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# AVIATION WEEK

## & SPACE TECHNOLOGY

# Quest for Speed

**BOOM XB-1 TAKES SHAPE**



**RICH MEDIA EXCLUSIVE**

**PRIME TIME FOR  
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**Europe's Hydrogen-  
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66  
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*In addition to the airframe, Pipistrel itself developed the motor, battery system, propeller and avionics for the Velis Electro.*

PIPISTREL

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### ON THE COVER

*After many false dawns, new high-speed aircraft and weapon projects are underway in the U.S. Boom Supersonics' XB-1 demonstrator will pave the way for the Mach 2.2 Overture, the first clean-sheet airliner of the 21st century, while heading into faster flight regimes. Our hypersonics special package led by Propulsion Editor Guy Norris and Defense Editor Steve Trimble begins on page 40. Boom Supersonics photo.*

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## Let's Connect!

As the COVID-19 pandemic continues along its devastating path, the aviation and aerospace community is doing everything possible to keep each other safe while moving forward (and increasingly upward). For our part, the Aviation Week Network is supporting the industry with crucial information and data to help navigate the crisis and ultimately recover and grow again.

The demand for trusted, actionable content has exceeded our wildest expectations, and our teams of editors, analysts and event producers have significantly ramped up their efforts to deliver more. We are all proud to be able to help you **know, predict and connect** during this unprecedented time.

There is much, much more to do, and increasingly it will revolve around connecting with each other directly. I don't know about you, but I can't wait to get back on an airplane to interact with peers and customers in a face-to-face environment. For the past 25 years, our event business has been a catalyst for connecting the industry at conferences and tradeshow around the world—from our big MRO shows to SpeedNews, Routes and CAPA Summits.

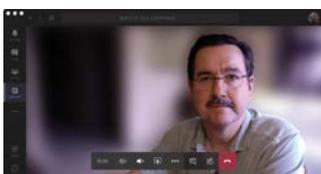
But the sad reality is that face-to-face events will remain “grounded” in the near term, even as the need to network, share information, buy-sell and build relationships grows more intense. For us, that has meant finding new and innovative ways to satisfy the human need to interact:

- Our **webinar series** has topped 80,000 registered viewers, attracting aerospace professionals and senior executives from around the world. These will continue.
- Look for more elaborate **virtual events** that not only include video-delivered content but also digital marketplaces for showcasing products and services and generating leads, with meeting and matchmaking tools and organized networking time. We can't totally emulate the networking of a face-to-face event, but you'll be surprised at how well some of the new tools perform in that regard.
- **Aerospace & Defense Week** (actually spanning two weeks from July 10 to July 24) will continue the industry's mid-year ritual of getting together in Farnborough or Paris to look at the future. Our editors will bring deep new forward-looking content under the theme “Reset – Flight Paths Forward” and present it in multiple digital formats, including interviews with leading aerospace CEOs and Tech Talks.
- **Virtual MRO Asia** will convene airlines, OEMs and suppliers from across Asia and the world to network on a new matchmaking platform and discuss fleet plans, aircraft reentry to service and MRO demands for the short and long term.
- Both events will showcase the newly launched **Aviation Week Marketplace**, an expanded version of our successful MRO Links, now incorporating suppliers and buyers from the aerospace sector. Some 1,000 companies and their products will be featured to create a new, convenient sourcing resource for buyers across the industry.

While we are working on these large digital events—and more in air transport, aerospace and MRO—we are still planning for several face-to-face events in the fall where we have permission from governments and the confidence in a safe and productive environment. You can keep abreast of all of our coming events at [AviationWeek.com](http://AviationWeek.com).

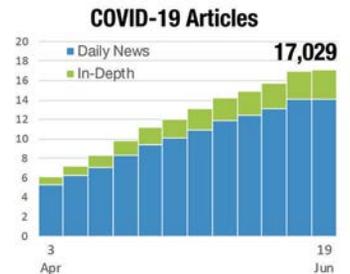
The Aviation Week Network is committed to helping the industry through this crisis as we have so many times in our past 103 years. Since March, we have published more than 17,000 pieces of content, including 2,600 analytical articles, to help show how our industry will deal with and make its way out of this unprecedented crisis.

We're looking forward to the clouds breaking and to connecting with you very soon.



**Greg Hamilton,**  
President, Aviation Week Network

[hamilton@aviationweek.com](mailto:hamilton@aviationweek.com)



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[AviationWeek.com/COVID19](http://AviationWeek.com/COVID19)

## 'MEGAFORTRESS'

While many disagree with converting transport airplanes into Arsenal Planes as a waste of high-demand airframes (*June 15-28, p. 12*), I agree that it will be a valuable stopgap measure until a dedicated design is fielded. Keeping the ability in the arsenal even after a dedicated design enters service—both as a force multiplier providing flexible capability as well as acting as an aircraft-based version of the U.S. Navy's "Distributed Lethality" concept—would keep our enemies guessing as to our intentions and how big our airstrikes would be. As for what aircraft the actual Arsenal Plane will be, we already have one in service: the B-52 Stratofortress. The aircraft can drop a vast majority of our ordnance (and also is used as a mothership for experimental airframes) and carry 70,000 lb. of payload; upgrades to the aircraft will keep it in service for at least 20-30 more years. The only problem with the "BUFF," as it is affectionately called, is that the last airframe rolled off the assembly line in 1962. Maybe an updated design specialized for the Arsenal Plane concept might be called for, possibly incorporating some stealth characteristics like Dale Brown's famous but fictional "EB-52 Megafortress."

*Jacob Katz, Norfolk, Virginia*

## CLEARANCE QUERY

Graham Warwick's Leading Edge column "Load Lifter" (*June 15-28, p. 11*) states that the Kaman "12,000-lb. optionally piloted aircraft [is] expected to be on the market in 2021." The article includes a sketch of the aircraft attributed to Kaman Aerospace.

I hope Kaman has not invested heavily in this aircraft. It appears from the sketch that the two counter-rotating rotors are mounted on individual masts, the right mast being taller to provide clearance between the rotors. It is not clear, however, how the left rotor clears the right mast in its rotation.

*William J. Keck, Rancho Palos Verdes, California*

*Editor's note: It is an intermeshing rotor. The two sets of blades overlap at an angle to each other—intermesh—but rotate in opposite directions and never collide.*

## HOOK AND RECOVERY LINE

In reference to James R. French's letter "Forward-Looking Design" (*June 1-14, p. 6*), the rebound maneuver described in my letter "Revising Rockets" (*May 4-17, p. 5*) uses the least amount of propellant in a retro burn to put the rocket skimming along the top of the atmosphere, where it immediately maneuvers down toward the Earth, rapidly gets to thick enough air to then turn and powerfully maneuver back into space, then it repeats the maneuver with steeper parabolic trajectories. The rocket fuselage would also slowly rotate about its longitudinal axis to prevent hot spots and uneven heating of the structure.

I have tested this with a wooden rod with four hooks around the circumference, to crudely simulate a rocket body, and thrown it approximately 20 ft. horizontally against a slack line strung between two supports, and the "rocket" always engages and remains on the line, even without latches on the hooks.

For a real rocket, the line is slack to prevent any loads on the side of the rocket before engaging the hook. Stretching and straightening of the line and shock absorbers in the towers could provide long deceleration distances to allow high-descent-rate landings, if desired, without overstressing the rocket. After landing, the rocket can't be blown or knocked over by winds or high sea states.

This approach also avoids carrying the weight, cost, complexity and potential failure modes of landing gear up to or near orbital speeds and then back down just to stabilize the rocket on the ground. It also holds the rocket higher above the sea for less salt-water corrosion.

For rapid reusability, this hook-and-recovery-line approach can be used to erect the rocket before launch, transfer passengers to the crew compartment and provide a degree of lightning protection. After landing, it can immediately and automatically move the rocket laterally from over the landing pad and lower it onto a water or ground vehicle for transfer

back to its hangar by reeling in and out the line from the two towers.

*Randy McDonnell, Las Vegas*

## TEACHING 'AERO 101'

Thank you for Sean Broderick's article on the FAA's scrutiny of the Boeing 777X post-MAX (*June 1-14, p. 24*). This is the heavy-artillery approach to certification. One wonders whether Boeing really needed reminding of the disastrous Maneuvering Characteristics



Augmentation System design flaws. But all pilots know that neither MAX accident would have occurred without both crews' appalling ignorance of basic aerodynamics. However, will regulators even ask how widespread this ignorance is? The omens are not good.

Following the lack of skill revealed by the Air France Flight 447 accident, the official response was to mandate upset recovery training. So a crew unable to fly straight and level in adverse circumstances is supposed to execute a complex recovery, probably blind? The fundamentals were never addressed, and likely won't be post-MAX. Is the technical syllabus even adequate? Hardly. Even Aero 101, Lift, as usually taught, is nonsense, never mind stability and control. The whole training establishment needs to take a good hard look at itself—not something we've been very good at in the past.

*Alex Fisher, Chacombe, England*

## CORRECTION

In "Designer-Optimized" (*June 15-28, p. 43*), the name of Dassault Systemes' aerospace and defense industry vice president should have been spelled David Ziegler.

*The article has been corrected online and in the Aviation Week & Space Technology digital archive.*

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

C-390 MILLENNIUM

# READY FOR THE MISSION

It's been a few months since the C-390 MILLENNIUM airlifters started serving the Brazilian Air Force, fulfilling the missions for which they were designed with complete success, and in the coming months more units will join the service. At the same time, the Portuguese Government signed a contract for the acquisition of five units to be operated by the Portuguese Air Force. This is a significant moment in the C-390 MILLENNIUM program, marking its Entry Into Service and the confirmation of the aircraft's operational effectiveness within NATO. The combination of 21st century, state-of-the-art advanced systems and proven engines, in conjunction with a worldwide sustainment alliance of reputable suppliers, makes the C-390 MILLENNIUM the most reliable, easy to operate and efficient aircraft in its class.





**Heidi R. Wood** has been named interim group president of CAE Defense and Security. She takes over from recently appointed Todd

Probert, who is stepping down to pursue a U.S. National Security opportunity.

**Joel Montalbano** has been named NASA's International Space Station program acting manager; he had been deputy program manager. He succeeds Kirk Shireman, who has retired. Kenneth Todd will continue as deputy program manager. Montalbano, who was a NASA human spaceflight program director in Russia in 2008-12, is a recipient of NASA's Distinguished Service and Exceptional Service medals, among other awards.

Embraer has promoted **Arjan Meijer** to Embraer Commercial Aviation president and CEO from chief commercial officer as the company begins its reintegration restructuring. He succeeds John Slattery, who is leaving. Meijer's previous executive roles include vice president of technical services and fleet development at KLM Cityhopper and managing director at KLM UK Engineering.



**Anand Stanley** has been promoted to president of Airbus Asia-Pacific. He succeeds Patrick de Castelbajac. Stanley

will lead commercial aircraft sales, customer and government affairs, industrial and joint-venture partnerships and local operations and will liaise with the Airbus Helicopters and Defense and Space divisions. He was Airbus India president and managing director and held senior positions at Linde Group, United Technologies Corp., Pratt & Whitney, Lockheed Martin and Sikorsky.

Redwire, a new mission-critical space-components technology entity, has named **Peter Cannito** chairman and CEO. Redwire was launched through AE Industrial Partners' merger of Adcole Space and Deep Space Systems. Cannito brings more than 25 years of experience in defense, technology and government services industries.

Gulfstream Aerospace has promoted **Naveed Aziz** to vice president and general manager of the Gulfstream Dallas facility. He will oversee service center operations and Gulfstream G280 completions. He succeeds Robby Harless, who retires this month. Aziz was director of completions research and development.



Vertical Aerospace has appointed **Dean Moore** lead flight-test engineer for its first electronic aircraft to be certified. Moore

was UK lead flight-test engineer at Boeing and has spent time generating and implementing safety cases for a range of autonomous vehicles. He flew the first UK Chinook.

**Wan Zulkiflee**, former CEO of Malaysian petroleum company Petronas, has been named board chairman of *Malaysia Airlines Berhad*. The position had been vacant since Mohammed Nor Yusof resigned in March 2019.

Raytheon Technologies has promoted **Dantaya Williams** to chief human resources officer.



Williams succeeds Doug Balsbough, who guided HR functions through the Raytheon-United Technologies Corp. merger and is now retiring. Williams was vice president of human resources for Pratt & Whitney's Commercial Engines division.

AeroVironment has promoted **Ken Karklin** to chief operating officer from senior vice president. He will oversee product line management, engineering, manufacturing and corporate quality for the producer of unmanned aerial systems. Karklin was AeroVironment's vice president and general manager of Efficient Energy Systems.

The Atlantic Council has named **Christopher Preble** co-director of the New American Engagement Initiative, a Scowcroft Center for Strategy

and Security program. Preble, with co-director **Mathew Burrows**, will examine initiatives to challenge assumptions governing U.S. foreign policy and will provide input for recalibrating U.S. foreign policy.



Rotterdam-based APOC Aviation has promoted **Karim Grinate** to vice president of component sales from manager of sales and business development.

Liteye Systems has hired **Matt Pflieger** as vice president of finance. Pflieger had worked with L3, SAIC and CACI.

