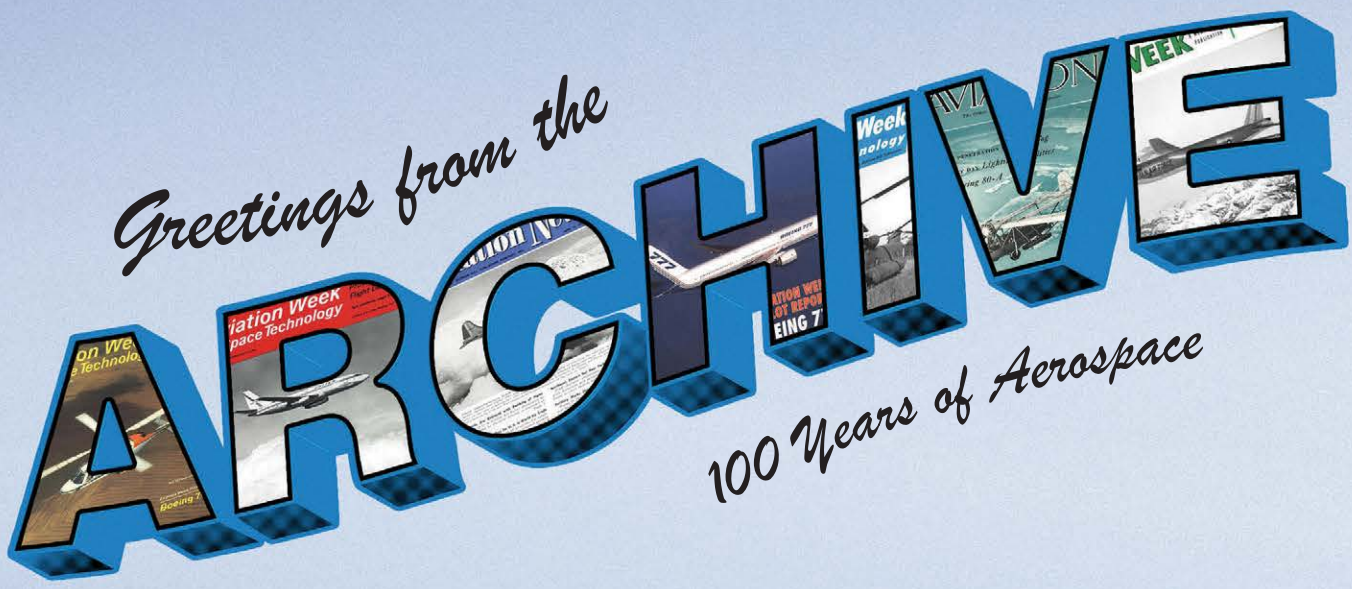

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