Exyn Technologies, a pioneer in autonomous aerial robotics, has named **Katharina McFarland** to its board. She will address Exyn Technologies' deployment of flying disinfecting robots for government structures. McFarland is a former assistant secretary of defense for acquisition; former acting assistant secretary of the Army for acquisition, logistics and technology; and a materials, mechanical, civil and electronics engineer.



Leviat Air Group has hired **Chad Beaulieu** as managing partner of aircraft sales and **Eric Dufay** as vice president of fleet sales for the Dallas-based carrier. Beaulieu has 20 years of sales experience with Bombardier and Gulfstream. Dufay is an air charter veteran of over 10 years.

The Asian Business Aviation Association has appointed **Anthony Lam** director of marketing and external affairs, a new internal position. Lam was editor-in-chief of JET Asia-Pacific magazine. He is an FAA-licensed fixed- and rotary-wing pilot and a former member of the National Transportation Safety Board's aviation accident investigative team. ✎



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# FIRST TAKE

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## COMMERCIAL AVIATION

**France and Germany have committed billions of euros in financial aid for aerospace companies, with France defining an ambitious road map to a carbon-neutral narrowbody aircraft to enter service by 2035 (page 16).**

**Boeing told prime 737 supplier Spirit AeroSystems to cut production to 72 shipsets this year—including 35 already delivered. The figure, down from a target of 125 just a few weeks earlier, cites the COVID-19 crisis and a growing inventory of undelivered 737 MAXs.**

EMBRAER

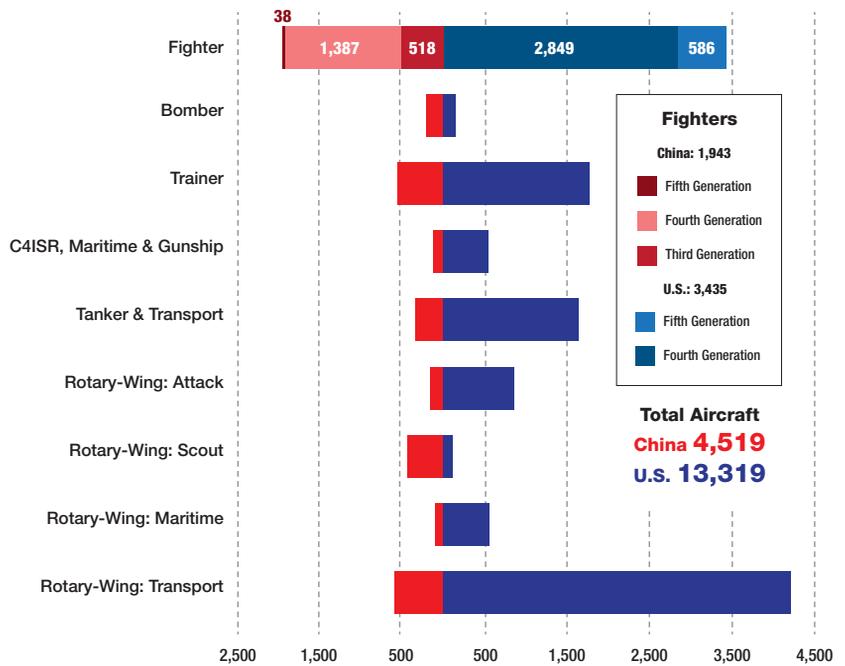


**John Slattery**, who led Embraer's Commercial Aviation business since 2016, will become CEO of commercial and military aircraft engine giant GE Aviation on Sept. 1, replacing

David Joyce, who will retire.

**A California startup** that is working with Boom Supersonic to develop a carbon-neutral fuel for future high-speed airliners has received an investment from the venture capital arm of

## Military Aircraft Snapshot China vs. the U.S.



Source: Daniel Urchick and Michael Tint/Aviation Week Intelligence Network

The U.S. military operates about three times as many manned aircraft as the Chinese military—the ratio is not even across all types of aircraft. The U.S. possesses especially large advantages in rotary-wing aircraft (4.3:1); tankers and transports (4.8:1); and command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) platforms (4.1:1). While China's fleet of fighters is closer in size, the U.S. has a considerable qualitative edge in combat aircraft.



For more information about Fleet Discovery and other Aviation Week data products, go to [aviationweek.com/products/fleet-discovery-military](http://aviationweek.com/products/fleet-discovery-military)

BMW. Prometheus Fuels has developed a process to capture CO<sub>2</sub> from the air and convert it to liquid fuels

using renewable electricity, at prices competitive with fossil fuels (page 56).

**Airbus has completed** the first fully autonomous vision-based taxi, takeoff and landing by an A350, completing a two-year project to demonstrate fully automatic takeoff and landing using onboard image-recognition technology (page 36).

**A new study by a team of U.S.** universities found that boarding from the rear of an aircraft creates bottlenecks that put passengers at a higher risk of contracting COVID-19 than random boarding.

**The European Commission and Lufthansa** shareholders approved a €9 billion (\$10.1 billion) bailout for Lufthansa, enabling the carrier to avoid bankruptcy and giving the German government a 20% ownership stake in the airline.

## DEFENSE

**The U.S. Navy on June 22 delivered** the first Bell Boeing CMV-22 Osprey to an operational squadron at NAS North

## VIEW FROM WASHINGTON

### DOD Research Chief, Deputy Resign

After three years as the Pentagon's chief technology officer, Michael Griffin, and his deputy, Lisa Porter, will step down from their respective roles on July 10. They plan to set up a private venture.

In 2017, Griffin was brought in as the undersecretary of research and engineering at the Office of the Secretary of Defense. Congress had recently elevated the role. During his tenure, Griffin placed a high priority on development of hypersonic weapons.

Griffin previously served as the NASA administrator as well as space department head at the Johns Hopkins University Applied Physics Laboratory. He held numerous executive positions in industry, including In-Q-Tel president and chief operating officer. Porter was an In-Q-Tel executive vice president and the director of IQT Labs. She was the first Intelligence Advanced Research Projects Activity director in the Office of the Director of National Intelligence.

Island in San Diego, keeping the tiltrotor aircraft on track to make its first carrier deployment in 2021.

**The UK Royal Navy has declared** an initial operating capability for its amphibious assault fleet of triple-engine Merlin Mk. 4 transport helicopters. The UK Commando Helicopter Force now has 13 Merlin Mk. 4s available after modifications by Leonardo Helicopters.

**A House panel voted** to allow the U.S. Air Force to keep fewer B-1 bombers in its inventory and slow production of Boeing's tanker from 15 to 12 until deficiencies are corrected in a draft version of the 2021 Defense Authorization bill.

**Britain's seventh front-line Eurofighter Typhoon unit**, its first joint unit with Qatar's Amiri/Emiri Air Force, has begun flight operations. The unit is the Royal Air Force's first multinational fighter squadron since World War II and will support security operations for soccer's 2022 FIFA World Cup tournament.

**The U.S. Air Force has delivered** General Atomics' MQ-9 Reaper medium-altitude, long-endurance unmanned air systems to Estonia, the first deployment of the platform to a Baltic nation.

**The European Commission awarded** €205 million (\$230 million) in research and development funds to 16 multinational defense projects that include: development of a low-observable tactical unmanned air system, research into high-resolution observation payloads for satellites and work on a detect-and-avoid system for the future EuroDrone air system.



**Boeing delivered the first F/A-18E/F Block III** to the U.S. Navy to launch a yearlong testing campaign on a new configuration with around a \$60 million flyaway cost that is currently being offered to five foreign air forces.

**SPACE**  
**Chinese scientists have taken** a large step toward a theoretically secure communication technology, demonstrating

quantum key distribution between ground stations via a satellite.

**Virgin Galactic will develop** a training program for private astronaut missions to the International Space Station (ISS). An agreement with NASA also includes management of supporting ground and flight resources to transport astronauts to the ISS for privately organized missions and government-enabled research.

**After an 11-week hiatus** due to the COVID-19 pandemic, Rocket Lab resumed launch operations on June 13 by successfully launching a payload of small satellites into low Earth orbit for NASA, the U.S. National Reconnaissance Office and the University of New South Wales Canberra Space.

**GENERAL AVIATION**  
**Textron will cut 1,950 positions** at its aviation, simulation and training, and industrial divisions due to the COVID-19 pandemic, reducing its workforce by 6%.

**Gulfstream took its last G550 order** as it winds down production of the large-cabin, ultra-long-range business jet. More than 600 G550s have been sold since certification in 2003.

## 50 YEARS AGO IN AVIATION WEEK

**This week's special report** on hypersonics (page 40) is the latest in a long line of Aviation Week articles about the atmospheric speed regime above Mach 5. A half century ago, our June 22, 1970, edition featured a six-page report on the potential of hypersonic transport, among other high-speed projects. While still in their infancy, hypersonic studies were already active across realms ranging from reusable reentry vehicles and missiles to piloted interceptors and even passenger aircraft. The DNA of today's hypersonic glide vehicle and air-breathing missile developments, as well as the genesis of the space shuttle, are embedded in these updates about high-speed aerodynamics, high-temperature materials and advanced propulsion. While unapologetically U.S.-centric in its coverage, the 1970 report reflected America's clear lead in hypersonics and high-speed flight research. Today, that position is severely compromised.

The report is also a reminder of the old joke: "Hypersonics are the future and always will be." References are made to an ambitious hydrogen-powered Mach 10 passenger vehicle concept from Douglas Aircraft called DC-2000, after the year in which the company thought it might be ready for prime time. Sadly, neither the concept nor the company existed by the 20th century's end. Another story notes that "even if ramjet-powered, hypersonic transports prove to be practical, many aeronautical researchers in government



and industry believe it will be at least 1990, and probably closer to the year 2000, before such a vehicle makes its appearance."

The archive pages provide a valuable backdrop against which the achievements of programs such as the space shuttle, X-43 and X-51 can be better appreciated. They also are a sobering reminder of the huge hurdles still facing the hypersonic community as it prepares to field the first generation of Mach 5-plus weapons and, further off, continues to pursue bigger vehicles for military and commercial roles and ultimately access to space.

Subscribers can access our 1970 report on high-speed transport and every edition back to 1916 at: [archive.aviationweek.com](https://archive.aviationweek.com)

## UP FRONT

## RICHARD ABOULAFIA



**FOR DECADES, WHEN ASKED IF** China's Comac will challenge Airbus and Boeing in world jetliner markets, analysts like me have been skeptical. Most

(but not all) of us pointed to the enormous challenges confronting any emerging jetmaker, and to China's lack of progress on a very long road. For years, I've written on the topic in Aviation Week and elsewhere, concluding that Airbus and Boeing really don't need to lose any sleep about Comac.

But what if we've been reading Comac, and China, incorrectly? What if global aviation competition is secondary or irrelevant for them? What if their real objective is to create acceptable substitutes for West-

## China's Jetliners

Not competitors: **Substitutes**

ern equipment after both sides turn their back on a robust trade relationship? Worse still, what if that moment has arrived?

Aircraft play a key role in China's trade with the West. As trade grew and supply chains were interlinked, China enjoyed strong trade surpluses. One way to help make that palatable to Western countries was to play up high-profile jetliner orders, for which the Chinese government always took credit, even when it actually came from individual airlines. At its peak in 2018, the U.S.-China aerospace trade balance stood at a remarkable 17-1, with Europe enjoying similar success thanks to Airbus and its suppliers.

Yet China and the West are quickly reversing this process with what's known as the Great Decoupling, a move away from trade relationships. Trade flows are slowing, and foreign direct investment between the U.S. and China has fallen precipitously. As Aviation Week has reported, the past few years have seen a serious decline in U.S.-China aviation industry investment.

The COVID-19 pandemic has accelerated this process. One of the most experienced China watchers, Orville Schell, this month went so far as to declare U.S.-China engagement dead. As recent events show, even U.S.-China direct airline links are at risk.

Meanwhile, President Xi Jinping's Made in China 2025 strategy is designed to transform the economy from low-cost manufacturing to high-tech creation, but it also emphasizes import substitution. In some ways, it has yielded impressive results. China's tech sector is large and growing, and Western companies like Google, Facebook and Twitter have no presence.

Aviation, unsurprisingly, has been the biggest challenge. China flew its first national jet, a 707 knockoff, in the 1970s. Since then, just a handful of locally created aircraft have been produced, with no exports except for a handful of unreliable turboprops. But the Chinese government, through Comac, presses on. In a few

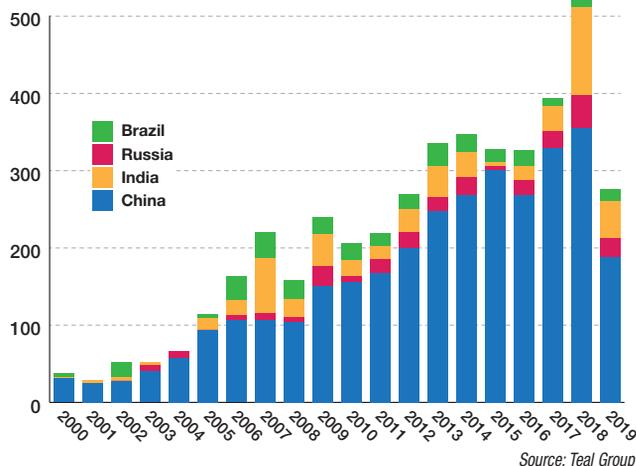
years, the C919 will enter service, followed, in theory, by the Sino-Russian CRJ929 widebody.

If China closes its borders to jetliner imports, these aircraft will enjoy very solid production runs, even if they are merely copies of jets that entered service 10-20 years before. They will have no chance in export markets, except perhaps as a form of foreign aid.

This process will look a bit like China's regional aviation sector. China hasn't imported a regional jet in about five years. Instead, deliveries of Comac's ARJ21 have slowly begun. This design is overweight, technologically obsolete and around a decade late to market. It has no hope whatsoever in export markets. But for domestic purposes, it will do, as long as China's airlines are forbidden from ordering better aircraft.

This process will also look like the old Soviet Union. The Soviets built local, inferior alternatives to many

BRIC Aircraft Deliveries: All About China



Western jets, from the Boeing 727 (Tupolev Tu-154) to the Concorde (Tupolev Tu-144).

For Western suppliers, losing China, the biggest jetliner export market, would be a serious blow. China took just 2% of global jetliner output in 2001 but rose steadily, to 23% in 2018. As our chart shows, the other emerging markets show no sign of gearing up to China's level of demand. The only consolation is that the C919 won't be ready for any 2023-24 market recovery. For Airbus and Boeing, China is probably good for one last hurrah.

But all industries dependent on the China market might want to pay close attention to the country's aviation plans. Once they close the borders to Western jets in favor of their own planes, one of the last arguments for free trade with China will vanish. In other words, the C919 will play an outsized role in determining what happens next between China and the West. 🇨🇳

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



## GOING CONCERNS

# MICHAEL BRUNO

**DON'T LOOK NOW, BUT THE** “Bank of Boeing” is back in business.

On June 11, the U.S. Export-Import Bank (EXIM) revealed two new insurance coverage deals that—subject to Congress not stopping them—allegedly would support an estimated 14,200 jobs at Boeing, General Electric and their respective suppliers.

In the first, EXIM says it will guarantee \$459 million, or 90%, of a \$510 million loan for Credit Agricole to purchase accounts receivable from CFM International—a 50-50 joint venture between GE Aviation and

## Boeing's Bank Is Back

**EXIM support for Boeing and GE makes sense**

Safran Aircraft Engines—that are due from Boeing.

The planned one-year purchase facility, in turn, would support an estimated \$3 billion in export sales of aircraft engines and an estimated 11,200 direct and indirect jobs throughout the U.S. supply chain, including 1,180 CFM/GE positions across Indiana, North Carolina and Ohio, according to EXIM.

“The proposed financing support is needed due to the current lack of capacity among commercial banks and heightened risk associated with the aircraft manufacturing industry resulting from the COVID-19 pandemic and global economic conditions,” the U.S. credit export agency says. The deal will further boost liquidity for CFM/GE and its suppliers.

In a separate, second proposed transaction, EXIM would provide a loan guarantee of up to \$498 million for Turkish Airlines to buy Boeing aircraft with GE Aviation engines. This move would support around 3,000 jobs across the U.S., the bank asserts.

The bank once again attributed the need for the loan to COVID-19 and industry conditions. “EXIM financing is also needed to meet competition from foreign, officially sponsored export credit financing from Germany, France and the UK,” EXIM adds.

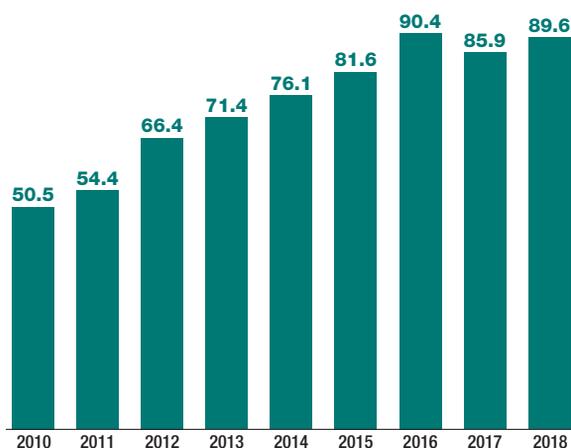
The guaranteed financing for Credit Agricole is supposed to be repaid over 12 months. The financing for Turkish Airlines would be repaid over 12 years in 48 quarterly installments of principal, with interest in arrears, following delivery of the aircraft. Both proposed transactions are supposed to generate “millions of dollars” in fees for EXIM. The announcements start a 35-day congressional notification period, and the public can weigh in on the transactions through the Federal Register.

Will Washington hear an earful? It might. According to bank haters, Boeing and GE are the same blue-chip corporate welfare recipients of federal largesse that gave EXIM a bad name in the first place. For a generation of Republican tea party lawmakers, the taxpayer-backed EXIM was the epitome of crony capitalism.

Work by antibank academics at George Mason University's Mercatus Center shows far more loan support going to Boeing than small and medium enterprises when it was business as usual.

What is more, tea partiers supported President Donald Trump's 2016 election, and he campaigned against EXIM. One of their own, former Rep. Mark Meadows (R-N.C.), is now a close advisor inside the White House. So how could this happen? How could Boeing and GE be back basking in the shade of EXIM's umbrella? And in a presidential election year, no less?

**Total U.S. A&D Trade Balance**  
(U.S. \$ billion)



Source: Aerospace Industries Association

Because it is the right thing to do. Credit is due, and Trump deserves praise for flip-flopping, for keeping the bank alive and unleashing EXIM to do what it does best: promoting U.S. aerospace exports by supporting OEM sales. Indeed, Democrats and moderate Republicans alike have fought all these years to maintain EXIM precisely for today's circumstances, when another recession threatens to gut aerospace and defense (A&D), the largest U.S. exporting sector.

“By advancing these transactions today, EXIM continues to deliver on our mission to support U.S.-based jobs,” says bank board member Spencer Bachus III. “This is especially important as we deal with the effects of COVID-19. With EXIM backing, over 14,000 Americans nationwide will continue to work and be able to provide for themselves and their families.”

EXIM President and Chairman Kimberly Reed, echoes Bachus' sentiment: “EXIM is needed now more than ever, and we will continue our important work to support American jobs by facilitating exports.”

Whether there is a new recognition of government's role in promoting and protecting the A&D sector remains to be seen, but at least ideology did not overcome good sense here. Waffling politicians usually are nothing to celebrate, but this time, Trump was right on the money. 🗳️



## INSIDE BUSINESS AVIATION

# WILLIAM GARVEY

**ITS PROMISE OF BEING THE** “lowest, slowest” jet was unorthodox. Its reliance on a single engine and single pilot seemed dubious. And the fact that its manufacturer had never produced an aircraft with retractable gear, let alone a pressurized one with turbofan power, made the whole enterprise a reach. Finally, the project’s launch year—2006—could hardly have been worse, with the Great Recession about to choke the roaring economy to a whimper.

Fast-forward 14 years, and Cirrus Aircraft has proved to be as prescient as it was persistent since its SF50 Vision Jet—the world’s first “personal jet”—has become as popular as it is unique. And that singularity very much includes pricing: Its \$2.85 million sticker (typically equipped, type rating included) is roughly \$1.5 million less than the least expensive light jet, and even well below most pressurized, single-engine turboprops.

The journey to this happy place was not without setbacks. Foremost among those was the aforementioned recession that essentially slowed aircraft development to a crawl and ultimately resulted in the company changing hands.

In 2011, a subsidiary of the Aviation Industry Corp. of China (Avic) offered \$210 million for the Duluth, Minnesota, manufacturer. Cirrus’ then-Bahrainian owners readily accepted the deal, and Avic soon announced plans to revitalize the jet project.

Although there had been excitement in the early 2000s about the very light jet segment coming of age, the promise of the Sport Jet, ProJet, AdamJet, Safire Jet, D-Jet, PiperJet, among others, essentially went *poof!* The Eclipse 500 did earn its certification and entered into production, but after a series of financial reversals, by 2018, it was done.

Meanwhile, the Chinese invested heavily in the Vision Jet’s development and flight testing. In October 2016, the aircraft was awarded a Federal Aviation Regulation Part 23 Type Certificate. Cirrus delivered its first customer jet two months later. Since then, it has delivered another 200 and expects to produce 80 this year, essentially matching 2019 output despite being slowed by the coronavirus pandemic. By unit count, the SF50 is the most popular private jet in production today. And there are another 400 of them in the orderbook.

What’s the appeal? Price, obviously, but the draw goes well beyond that. When Cirrus began the project, its target buyers were owners of its popular SR series of single-engine piston aircraft. Accordingly,

its designers took cues from those aircraft to ease the transition. So, like its piston siblings, the SF50 has composite construction, sidestick controls, excellent visibility and a five-screen Garmin avionics flight deck. Although similar to a Beechcraft Baron in length and wingspan, the SF50’s 5.1-ft.-wide, 4-ft.-high, air-conditioned, flat-floor, USB-ported, LED-lit cabin can comfortably accommodate five passengers.

The aircraft is propelled by a Williams International FJ33-5 turbofan rated at 1,846 lb. of thrust and fitted with a full authority digital engine control. It provides a top cruise speed of just over 300 KTAS (345 mph). With seats full, the aircraft can fly 461 nm, with reserves, and can cover 1,171 nm with maximum fuel.

CIRRUS AIRCRAFT



## Winning Underperformer

**Perseverance, prescience and pluck prevail**

One of the manufacturer’s signature moves from the outset was to equip its aircraft with an emergency parachute. And the SF50 is no exception; the Cirrus Aircraft Parachute System comes standard. None has been activated on an SF50.

Another Cirrus trait is to regularly make product improvements. So just 15 months after SF50 production began, the compa-

ny introduced the G2 Vision Jet. This second-generation version has increased cruise altitude by 3,000 ft., to 31,000 ft., provides a quieter cabin, more powerful avionics, a radio altimeter and an autothrottle. The digital equipage is key to another new feature: “Safe Return,” the autonomous landing system created by Garmin that in an emergency anyone onboard can activate with the push of a button. That system is expected to be certified in the aircraft later this year.

As intended, a significant majority of SF50 buyers are moving up from Cirrus piston models. But among the owners of the 200 SF50s already on the market are several charter operators as well as businesses. Hoping to increase its share, Cirrus has launched “Smart Lift,” a website tutorial intended to educate and encourage business aviation flight departments to supplement their fleets with a Vision Jet as a low-cost, responsive regional people mover.

In an Operators Survey published in the January 2020 issue of *Business & Commercial Aviation*, owners gave the aircraft high marks for its comfort, excellent visibility, reliability, handling ease, advanced avionics, safety features and Cirrus product support.

Turns out that low, slow, inexpensive and reliable make for a winning combination. ☺

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



## AIRLINE INTEL

# JENS FLOTTAU

**IN JUNE, AIRLINES HAVE BEGUN** what they hope is a path to recovery as capacity in many regions has increased to more meaningful levels. Executives

are hoping that passengers will react to the return of some offerings and resume flying in numbers significant enough to reduce the dramatic cash outflow occurring in what would normally be peak season.

One of the most important factors is the trust that flying is safe. Passengers want to know they are unlikely to be infected with the novel coronavirus during the journey. The International Civil Aviation Organization has defined guidelines for resuming flying safely without quarantines and without forcing airlines to leave the middle seat empty.

Airlines have largely gotten it their way. Regulations are making flying a little more inconvenient for passengers. Wearing a face mask for hours may be unpleasant, but it is bearable and will not keep many from making necessary business trips or families from vacationing if all the other steps in the process are adhered to properly.

Disclaimer: Some of the following conclusions are based on four intra-European flights during the week of June 15 and conversations with other travelers. They are not reflective of anywhere near a complete picture, but they paint one that is concerning enough to write about.

The first problem is that a substantial number of passengers are not abiding by the new rules. Many who have started flying again will confirm that social-distancing rules at airports are often not being followed. The distancing may work at security lines, but the usual chaos typically ensues during boarding. Moreover, while face masks are mandatory, all too often people ignore the requirement.

The second problem is a lack of strict rules reinforcement. Airline staff and automated announcements remind people that the crisis is not over and that certain behaviors are expected. It is not surprising that after weeks or months in lockdown many are weary of limitations. Passengers are not paying attention to the rules, and staff are not reinforcing rules enough—if they did, boarding time would likely be excessive. But for aviation to start a recovery in earnest, discipline is crucial.

Airlines also have been vocal in the public debate around the air inside cabins and the use of high-

efficiency particulate air (HEPA) filters onboard. Doing everything to promote the idea that flying is safe is understandable: Airlines have a high interest in regaining passenger confidence. But to compare an airline cabin to an operating room is misleading.

Additionally, HEPA filters only work throughout the journey when the air conditioning system has been turned on prior to boarding—based on evidence, that is not (yet) the case on every flight in spite of the promise by industry to introduce new procedures.

“The air quality inside an aircraft is comparable to that of an operating theater when 200 people stand around the operating table watching,” says Dieter Scholz, a professor and head of the aircraft design and systems group at HAW Hamburg University.

This leads to another crucial question: Should the middle seat be left empty? Airlines have approached the issue in different ways. Delta Air Lines has been the clearest, leaving the seat free for now as long as load factors permit. The International Air Transport Association says the seat vacancy does “not

add any healthy benefit,” so it is “strongly opposed” to making empty seats mandatory.

HEPA filters may be as efficient as airlines claim, but they do not prevent you from being infected by your immediate seat neighbor in a full cabin. To compensate for the lack of spacing, FFP2 masks would be required. But given insufficient supply and the fact that the equipment is supposed to be reserved for medical personal, regulators such as the European Union Aviation Safety Agency recommend passengers use medical face masks one tier below the FFP2 standard. Passengers are not even using these—opting instead for the types of masks used for shopping.

However one looks at COVID-19 and flying, the risk of being infected, though small, is certainly not zero. Scholz calculates that it is 10 times more likely for someone to get the virus onboard than to be involved in an aircraft accident.

There are many legitimate reasons for flying to resume; there are also many legitimate reasons to be concerned. The decision is one individual travelers have to make themselves. But industry must implement rules and processes more forcefully, be transparent about the remaining risks and not be caught making questionable claims. There is more work to do. 🌐

## Filtered Truth

The industry’s response to **COVID-19 health protection** challenges is inadequate



ELEONORE SENS/AFP/GETTY IMAGES

# INTO THE HYDROGEN FUTURE



- > HYDROGEN-POWERED AIRBUS A320 REPLACEMENT PREDICTED FOR 2035
- > MASSIVE FINANCIAL AID ALLOTTED TO SAVE AEROSPACE COMPANIES

**Thierry Dubois** Lyon, **Jens Flottau** Frankfurt and **Graham Warwick** Washington

**F**or decades, research on hydrogen-powered aircraft has remained at the embryonic stage. The year of the COVID-19 pandemic—2020—may be the moment when the use of such fuel is firmly chosen for the future of commercial aviation.

As a response to the brutal downturn the coronavirus pandemic has caused in the aviation sector, the French government announced on June 9 an €8 billion (\$9 billion) bailout plan that notably sets an ambitious environmental goal by requiring OEMs to develop a hydrogen-powered aircraft in a dozen years. Germany has an unrelated bailout plan that also supports hydrogen-fueled propulsion.

In addition to supporting activity in design offices, both approaches are intended to save employees from layoffs and aerospace companies from bankruptcy. In France, the bailout is designed to force an overdue consolidation and modernization of the supply chain. The French deal essentially looks like financial support to survive the crisis in exchange for a spectacular acceleration in the greening of civil air transport.

That environmental angle may be the most far-reaching for the global aerospace industry, if the French government's road map materializes. Europe's commercial aerospace products have roughly a 50% share of the global market, and France and Germany play a leading role in European civil aeronautics. Therefore, their efforts may result in new standards.

The French government will fund a research and development (R&D) plan with €1.5 billion over three years, including a contribution from the European Commission's economic stimulus plan. The French Council for Civil Aeronautics Research will manage the funding. While the amount is



**Using hydrogen in aviation, such as in the European Mahepa project, may involve a fuel cell for better efficiency.**

H2FLY

well below the €10-15 billion usually needed for a new aircraft program, it is a welcome activation at a critical time, notes Marc Durance, a partner at Archery Strategy Consulting.

The German government is investing €7 billion into what it calls its “national hydrogen strategy.” It specifically says it will support the use of hydrogen in aircraft propulsion and hybrid-electric flying. The endeavor is consistent with the European Commission’s plan, announced this March, to launch a Clean Hydrogen Alliance as a centerpiece of a new strategy to accelerate both the decarbonization and digitalization of the region’s industries (*AW&ST* April 6-19, p. 42).

In Germany, the government is also considering a mandatory power-to-liquid ratio in aviation fuel (the process would use sunlight as the power source to convert CO<sub>2</sub> and water into jet fuel), though that plan is not firmed up.

Another €1 billion is allocated to a fund supporting research activities that would otherwise have to be abandoned. It is not limited to aerospace, but executives believe a relatively large portion of the money could end up being used for the industry.

The French ministers’ wording suggests OEMs have committed to launching a major ecological effort in return for funding that will help keep engineers busy in design offices. They will work on a further, significant cut in CO<sub>2</sub> emissions for relatively conventional aircraft. They also are being asked to design a hydrogen-powered aircraft.

First, an Airbus A320 replacement will be designed to enter service in the early 2030s, says Bruno Le Maire, France’s minister of economy and finance. It will feature a 30% reduction in fuel consumption, thanks to ultra-high-bypass turbofans and improved airframe-engine integration. Five preliminary research projects are scheduled to start this year for the fan module, which is targeting a 20-25 bypass ratio (up from the CFM Leap’s 12).

Another research program, called Majestic, is to study a high-aspect-ratio wing, including control surfaces, that could contribute a 5% fuel-burn reduction.

In parallel, a hydrogen-powered narrowbody aircraft will be developed for entry into service in 2033-35. The government describes it as a zero-CO<sub>2</sub>-emission aircraft. A demonstrator should fly as early as 2026-28.

A New regional aircraft, either hybrid electric or hydrogen-powered, should enter into service in 2030.

Airbus has yet to announce a choice between burning hydrogen in a turbine engine or installing a fuel cell in the fuselage. The latter is usually seen as the most efficient use of hydrogen. “We don’t know yet,” Airbus CEO Guillaume Faury says when asked about the two different approaches and which one the company prefers. “They probably don’t have the same time frame, not the same complexity, not the same investment. That’s why today we say that we look at different routes. We accelerate [the process] by looking at all of them at the same time.”

The company is to tap ArianeGroup for its expertise in hydrogen for space launcher applications. The Hyperion research program will assess risks for hydrogen aircraft propulsion, including the cryogenic system. This suggests Airbus is considering liquid, as opposed to compressed, hydrogen—the former means of storage looks more suited to aviation’s need for energy density but is more challenging both in technology and efficiency.

Faury points out that the French aerospace program “is designed to prepare the launch of a new plane at a later stage with a package of technologies that does not exist today and that we need to develop and mature.” He adds: “What will be the first program is not decided. It is not unlikely that it will be a smaller plane and not a wide-body because the technologies will probably mature [faster] for shorter distances than for long ranges.”

Faury agrees with the government’s assumptions that entry into service of the first hydrocarbon-fuel-free aircraft by 2035 is “reasonable.” It would mean a program launch in 2027 or 2028. “We have to have completed maturity of the technologies by 2025,” he says. “Then you have two years for the preparation of the launch, consulting the suppliers, defining the general architecture, doing the business case.”

Still, for now, Airbus’ level of commitment appears to be more on the level of research and technology rather than the concrete programs that the government has firmly in mind. A company executive says the talks have only been about demonstrators. “We are studying different technological avenues at the moment, including hydrogen,” the spokesperson adds.

The schedule looks consistent with the road map of the Clean Sky joint undertaking released last year. A bid for a follow-on Clean Sky 3 project in Europe, it emphasized the need to have green aircraft joining fleets in 2035 if CO<sub>2</sub> emission reduction objectives are to be met in 2050.

A new independent study commissioned by the Clean Sky 2 and Fuel Cells & Hydrogen 2 Joint Undertaking comes to the conclusion that “novel and disruptive aircraft, aero-engine and systems innovations in combination with hydrogen technologies can help to reduce the global warming effect of flying by 50-90%.”

The study found that hydrogen could “feasibly power aircraft with entry into service by 2035 for short-range aircraft.” This was the case with hydrogen as a primary propulsion source either for fuel cells, burning in gas turbine engines or “as a building block for synthetic liquid fuels.”

According to calculations, hydrogen power would cost less than €18 extra per person on a short-range flight. Therefore hydrogen “could play a central role in the future mix of aircraft and propulsion technologies.”

Developing infrastructure, regulation and certification standards for safe hydrogen-powered aircraft will take “10 to 15 years.” With the necessary investment in research, the first demonstrator could be ready by 2028, according to the study.

By contrast, the paper also concludes: “For the next decades, long-haul air travel is likely to be based on liquid hydrocarbon fuels. But increasingly these, too, will need to be sustainable and these drop-in fuels will also rely on hydrogen for their production.”

“The results of the study are clear on the huge potential of hydrogen in aviation,” says Bart Biebuyck, executive director of the Fuel Cells & Hydrogen 2 Joint Undertaking. “The cost of producing clean hydrogen has come down in recent years, thanks to cheaper renewable electricity and bigger and cheaper production technology. At the same time, fuel cell performance in terms of durability, capacity and cost has made big steps forward.”

Massive investment of resources into the design of environmentally friendly aircraft may force competitors to follow suit.

Hydrogen propulsion is “something that we were looking at,” says NASA Administrator Jim Bridenstine. “It’s definitely a capability that we are interested in and continue to monitor. We don’t have big investments necessarily in hydrogen right now, but that’s not to say that we couldn’t [make them] in the future if it looked promising.”

Bridenstine stresses that it is “important to keep that R&D funding going.” He adds: “We need to use this moment, as an agency and as a nation, as a leadership opportunity to actually move ahead. And not use it as an opportunity to fall behind.

“And if you look at the investment from France, that’s what they are



A. PECCH/ARBUS

### For an Airbus A320 replacement, the French government envisages both ultra-high-bypass-ratio turbofans and hydrogen-based propulsion.

intending to do,” Bridenstine points out. “We are seeing a lot of industry being affected right now, and I would encourage them to not give up. Now is the time to make the investments for the transformational leap-ahead technologies that will keep [the] U.S. preeminent in aeronautics.”

Meanwhile, the French and German governments are striving to prevent companies from going belly-up and jobs from being cut.

In France, the sector is reckoned to employ 300,000 (directly or indirectly), one-third of whom would have been threatened over the next six months if nothing were done, according to Le Maire.

Not appearing in the €8 billion, although crucial, is the promised two-year extension of the short time scheme created to mitigate the crisis. Germany also offers short time schedules.

Extended in France also is a program for companies to resort to state-backed loans. They amount to €1.5 billion thus far in aerospace.

To support exports, the government has decided to allow aircraft buyers to suspend capital repayments for 12 months. The idea is intended to prevent defaults for which France’s export credit agency would have to pay the lender. Moreover, a new customer may wait for 18 months instead of six before beginning repayments. These two measures account for €3.5 billion, says Le Maire.

To support ailing small and mid-size enterprises (SME), a dedicated fund will be formed this summer. It will help those SMEs that need equity capital and may be instrumental in the overdue consolidation of the supply chain.

It will start with €500 million—€200 million from the state, €200 million from

the “big four” in the country—Airbus, Dassault, Safran and Thales—and €100 million from the manager of the fund. A request for proposals is about to be issued to find a fund manager.

The fund will raise an equivalent amount, bringing the total to €1 billion, says Le Maire.

The creation of such a financial partnership will be the first time the big four have pooled resources to support the industry as a whole, which reinforces the cohesion of the industry.

The CFE-CGC labor union, however, fears that not every company will be saved. The most vulnerable companies may fail before they have a chance to get any of the money, says Francoise Vallin, coordinator of the union for Airbus. Moreover, the GIFAS lobbying group, which has negotiated the bailout with the government, may have already quietly chosen to support some key aircraft-part suppliers, as opposed to engineering service providers, she suggests.

In Germany, the economic stabilization fund, a tool established earlier to provide financing for companies with urgent liquidity needs, is open to the aviation sector, including small suppliers.

In France, a second fund, allocated €300 million of subsidies over three years, will focus on SME modernization. French SMEs are seen as trailing behind their German and Italian counterparts when it comes to digitalization and automation.

The French plan also includes orders for defense hardware, as most companies have dual civil-military activity.

Also for the short term, €1 billion is earmarked for German airlines renewing their fleets with aircraft that are at least 30% more fuel-efficient. 🌐

## Europe Focuses on Aircraft Powered by Hydrogen

- > LIQUID HYDROGEN FAVORED OVER COMPRESSED GASEOUS FORM
- > FOR PASSENGERS, THE EXTRA COST MAY BE LOWER THAN THOUGHT

**Thierry Dubois** Lyon

**T**he use of hydrogen in aviation has received sudden and strong attention in Europe. It began in early June, with the French government setting environmental goals for aviation (after consulting with the industry), including switching to hydrogen as a primary fuel.

Two weeks later, McKinsey and Co. issued a report on the same topic, essentially concluding a target of 2035 is within reach, albeit challenging. The six-month study was commissioned by two European Joint Undertakings, Clean Sky 2 and Fuel Cells and Hydrogen 2. The European Commission expressed support to the still-to-be structured project, linking it to the “hydrogen strategy” it is to adopt in July.



**A massive liquid-hydrogen tank may soon become a common sight at airports, not just at space launch facilities.**

CORY HUSTON/NASA

The well-funded, converging moves mark the start of a tectonic shift, at least in research and perhaps, in a few years, for the entire industry. Powering aircraft with hydrogen will benefit from the maturity of the technology in the automotive field, decreasing production costs, as well as from the recent discovery of natural hydrogen sources.

Nevertheless, many obstacles lie ahead. Choices will have to be made that may shape the future of the industry—between gaseous and liquid hydrogen as well as between fuel cells and turbine engines, among others. Every decision will have implications both for aircraft and the entire ecosystem—from airports to air traffic management (ATM).

The respective merits of gaseous and liquid hydrogen are being thoroughly assessed. Views are beginning to coalesce.

“A propulsion system made of a high-pressure tank for gaseous hydrogen, a fuel cell, an electric motor and a propeller would easily reach a high level of technology readiness, up to the size of an ATR 72 or even a 100-seater,” says Luis

Le Moyne, director of France’s automotive and transportation academy (ISAT). The sector has experience with in-service vehicles such as the Toyota Mirai. An aircraft’s range might be limited to 1,000 km (540 nm), however, due to the heavy storage systems, he estimates.

He even suggests greater storage pressure should be adopted. In automotive, 700-bar tanks are standard. “They make hydrogen competitive with hydrocarbons, in terms of range,” Le Moyne says. “In aviation, as hydrogen propulsion will be more expensive, increasing the pressure to more than 900 bar could make sense, as it would give a better cost-to-performance ratio.”

McKinsey’s report focuses on liquid hydrogen, which it deems better suited to most of aviation. But it does not rule out gas. “Gaseous storage can be suitable for shorter flights and is commercially available,” it notes. Development of an evolutionary hydrogen aircraft design and tests with gaseous hydrogen tanks might enable faster time to market, it adds, although capping the aircraft size at 19 seats.

Two members of research and technology organizations concur. Gaseous hydrogen could be suitable only on a small-size aircraft, says Philippe Novelli, program director for propulsion and environment at France’s aerospace research office (Onera). Refueling with gaseous hydrogen would be

prohibitively lengthy for an aircraft with a capacity greater than 19 passengers, adds Jean-Francois Brouckaert, Clean Sky’s chief scientific officer.

There are caveats against the use of liquid hydrogen. “Using liquid hydrogen would be very difficult in aviation,” says Le Moyne. One reason would be the complex system required to maintain a temperature of -253C (-420F), he explains.

A major problem appears at the liquefaction stage. “The process is exothermic, meaning you lose energy if you want to use liquid hydrogen instead of compressed gaseous hydrogen,” says Isabelle Moretti, a researcher at the University of Pau in France and former chief scientific officer at Engie, a major energy supplier in Europe.

But liquid hydrogen seems to be increasingly perceived as the way to go. Using gaseous hydrogen in a 700-bar tank is inconceivable because the tank’s weight would be prohibitive, Novelli contends. The relevance of using gaseous versus liquid hydrogen can be measured using the gravi-

metric index—the ratio between the fuel’s mass and the combined mass of the fuel and its tank.

In that regard, liquid hydrogen is believed to be a better fit than its gaseous form, though progress is needed with liquid hydrogen tanks. A state-of-the-art tank has a gravimetric index close to 20%, while the target is 35%. “So we are talking about halving the tank’s weight,” says Brouckaert.

The choice for liquid hydrogen may be assisted by expertise at space launcher manufacturer ArianeGroup. The Hyperion research program will evaluate risks for hydrogen aircraft propulsion, including the cryogenic system. The French government is funding the program, which is starting this year.

What about the fuel cell and turbine engine options? A fuel cell is more efficient and would be the best option to

“They probably don’t have the same time frame, not the same complexity, not the same investment,” Faury says. “That’s why today we say that we [are looking] at different routes. We accelerate [the process] by looking at all of them at the same time. There is more investment going into innovation now, by the way, not only in aviation. There is cross-fertilization with other means of transport. We are in the hydrogen council like many other industries, including cars, shipping, energy—everybody is there.”

“While a fuel cell would be suitable up to the size of a regional aircraft, burning hydrogen in a turbofan would better suit short-to-medium-range aircraft such as the [Airbus] A320,” says Onera’s Novelli. The maximum power available from a fuel cell has yet to increase to meet an A320-size aircraft’s need of about 10 megawatts, adds Clean Sky’s Brouckaert. “Such an aircraft could use a combination of a fuel cell and turbofans, the latter being only used at takeoff.”

For widebody, long-range aircraft, the most suitable option is not hydrogen due to the spiraling complexity and size of the hydrogen systems, according to McKinsey. Rather, they would rely on synfuel, also known as power-to-liquid. The process uses renewable energy to convert CO<sub>2</sub> and water into jet fuel. Hydrogen is therefore a major part of, but not the entire, solution, says McKinsey.

In terms of schedule, researchers and Faury agree that 2035 is realistic. “We are talking about the entry into service of the first decarbonized plane by 2035,” says Faury. “It is really something I believe in because it means launch of the program in 2027 or 2028. We have to have completed maturity of the technologies by 2025. Then you have two years for the preparation of the launch, consulting the suppliers, defining the general architecture [and] doing the business case.”

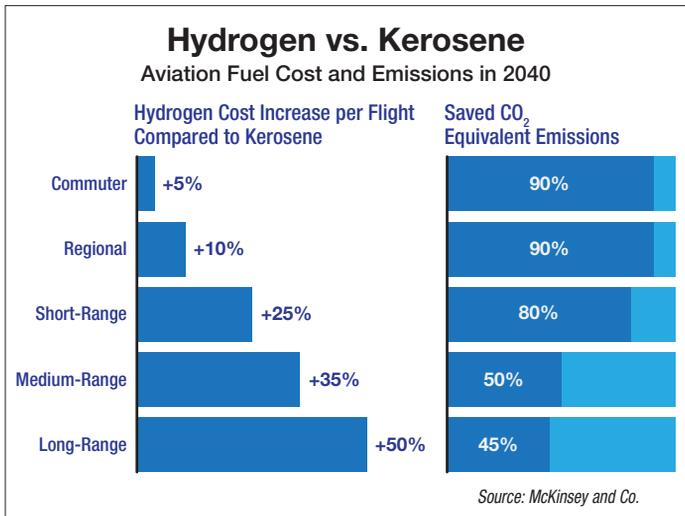
“With a few years of research ahead of us and some specific technologies to mature, we can do it. But we shall not underestimate [the] technical challenges, including safety,” says Brouckaert.

In terms of infrastructure, a favorable factor is the intent expressed by a number of airport managers—such as in Toulouse—to begin using hydrogen for ground transportation vehicles in the 2020-25 time frame. This will familiarize them with the technology, says Glenn Llewellyn, Airbus vice president for zero emissions technologies.

Liquid hydrogen will drop from four times the cost of kerosene today to roughly the same cost by 2050, according to McKinsey. This will be part of a lower-than-expected extra cost for the passenger (see graph). While it may make air travel more expensive, it would remain affordable, especially if consumers keep in mind what is at stake for the Earth’s environment.

Overall, McKinsey’s report is in agreement with studies released over the last 12 months by competing consultancies Roland Berger and Oliver Wyman, thus strengthening the conclusion that hydrogen-powered commercial air transport is feasible.

Finally, environmentally friendly hydrogen may come from natural sources (and not necessarily from water electrolysis with renewable power). Local hydrogen flows at the Earth’s surface—as opposed to underground pockets—are being discovered, notably in volcanic areas. “What happened with natural gas, which replaced gas obtained from coal, will happen with hydrogen,” says the University of Pau’s Moretti. ☪



reduce an aircraft’s climate impact. But practicality depends on aircraft size.

A fuel cell’s efficiency, at 55-60%, compares favorably to that of a gas turbine—40-45%. Its power density (per weight unit), however, is lower.

Combining a fuel cell and a propeller is well-suited to aviation propulsion, according to ISAT’s Le Moynes. Fuel-cell power density has made great progress in recent years.

There is another environmental advantage. Hydrogen emissions do not contain soot, reducing the formation of climatically harmful contrails. This is counterintuitive, as more water vapor is created. But droplets most often form around soot particles.

The benefit would be even stronger with a fuel cell as opposed to burning hydrogen in a turbine engine. “Water vapor emitted by a fuel cell is cooler and fully controllable inside the aircraft. It could be conditioned, depending on the state of the atmosphere in which the aircraft is flying,” according to the McKinsey report.

Minimizing contrails could imply optimizing cruise altitude, thus involving ATM.

As a result, fuel-cell propulsion could reduce climate impact by 75-90%. This would be more than hydrogen combustion, which would cut it by 50-75%, according to McKinsey’s estimate.

Which option does Airbus CEO Guillaume Faury prefer? Although he sees “many more constraints” with a fuel cell, he and his company’s engineers do not know yet.

# Airbus Planning Fuel-Thrifty Ecureuil Successor

- > PLANAERO IS FUNDING THE HYBRIDIZATION RESEARCH PROJECT
- > AIRBUS IS WORKING ON A LIGHT-HELICOPTER TECHNOLOGY DEMONSTRATOR FOR 2029

**Tony Osborne** London

A series of research programs, to be partly funded through France's aerospace stimulus package, will develop the building blocks for a successor to Airbus Helicopters' best-selling H125 single-engine light helicopter.

The most recent version, the AS-350B3e, was rebranded as the H125 in 2015, when the company was renamed from Eurocopter to Airbus Helicopters.

The H125 is currently built at Airbus' plant in Marignane, France, near Marseille, but kits are also sent

higher turbine output, with the aim of initially reducing fuel consumption by 40%, Tomasz Kryszinski, Airbus Helicopters head of research and innovation, tells Aviation Week. "These three components should get us to 40%," Kryszinski says, noting that the addition of electric hybridization of the aircraft could achieve another 10% reduction.

An Airbus research and development program called Helybrid will receive funding from a €300 million (\$338 million) aviation decarbonization investment. Helybrid will demonstrate hybridization of lightweight-helicopter propulsion.

Projects called Compaq and Eprop-tech, the PlanAero documents state,

AIRBUS HELICOPTERS



## The H125 is used in a wide variety of roles, including law enforcement duties.

Although the new rotorcraft is still at least a decade away, the PlanAero package—developed to help the French aerospace industry through the novel coronavirus pandemic—confirms industry hints that the manufacturer is still looking to address the conventional light-helicopter market at a time when urban air mobility systems are grabbing the investment and limelight.

The H125, known by its French product name Ecureuil (Squirrel) and marketed as the AStar in the U.S., was originally developed by predecessor company Aerospatiale during the 1970s. Some 5,000 H125s have been produced during its 45-year production run, with the type in use with commercial, military and parapublic agencies.

to Helibras in Brazil and Airbus Helicopters in Columbus, Mississippi, for final assembly for the Latin American and U.S. markets, respectively. Airbus has been looking at the development of an Ecureuil replacement for more than a decade and had considered opening part of the design effort to the company's Brazilian affiliate Helibras, in part because of the heavy demand for the platform in Latin America.

Any future platform is likely to remain a conventional helicopter because the wide range of missions it is expected to perform—everything from training to law enforcement to firefighting and aerial lifting—are unlikely to disappear.

Efforts will be focused on improved aerodynamics, weight reduction and

will work on electrical network technologies to allow megawatts of electrical power to be used on an aircraft.

"The ultimate step is to go to another sort of energy, which could be hydrogen or fuel cells," Kryszinski says.

The plans are part of Airbus Helicopters' long-term innovation road map to develop autonomy, electrification, hybridization and alternative technologies, so-called techno-bricks, which will contribute to reducing the carbon footprint of their future models. Airbus is planning to fly a demonstrator for the future light helicopter around 2029 to prove the technologies for 40% fuel-burn reduction, and if the hydrogen technologies are mature enough, they could fly them, too.

Kryszinski notes significant advances in hydrogen-fuel-cell technology, notably in the fixed-wing arena, but says

the power requirements for a helicopter remain a significant hurdle.

Currently, the company is gearing up to tackle the hybridization challenge. In 2011, it successfully flight-tested an Ecureuil with an electric motor to drive the dynamic system of the main rotor. Designed as a safety device, the motor would kick in when the aircraft's systems detected main rotor speed droop, usually the result of an engine failure, giving the pilot more time to achieve a smooth and safer autorotation with a reduced rate of descent.

Airbus is to begin modifying a single-engine H130 helicopter with a 120-kW motor, which will act as an electric backup system (EBS) to

provide power for a safe rotation, whereas later tests will see two 120-kW motors connected in parallel to the dynamic system, which would allow the aircraft to make 2 min. of electric-powered flight in a low-power setting. Modification of the test helicopter should begin during September and will fly in early 2021.

"Motors have made very big progress . . . and compared to 2011, you can get twice the energy from 1 kg [2.2 lb.] of batteries than before," Krysinski explains.

"This is a good steppingstone toward the hybrid rotorcraft," he says. "It opens the chapter, a revolution in rotary-wing performance."

Hybridization can also introduce new functions to lower the noise levels, Krysinski notes. "With an electric system, we can get the torque very quickly, and this gives us an extra degree of freedom," he says. "We can reduce the rotational speed of the turbine, and this provides lower noise emissions."

Airbus has not said who it is partnering with on the EBS project, but the company will work with Safran Helicopter Engines in the long term on a hybrid-electric propulsion system. The two companies announced commitments at last year's Paris Air Show on hybridization for the European Union's Clean Sky 3, now the Clean Aviation research and development program. ☛

ELECTRIC AIRCRAFT



PIPISTREL

## Velis Electro Certification Clears Way for Commercial Use of Electric Aircraft

- > PIPISTREL TRAINER IS THE FIRST ELECTRIC AIRCRAFT APPROVED FOR COMMERCIAL OPERATION
- > EASA: EXPERIENCE PAVES THE WAY FOR FUTURE ELECTRIC AIRCRAFT

**Graham Warwick** Washington

**F**or Slovenian light aircraft manufacturer Pipistrel, European type certification for its Velis Electro all-electric training aircraft is both a milestone on a yearslong journey and the start of something bigger.

"I've dedicated almost the last two decades of my life to this goal," says founder and CEO Ivo Boscarol. "And this is big proof that my vision—and

the strategy we have at Pipistrel—is the correct one. Quiet, emission-free aviation is not only possible, it is becoming commercially useful."

Pipistrel has received the first type certificate for an electric aircraft from the European Union Aviation Safety Agency (EASA). The company has separately received the first type certificate for the aircraft's electric pro-

**In addition to the airframe, Pipistrel developed the motor, battery system, propeller and avionics for the Velis Electro.**

pulsion unit, which it will also market to other manufacturers.

Additionally, EASA has approved the operating rules that will allow customers to begin flight training with the Velis Electro as soon as aircraft are delivered. Pipistrel plans to deliver an initial 31 aircraft in 2020 to launch customers in seven countries.

The two-seat Velis Electro has been certified under EASA's CS-LSA airworthiness regulations for light sport aircraft. Electric-powered LSAs have been approved previously in China, but "in Europe, LSA standards have been amended to meet full ICAO-compliant

certification specifications,” EASA says.

This approval and additional special conditions developed to address electric-propulsion requirements beyond LSA are paving the way toward electrification of CS-23 general-aviation aircraft, the regulator says, adding: “EASA considers the Pipistrel Velis Electro to be the first ‘type certified’ electric aeroplane.”

Work to certify the Velis Electro and its electric engine started less than three years ago. Although the company originally wanted to achieve approval in 18 months, “three years to certify such an innovative product is remarkable,” says Dominique Roland, head of EASA’s general aviation department. “We believe [certification of the Velis Electro] is creating the foundation for the certification of more electrical aircraft.”

In addition to the challenges involved in certifying the aircraft, its electric motor, high-power lithium batteries and 400-volt electrics, Roland said EASA, Pipistrel and the aviation authorities of France and Switzerland worked to-

gether to amend the operating rules to accommodate an electric aircraft.

The regulations governing flight crew licensing, continued airworthiness and operations are EU “hard law” and take years to modify, so EASA used an exemption process to introduce a quick change to the regulation, Roland says. Working with France’s DGAC and Switzerland’s FOCA, EASA developed an exemption request that aviation authorities in member countries can use to approve the Velis Electro.

With the ability to fly a 50-min. training mission, plus reserves, the Velis Electro is designed to perform the initial 10-15-hr. pattern-flying phase of pilot training, dramatically reducing operating cost, noise and emissions. It is intended to operate alongside Pipistrel’s conventionally powered Virus SW121, which will perform other parts of the training program that require more endurance, such as cross-country flights.

“In Europe, there are 90 or more small airports that are closed for training during the weekend because of

noise,” Boscarol says. “The Velis Electro is the quietest aircraft on the market—we say 60 dB—and this will bring back training to those airports in France, Switzerland, Belgium and Germany.”

The Velis Electro’s electric power train is liquid-cooled, including the batteries, and has demonstrated the ability to withstand faults, battery thermal runaways and crash loads as part of the EASA certification process, Pipistrel says.

The battery system is self-contained in that all the safety- and performance-related elements are contained within the battery enclosure and are not part of the airframe. This will allow for future performance upgrades, says Tine Tomazic, Pipistrel chief technology officer.

Involvement of the Swiss and French authorities will facilitate entry into service in those countries, EASA says. Launch customer AlpinAirPlanes plans to distribute 12 Velis Electros to 10 airfields across Switzerland. Each base will be equipped with solar panels to recharge the aircraft. ☛

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# MOVING FORWARD

> SU-57 TESTING AND DEVELOPMENT CONTINUES AFTER 2019 CRASH

> NEW MISSILE IS INTENDED TO DESTROY SMALL, HARDENED TARGETS WITH KNOWN COORDINATES

Piotr Butowski Gdansk, Poland

**T**he Russian aviation industry has pinpointed the factors leading to a December 2019 crash of the first pre-production Sukhoi Su-57 fighter for the nation's military. The second aircraft is scheduled to be ready in the second half of this year, as weapons-integration testing continues on the advanced aircraft.

The crash, about 75 mi. (120 km) from the Komsomolsk-on-Amur Aircraft Plant's airfield, was caused by two factors: The manufacturer incorrectly adjusted the tail plane drive, which overlapped with a failure of one of the flight control system processors, according to a summary published by the Russian aviation industry consulting firm Aviaprom.

The accident involving the first preseries Su-57, No. 01, occurred during the handover flight before it was scheduled to be delivered to the 23rd Fighter Aviation Regiment stationed at the same airfield. The pilot, Aleksey Gorshkov from the defense ministry's 485th Military Mission at the Komsomolsk-on-Amur factory, ejected successfully.

The reasons for the crash included "incorrect adjustment of the first channel of BUP-50 [the Russian acronym for drive control unit] of the left tail plane section as a result of violation of requirements of operating manual of the KSU-50-01 [the Russian acronym for complex flight control system], and a failure of processor 'A' of the BU-7 module of the ShS-80-01 block of the KSU-50-01 system," says the document, published in May.

The second Su-57, No. 02, is to be ready by year-end. The preliminary batch of these two fighters was ordered during the Russian Army 2018 exhibition that August.

Then, in July 2019, the Russian defense ministry ordered an undefined number of fighters for delivery in 2021-27.

Russian President Vladimir Putin, in May 2019, publicly recommended that the ministry "reequip three Aerospace Force air regiments with the Su-57s." That would equate to six 12-ship squadrons, or 72 aircraft. Other Russian officials have mentioned the number 76 several times; it is not known if the earlier two preseries aircraft are included in this amount.

## WEAPONS TESTING

The current stage of Su-57 testing is focused on integrating new weapon types. The Russian JSC Tactical Missile Corp. (KTRV) has created a new set of air-to-ground missiles especially for the Su-57.

"[The developers] did not have any problems with externally carried weapons," KTRV CEO Boris Obnosov told the media this February. "But to fit a missile inside the fuselage

smaller dimensions, folding wings and fins are required. There are also certain difficulties at the missile launch from an enclosed space, as additional loads on the airplane arise."

The Su-57 carries its basic ordnance load in two large internal weapon bays that are arranged in tandem and occupy the entire length of the fuselage ventral surface, from the nosewheel well to the engine nozzles. Each weapon bay can accommodate weapons on two side-by-side UVKU-50 ejection release units.

On March 16, 2016, the Su-57 fired a missile from the internal weapon bay for the first time; the type of weaponry



Russia's Sukhoi Su-57 is currently undergoing weapons-integration tests.

is unknown. But it is notable that it occurred six years after the first Su-57 flight.

## LONG-ARM MISSILE

The most capable long-range, air-to-surface weapon designed specifically for the Su-57 is a missile with the supposed Russian designation Kh-69, made by the Raduga Design Bureau from Dubna, north of Moscow. The designation has never been officially confirmed. The missile was presented in public in 2015, with the export designation Kh-59 Mk. 2. It fully uses the space available in the Su-57 weapon bay. It features a square-section box-shaped airframe 4.2 m (13 ft., 9 in.) long and 40 cm (16 in.) both wide and tall. Two missiles can be carried in each weapon bay, side-by-side. A deployable 2.45-m wing is fitted to the top

of the box airframe. The officially announced launch weight of the export version is 770 kg (1,698 lb.), which slightly exceeds the declared load capacity of the UVKU-50 catapult (700 kg). Perhaps the catapult was made stronger than originally planned.

The Kh-69, a counterpart to the MBDA Storm Shadow, is intended to destroy small, hardened targets of known coordinates. For this purpose, it has a guidance system borrowed from a strategic cruise missile that includes strap-down inertial navigation corrected by GPS/Glonass for the cruise phase, and an electro-optical digital scene-matching area correlation system for use close to the target. Powered with a small turbofan, it flies to the target at high subsonic speed. The range declared for the export version is 180 mi., limited by restrictions of the Missile Technology Control Regime. The Russian Aerospace Forces variant can have a much longer range.

The Kh-69 missile was shown for the second time at a Russian defense ministry board meeting on May 25, 2018, when Defense Minister Sergey Shoygu explained the use of the Su-57 in Syria in February 2018. “Practical launches of

“product”) numbers are the manufacturer’s internal markings. The R-77M and 810 are carried in the large centerline weapon bays and launched by UVKU-50 catapults. R-74M2 missiles are carried in two so-called quick bays, in the form of oblong underwing fairings close to the fuselage, each for a single missile launched from a VPU-50 rail. Obnosov has said the company will complete state evaluations this year; none of the missiles has been publicly displayed.

On July 26, 2019, the R-74M2 completed initial testing and was submitted for state evaluations on the Su-57. On March 25, 2020, the Russian defense ministry released a video showing for the first time an Su-57 fighter launching a close-air combat air-to-air missile from a small weapon bay located at the wing-root section. It was intended to be an R-74M2 missile, although a legacy R-73 or R-74M missile could be provisionally fired with the weapon bay’s cover not closed.

The beyond-visual-range Vypel R-77M is an adaptation of the currently produced R-77-1 (izdeliye 170-1) for internal carriage. Externally, the most visible differences are normal flat tail fins on an R-77M compared to lattice fins on the R-77. A modernized active radar seeker has increased lock-on range. A new solid-propellant engine features an adjustable pause between the impulses and a larger fuel reserve. The path-correction radio data link and inertial control system have been improved.

The very-long-range izdeliye 810 (its military designation is still unknown) is being developed on the basis of the R-37M missile for the MiG-31BM interceptor, but it has a shape optimized for carriage in the Su-57’s internal weapon bay. It also has a new MFBU-810 broadband passive-active radar seeker and an improved engine; the missile’s maximum range may be estimated at 186 mi.

## FIGHTER FEATURES

In March 2020, Mikhail Strelets, director of the Sukhoi Design Bureau and head of the Su-57 program, outlined goals for making the Su-57, in material published by parent company United Aircraft Corp. Most of them are typical for a fifth-generation fighter—including low visibility in radar range, supersonic cruising speed and maneuverability. But Strelets also emphasized the “high level of automation and high intellectualization of combat operations, and interoperability with automated command systems.” The Su-57’s fire-control system can make “omnidirectional and multi-channel use of the weapons,” he said.

Strelets stressed that the Su-57 was from the very beginning designed as a multirole aircraft, combining the functions of a fighter and strike aircraft; therefore, the aircraft received very roomy internal weapon bays. Strelets emphasized this as the most important difference between the Su-57 and U.S. fifth-generation aircraft, Lockheed Martin’s F-22 and F-35.

“The F-22 was originally created as an air-superiority aircraft. But only then did the Americans, realizing that it was fundamentally wrong to design an aircraft only for deploying air-to-air missiles, attempt to fit air-to-surface weapons in the existing configuration of the bays. But the geometry of the compartments did not allow accommodating larger loads,” he said. “[In turn], the characteristics of the F-35 as a fighter—acceleration and maneuverability—are inferior even to fourth-generation aircraft, not to mention the Su-57.”



PIOTR BUTOWSKI

prospective theater- and tactical-level cruise missiles from the fifth-generation Su-57 fighter were carried out,” he said. Low-quality video footage accompanying the speech showed the release of the Kh-69 missile from the aft internal weapon bay of an Su-57. Shoygu did not explicitly state that these launches were performed in Syria; and the red color of the fired missile indicates the weapon was experimental for range-test use.

## NEW AIR-TO-AIR MISSILES

Moscow-based Vypel is manufacturing three new types of air-to-air missiles adapted for internal carriage on the Su-57: the close-air combat R-74M2, beyond-visual-range R-77M and very-long-range “izdeliye” 810. “R” markings are added by the defense ministry, while izdeliye (Russian for

# Berlin Backs AESA

- > GERMANY TO RECEIVE CAPTOR-E MK. 1 VERSION
- > HENSOLDT WILL BE RETROFIT DESIGN AUTHORITY



**Tony Osborne** London

In a move that should bolster the Eurofighter Typhoon's export potential, Germany is set to become the first of the fighter's partner nations to retrofit it with an active, electronically scanned array (AESA) radar.

The German parliament has given a green light for Berlin to spend €2.8 billion (\$3.1 billion) to install the Euro-radar consortium's Captor-E radar in all—some 106—of the German Air Force's Tranche 2 and 3 aircraft from around 2023. Contracts should be signed in the coming weeks.

Export customers will receive the Captor-E first. Kuwait has ordered 28 aircraft, and Qatar 24, and a batch of Kuwaiti aircraft will be delivered this year. But program officials believe that with the AESA finally receiving partner-nation backing, the Typhoon's chances in competitions closer to home may have moved up a notch.

AESA-equipped Typhoons are proposed for both Finland and Switzerland. But the radar's capabilities could not be evaluated when the fighter took part in trials in those countries, as the participating aircraft were not fitted with it. The competing aircraft were.

All four Eurofighter partner nations—Germany, Italy, Spain and the UK—supported development of the radar by a consortium of Leonardo, Hensoldt and Indra, but have been reluctant to make the retrofit investment. That is due in part to budgets but also reflects their satisfaction with the currently installed mechanically scanned Captor. The AESA, however, boosts radar performance

and range, giving the aircraft a sensor that can match the performance of the MBDA Meteor beyond-visual-range air-to-air missile. A mechanical repositioner helps widen the radar's field of view to around 200 deg., from 120 deg. with the existing mechanically scanned radar.

For the German retrofit program, Hensoldt will take a leading role in the production and delivery of the radars and act as the design authority, while Airbus will act as the test and integration lead. Leonardo, which led Captor-E development, will provide support to Hensoldt in its role as design authority. Leonardo will also supply the radar's processor.

"With this decision, Germany is taking on a pioneering role in the field of key technology for the Eurofighter for the first time," says Hensoldt CEO Thomas Muller. "It is a signal for Europe that Germany is investing in a technology that is of crucial importance for European defense cooperation."

Airbus Defense and Space CEO Dirk Hoke says the addition of the radar will increase the mission effectiveness of the aircraft and help integrate it with the Franco-German Spanish Future Combat Air System.

Three versions of the Captor-E have been developed or are under development. The German retrofit program calls for the installation of the Mk. 1 radar, which has been developed from the Mk. 0 radar that will be delivered to Kuwait and Qatar. The Mk. 1 adds new modes and a multichannel receiver. Along with being retrofitted to the

German Tranche 2 and 3 aircraft, it also likely will be fitted to the 38 new-build aircraft planned under Berlin's Quadriga buy to replace its existing Tranche 1 Eurofighters, which lack the computing and electrical power for an AESA installation.

Work has also begun on the Radar 2 being developed for the UK, which will feature an electronic attack capability. It is expected to enter service in the mid-2020s, and the UK plans to install it on its Tranche 3 model aircraft.

Spain, too, is planning a retrofit program with the

**The Captor-E radar (inset) will be installed in Tranche 2 and Tranche 3 Eurofighters.**

Mk. 1 radar, also limited to its Tranche 3 fleet. Airbus revealed last November, however, that the novel coronavirus pandemic appears to have delayed Madrid's plans.

An AESA has been part of the Eurofighter's development road map for around 15 years. The consortium had originally hoped that it could form part of the Tranche 3 fleet. The capability was also part of the consortium's ultimately unsuccessful offer for India. But it was not until 2014 that the first Captor-E development radar began flying in the aircraft, making an appearance at the 2014 Farnborough Airshow.

The AESA radar capability is added through the Eurofighter's Phase 3B Enhancement (P3E(b)) package that will be delivered to Kuwait. Leonardo completed flight trials in support of the Mk. 0 radar development and P3E(b) in late May.

Along with the Quadriga purchase, known in Germany notionally as Tranche 4, the country is also planning to use the Eurofighter, as well as the Boeing F/A-18 Super Hornet, to replace the Panavia Tornado fleet, although these plans are subject to parliamentary approvals that could come as late as 2022-23 (*AW&ST* May 4-17, p. 50). Egypt is also reportedly interested in purchasing up to 24 Eurofighters, possibly as part of a multibillion-euro procurement from Italy that also includes jet trainers, helicopters and warships. ☛

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## Seoul's Surion Attack-Mission Decision Nears

> ASSESSMENT AGENCY BACKS SURION, AND MEDIA CRITICIZE IT

> KAI WORKS TOWARD 2023 LCH-LAH DELIVERIES

**Bradley Perrett** Beijing and **Kim Minseok** Seoul

**S**outh Korea has already once chosen a helicopter with a bulky and unnecessary cabin for the attack role. Within a few months, it may do so again.

First was the Airbus H155, which is being updated as the LCH civil helicopter and derivative LAH armed helicopter for the Republic of Korea Army, with all production transferred to Korea Aerospace Industries (KAI).



The second could be the KAI Surion, which is in army and marine service as a utility aircraft and is being proposed as an attack helicopter for the marines.

The defense ministry's evaluation office reportedly has recommended the Surion adaptation over foreign alternatives, mostly from the U.S. A final decision should be made no later than August, according to an industry official from a South Korean company with an interest in the program.

Meanwhile, KAI is working toward handing over the first LCH and first LAH in 2023. For LAH exports, the company is targeting countries where it has already sold other products. Several Southeast Asian countries are likely to be intended customers.

Possible selection of the Surion for the marines is attracting strong criticism in the South Korean media, however. And the army rejected the type for the attack role in 2013, preferring the Boeing AH-64E Apache. The latest proposal is to add weapons and sensors to the marines' utility version of the Surion, the MUH-1. This meets the marines' requirement, the industry source said.

As a domestic product, the twin-engine type could expect strong support from politicians for a new order. The Republic of Korea Marine Corps requires 24 attack helicopters. The defense ministry plans to spend 1 trillion South Korean won (\$834 million) on the acquisition, the *Chosun Ilbo* newspaper reported in 2019.

The MUH-1 already has features to facilitate operations at sea, notably folding main rotor blades. The MUH-1 attack version would have armament comparable to that of the Bell AH-1Z Viper and AH-64E. Sensors and weapon-control equipment will come from the LAH, and communications will be modified from the LAH and MUH-1 systems.

The Surion is powered by the T700-701K engine developed and built by General Electric and Hanwha. The Defense Agency for Technology and Quality evaluation office assessed the MUH-1 attack version against the Viper, Apache, Sikorsky S-70i and the Turkish Aerospace Industries T-129, the *Asian Economy* newspaper said in April. Following a yearlong study, the agency reported that domestic development was appropriate for the requirement and that the unit price would be 37 billion South Korean won, SBS television said. Inexpensive operation and maintenance would more than offset a high acquisition cost, according to a *Chosun Ilbo* report on the study.

The Surion's most obvious disadvantage for the attack role is that it would take the weight and target area of a large cabin into combat, whereas dedicated attack helicopters have compact fuselages. This is a compromise that the army was forced to accept with the LAH. In that case, the industry ministry—which is partly paying for the program—insisted that the chosen type have a passenger cabin so it would be adaptable to civil use.

All five LCH-LAH prototypes are

**KAI last year displayed this model of an attack helicopter based on the marines' MUH-1 version of the Surion.**

flying. As planned, the LCH segment is running ahead of work on the LAH.

The LCH is also running approximately on time. The program is working toward getting an amended type certificate (TC) from the European Union Aviation Safety Agency (EASA) in September, KAI says; in 2015, the target was 2020. Beyond that, KAI is aiming to get production organization approval from EASA in 2021, with which it can put the H155 into volume production (under the new names). An army requirement for 200 helicopters underpins the program.

Flight testing for the amended TC has been completed, KAI said. The first LCH prototype, built by Airbus in France, flew ahead of schedule in July 2018. KAI built the second at its Sacheon works in South Korea and began flying it in December 2019. It is being used to gain a supplementary TC from South Korean authorities. By late April, half of that work had been done.

KAI says it began marketing the LCH in early 2020, with the proposed roles being executive transport, ambulance services, law enforcement and firefighting. It has no customer so far, but KAI cannot deliver before the first half of 2023 anyway.

The LAH is basically an LCH with military equipment. LAH flight testing "is supposed to be performed by the end of 2022 in order to evaluate and verify its flight performance and weapon operation," KAI says. The first LAH prototype flew in July 2019, and the other two took flight in August.

First delivery is still due in 2023—as it has been since 2018 or earlier—but when the defense ministry chose KAI and Airbus for the program five years ago the army was supposed to begin receiving LAHs in 2022. The ministry has not yet "confirmed" an order, KAI says. 🗳️

# Japan's Aegis Ashore Program Suddenly Crashes

- > MINISTER'S ASSESSMENT SUGGESTS LITTLE ALTERNATIVE TO CANCELLATION
- > RADARS COULD BE REASSIGNED TO DESTROYERS

Bradley Perrett Beijing

**D**eployment of two planned Lockheed Martin Aegis Ashore anti-ballistic-missile batteries in Japan looks improbable following a decision to indefinitely suspend the program because of potential danger to civilians.

Defense Minister Kono Taro said rectifying the problem—the risk of falling boosters—could take more than a decade and cost more than \$2 billion. Announcing the decision to halt the deployment process on June 15, he said he needed to think about what to do next. He suggests a way of resuming the program.

## Japanese Aegis Ashore Sites



Since the batteries were supposed to take over from Aegis destroyers in providing nationwide ballistic-missile defense, one effect of the decision is to diminish Japan's deployable naval capability after the middle of the decade. The navy is calling for an alternative to using destroyers; it says the ships cannot maintain coverage in bad weather.

But Kono suggests Japan will still deploy two Lockheed Martin SPY-7 radars that it ordered in November for the Aegis Ashore batteries; they may go aboard new destroyers.

The defense ministry discovered in late May that, contrary to a government promise to local residents, boosters of the SM-3 Block 2A missiles from one of the two sites would not always fall onto a military training area, Kono says. The battery was to be built in that training area.

At first the government expected software modifications could ensure the boosters would fall into the training area. Now, following discussions with the U.S. side, the government

has learned that hardware would also need to be changed. Kono suggests physical changes would have to begin with the missile and flow to other parts of the system, notably the Mk. 41 vertical launch system (VLS). Raytheon and Japanese companies developed the SM-3 Block 2A, which is controlled by Lockheed Martin's Aegis system.

Japan decided in 2017 to buy the two batteries, later confirming that one would be installed at each end of Honshu—in Akita prefecture in the north and Yamaguchi prefecture in the southwest. In the face of the North Korean ballistic missile threat, deployment of the systems has been regarded as urgent, with the government aiming for delivery in 2025 and Lockheed Martin trying to accelerate the program.

For the time being, the destroyers will keep doing the job that Aegis Ashore was intended for, the minister says. This makes the destroyers vulnerable—limiting them to restricted areas of the sea—and prevents them from deploying freely to defend other ships against aircraft and missiles, which they were built to do. “We believe equipment that is independent of the weather will still be needed to replace Aegis ships,” Navy Chief Adm. Yamamura Hiroshi told reporters. Bad weather can drive ships off station, he says.

Japan has already contracted to spend ¥179 (\$1.66 billion) on Aegis Ashore. Speaking to reporters, Kono would not go so far as to say that the program was canceled, but his assessment was so bleak as to suggest little alternative.

“It took 12 years to develop SM-3 Block 2A, with the Japanese side paying ¥110 billion and the U.S. probably paying at least as much,” he says. “I think that if a new missile is developed, it will need that much money and time. And if its shape is changed, it is natural that the VLS could also need modification. . . . In considering that, and in view of the [prospective] cost and time period, the process of deploying Aegis Ashore has been stopped.”

Asked whether deployment of Aegis Ashore would be possible with the booster problem resolved, Kono says “this system” could go aboard ships. He apparently referred to the anti-ballistic missile capability of SM-3 Block 2As.

The government says the danger from falling boosters arises only for shots from the battery planned for the southwest of Honshu. But deployment of the one for the northern end of the island has also been stopped. As for the possibility of finding another location for the southwestern site, Kono says ensuring a booster falls in any particular area would be hard, so deployment at any site would be difficult.

It is not entirely clear why a location close to the coast facing North Korea is impracticable; from the northern Honshu site, boosters were expected to fall into the sea. The government has previously implied that chosen sites had to already be government owned, presumably to avoid the difficulty of buying land. Only two areas were considered for the southwest.

The government has also not said why it cannot go ahead with the northern battery alone. And one more issue that notably went without discussion during the minister's press conference was whether, if North Korea were firing a possibly nuclear ballistic missile at a Japanese city, the small risk to communities from falling boosters might be justifiable.

As for the sensors that are on order, Kono says: “The SPY-7 radar we have been planning to introduce has very high performance, so it can be used in various ways other than with Aegis Ashore. . . . You can use it if you have more Aegis ships.”

Japan commissioned its seventh Aegis destroyer, Maya, in March. One more is under construction. 🇯🇵

# Canada Mimics Marine Corps Makeover for F/A-18C/D Fleet

> NEW RADARS, WEAPONS FOR CF-18s

> FUTURE FIGHTER CONTRACT BIDS DUE JULY 31

Steve Trimble Washington

**W**ith operators in Europe, the Middle East and Asia looking on, an upgrade package approved by the State Department on June 16 for up to 36 Royal Canadian Air Force (RCAF) F/A-18C/Ds cements a new configuration aimed at keeping the Boeing-made jets in service decades beyond their planned retirement dates.

aligned with a U.S. Marine Corps initiative to keep at least two squadrons of F/A-18C/Ds in service beyond 2029, as both the Marines and the RCAF have waited longer than expected for a replacement jet to arrive.

The U.S. Navy tipped the radar selection for the RCAF in a June 11 presolicitation notice that specified the APG-79(v)4, showing an intent to prevent

F-35B has forced the Marines to keep a fleet of Legacy F/A-18s in service for a decade longer than planned.

The Canadian government's 11-year-old pursuit of a CF-18 replacement (highlighted by failed attempts to acquire 65 Lockheed Martin F-35As in 2010 and an interim fleet of 18 Boeing F/A-18E/F aircraft in 2016) is still in competition mode, with a contract award for 88 fighters due in 2022. Three bidding teams—F/A-18E/F, F-35A and the Saab JAS 39 Gripen—must submit final bids by July 31, which includes a one-month delay to account for the effect of the COVID-19 pandemic on the industry.

“These [CF-18] upgrades will provide a capability bridge until transition to a permanent replacement fighter,” the DND says.

Canada's fighter delays have not been easy for the RCAF to manage. The current fleet, acquired in the early 1980s, was originally expected to be retired in the early 2000s. A retirement date in 2020 fell through as the government of former Prime Minister Stephen Harper stalled on signing the contract for the controversial F-35A selection. The new administration of Prime Minister Justin Trudeau pushed the selection process to 2022. The CF-18 is now set for retirement in 2032.

The situation is different in Finland. Although the Finnish Air Force operates the youngest fleet of F/A-18C/Ds, the head of the HX fighter competition has roundly rejected calls to extend their service life into the 2030s, saying even a few extra years of operations would cost at least €1.2 billion (\$1.35 billion).

The State Department cleared the RCAF to buy 50 infrared-guided AIM-9X Block II missiles, 38 APG-79(v)4 radars and 20 AGM-154C glide bombs as part of an overall package worth \$862 million. The bundle includes electronic equipment, tactical data and support.

The CAD\$1.3 billion (\$960 million) CF-18 Hornet Enhancement Program is divided in two phases. Phase 1 updates all 94 aircraft, including 18 former Royal Australian Air Force F/A-18C/Ds acquired two years ago, with interoperability and regulatory upgrades, including a new GPS/international navigation system, Identification Friend or Foe transponder, Link 16 tactical radios, satellite communications, targeting pod modifications and improved helmets. 🇨🇦



DEPARTMENT OF NATIONAL DEFENSE

**As Canada's CF-18 fleet enters an unexpected fourth decade of service, the details of a nearly \$1 billion upgrade package are settled.**

A group of Raytheon-made sensors and weapons—APG-79(v)4 active, electronically scanned array radars, AIM-9X Block II air-to-air missiles and AGM-154C Joint Standoff Weapons—will be included in the RCAF's newly defined Phase 2 upgrade to help keep a subset of the 94-member CF-18 fleet operating into the 2030s. The State Department previously cleared Canada to acquire 32 AIM-120D advanced medium-range air-to-air missiles for the CF-18.

The package, defined in a Defense Security Cooperation Agency notification to Congress on June 16, offers few surprises. The Phase 2 Hornet Extension Program will be closely

Northrop Grumman from offering the APG-83 for the Canadian program. The Marines evaluated the APG-83 and the APG-79 two years ago, but selected the latter as the successor to the Raytheon APG-73 for the “classic” Hornet fleet.

“Partnering with the [Marines], who are completing the same radar upgrade, will enable the introduction of this new capability faster, more efficiently and at reduced cost for both services,” the Canadian Department of National Defense (DND) tells Aviation Week in a statement.

The upgrades by the Canadians and the U.S. Marines are driven by the same issue. A delayed delivery schedule for the Lockheed Martin

# Contactless Technologies To Help Airports Ensure Safe Recovery

- > CROWDVISION ANALYTICS HELP AIRPORTS WITH PHYSICAL DISTANCING
- > COVID-19 RULES HAVE BEEN ESTABLISHED TO DRIVE RISE IN NO-CONTACT AIRPORT PROCESSES



LONDON CITY AIRPORT

**Helen Massy-Beresford** Paris

**A**s airports begin to reopen since the COVID-19 pandemic brought many to a virtual standstill, operators are evaluating how the new hygiene and distancing measures they need to put in place will affect their operations in the months and years to come.

“Technology will be critical in supporting the resumption of flights post-COVID-19,” says Ross Powell, head of aviation at engineering and design consultancy Ramboll UK.

Airport layouts—like many public spaces—were not designed to easily incorporate the new social-distancing guidelines. And because airport environments are already subject to highly complex restrictions and regulations, their operators need to work out how to balance the new safety protocols with the need to get traffic flowing again.

“Airports are already very clean and controlled environments,” says Virginia Lee, ACI Europe’s director of media and communications. “They are probably the safest and most hygienic transport environment, and that is being enhanced. Physical distancing is an area in which it is feasible for airport operators to implement mea-

asures that can make a difference, but it needs to be flexible. Every airport has a different fixed footprint. There are certain points in the passenger journey where if you were to rigidly impose physical distancing, you would create a new bottleneck.”

Powell believes queue-management technologies could play a role in striking that balance.

“Mechanisms like virtual queuing—long the domain of the theme park, where you are allocated a specific time to enter high-congestion zones—could support both an enhanced passenger experience and lessen the risk of infection,” he says.

London City Airport—which suspended operations on March 25 and restarted domestic services on June 21 with a British Airways flight between the Isle of Man and London, followed by international flights in the coming weeks—has put in place a number of measures to enable it to meet short-term hygiene requirements.

In line with European Union Aviation Safety Agency (EASA) guidelines set out to help the air transport industry slowly increase its activity after an almost total shutdown, the airport has installed touch-free hand

sanitizer dispensers, one-way systems, signage to help maintain social distancing and protective screens at check-in counters.

“We want to get as much confidence back as we can,” says Alison Fitzgerald, London City Airport’s chief operating officer.

London City has also installed noncontact temperature-checking technology on departure and arrival. Staff will wear face masks and visors, and the airport is working with artificial-intelligence partner CrowdVision, whose technology interprets images taken from overhead-mounted cameras, providing

## London City Airport restarted flights on June 21.

airports real-time aggregated data about where members of the public are and how they are moving.

Although the technology has been in use at London City for some time, allowing the airport operator to understand passenger flows through the terminals, aspects of what it can do have taken on an extra layer of relevance in light of the need for physical distancing post-pandemic, explains Stuart Mills, CrowdVision’s chief operating officer.

CrowdVision technology had originally been used to provide data about travelers making the Hajj annual pilgrimage to Mecca, Saudi Arabia. Data elements that helped to keep crowds of millions of pilgrims safe have now come into their own in post-pandemic airports, branded as “safe-distance analytics,” Mills says.

“This is a long-standing capability for us,” he adds. “Originally, it wasn’t viewed in terms of disease transmission but [rather as a method] to understand where problems were going to occur with large numbers of people trying to get through narrow spaces.

“We now have the ability to see in real time where people might not be social distancing, where there might be congestion. It helps us to look at our processes, and if we start to have congestion, our customer services team can direct passengers to a quieter part of the airport,” Fitzgerald says.

CrowdVision’s operating analytics can help airports ensure passengers comply with short-term social-distancing measures, but in the long term these tools can also help op-

erators identify, for example, areas that could be designed differently to optimize passenger flow in future terminal revamps.

“The elements around social distancing are crucial for now,” Mills says. “But when the airport volumes build up again, and we’re already seeing places in the world where that’s happening, then crowd analytics are going to be fundamental to their operating efficiently.”

Powell sees a change in airports’ strategies as contributing to efforts to avoid congestion in the long term.

“The airport of the future is likely to decentralize security and passport control through multiple points of entry or egress to avoid large queues within a confined space,” Powell adds. “This will, however, generate a requirement for more space and staffing than is the current standard.”

Torsten Hentschel, managing direc-

tor of TH Airport Consulting, believes some changes to areas for seating and queuing, as well as the incorporation of health-check areas in bigger airports, may also be longer-term legacies of the coronavirus outbreak.

Powell agrees: “I believe we will see overall changes to waiting and seating areas, including more informed materials choices to make areas both more hygienic and easier to clean. Longer term, it is now a matter of

## Safety Management Programs Are Coming To OEMs

- > SYSTEMS HELP IDENTIFY RISK BEFORE PROBLEMS ARISE
- > SAFETY MANAGEMENT SYSTEMS ARE INDEPENDENT OF BUSINESS UNITS TO ELIMINATE FINANCIAL PRESSURES

Sean Broderick Washington

**T**he FAA is confident that its soon-to-be restarted plan to mandate safety management systems (SMS) for manufacturers will address some of the most glaring product certification deficiencies spotlighted during the Boeing 737 MAX crisis.

Mandating an SMS for manufacturers such as Boeing is one item in a package of FAA reforms proposed by the U.S. Senate in a bill unveiled June 16. The lawmakers’ call echoes one in a January report prepared by a special committee set up by the Transportation Department to review FAA certification. The FAA has committed to include an SMS rule among several changes it plans to introduce (*AW&ST* March 9-22, p. 46), and plans to release a draft rule this year.

“I think it’s the most important step that we can take to improve aircraft certification,” FAA Administrator Steve Dickson told the Senate Committee on Commerce, Science and Transportation during a June 17 hearing.

The FAA already requires an SMS for scheduled airlines. Mandating an SMS for manufacturers would align the FAA with International Civil Aviation Organization (ICAO) Annex 19 standards, which have called for organization-wide safety programs for aircraft manufacturers since 2013. A European Union Aviation Safety

Agency effort to mandate an SMS for some manufacturers is also underway.

The FAA’s mandate would complete an effort the agency began in 2014, but that was paused before a draft rule was published. Currently, the agency will review and “accept” a company’s SMS structure if the company signals that it complies with National Aerospace Standard NAS 9927, “Safety Management Systems and Practices for Design and Manufacturing,” developed by the Aerospace Industries Association and General Aviation Manufacturers Association and based on ICAO’s guidance.

Dickson told lawmakers that mandating the inclusion of an SMS will help the FAA gain a more complete picture of a product’s development, providing a “holistic” view vs. a “transactional” one that may mask ramifications of design changes. Investigations into the 737 MAX’s certification have cited the agency’s lack of understanding of the model’s flight control system as a key factor in setting the stage for two fatal accidents that killed 346 people and led to the MAX’s March 2019 grounding.

Investigations into the accidents, Lion Air Flight 610 in October 2018 and Ethiopian Airlines Flight 302 in March 2019, cited fundamental misconceptions Boeing made about how pilots would react in certain emergency sce-

narios. Boeing’s assumptions were not properly vetted by human-factors experts, in part because the FAA did not have them playing key roles in aircraft certification. The agency has pledged to change this as well.

Boeing also made questionable decisions during the model’s development, prioritizing potential training costs over ensuring that customers



STEPHEN BRASHEAR/GETTY IMAGES

were completely comfortable with their newest aircraft (*AW&ST* Jan. 27-Feb. 9, p. 20).

Dickson acknowledged the FAA should have had more complete details about the MAX’s flight control software system, including changes made during the aircraft’s development.

“There was incomplete and fragmented information, no doubt,” he said. “The full implications of the flight control systems were not un-

time before we see biometrically enabled airside infrastructure, which will dramatically improve travelers' experience and safety."

In the short term, as flights resume, other existing airport technologies are set to play an important role as airports attempt to balance EASA recommendations with passenger convenience and safety.

"Airports will definitely move more toward contactless processes

through biometrics, self-service and contactless touch points," Hentschel says. "That helps to reduce contact between passengers and staff and enhances the flow significantly, getting rid of queues."

Fitzgerald adds: "Some airlines used to think there was a customer service element, with people wanting to have that personal contact by checking in at a premium desk. But now I think there will be a much bigger

drive toward [automated check-ins] being the choice of passengers, [who will interact only if] they need to.

"I hope this will be a catalyst to accelerate toward a frictionless, contactless journey," Fitzgerald adds. "In some cases, the technology has not been ready, or in others the legislation [has not]. But this is something we've all been striving for, and if there are going to be unexpected benefits from this situation, let that be one of them." 🗳

derstood, and mistakes were made. The information was not provided in the way it was needed to be provided. That alone degrades trust."

The 2014 rulemaking effort was supported by an agency/industry advisory committee tasked with recommending how the FAA could apply a systems-safety approach to certification oversight. The committee's

cluding a three-year phase-in period.

Thanks to the nonmandatory program the FAA continued after the rulemaking stopped, manufacturers have examples to follow when SMS become mandatory. GE Aviation and Bell Helicopter were the first to establish SMS for their operations.

While an SMS is tasked with managing complex processes, its structure

key to creating a "just culture" that is critical to the success of an SMS. Risk management and assurance are the closely linked elements that determine risk and ensure it is managed.

An SMS creates a constant feedback loop that is independent of managerial and financial pressures. The independence is why Dickson and others believe SMS at the product development level will lead to safer designs. GE's SMS structure helps illustrate why.

The company's SMS program, launched in 2013 and accepted by the FAA in 2017, is administered by a 13-member flight safety office completely separate from its business units. Each engine program has a dedicated team led by a designated "accountable executive" responsible for implementing SMS at the product level. The teams meet monthly, at least, and safety concerns are reviewed by the accountable executive. A Product Safety Review Board holds quarterly, organization-wide SMS reviews.

The primary goal is to identify risks and mitigate them before they become issues, without interference from the business side.

"On the company side, the manufacturer puts safety responsibility where it belongs, and promotes transparency and voluntary employee reporting on safety issues," Dickson said. "It refocuses accountability for product safety to the highest levels of the company.

"On the agency side, it allows us to oversee the system and the process, and it reinforces the sharing of data in a dynamic process between the manufacturer and the agency. It greatly improves the regulator's ability to identify hazards and manage our oversight before a compliance bust actually occurs. We don't have to wait for that because we're getting a data feed throughout the process." 🗳



### The FAA will mandate systems-safety programs for manufacturers, heeding calls from lawmakers and an independent industry report that examined what went wrong during 737 MAX development.

650-page report took deep dives into how the FAA oversees manufacturers, including Boeing's Organization Designation Authorization, responsible for much of the 737 MAX testing and validation. It laid out specific recommendations for folding an SMS into product design regulations, in-

is straightforward. Its framework typically includes four components: policy, promotion, risk management and assurance. Policy is set at an organization's most senior levels, ensuring cultural buy-in. Promotion helps solidify that buy-in and trains employees on their specific roles—both are



SAFRAN

## New Cabin Technologies May Help Restore Passenger Confidence

- > MATERIAL ADDITIVES AND UV LIGHTS ARE STRONG CONTENDERS
- > TESTING HAS YET TO PROVE EFFECTIVENESS AGAINST COVID-19

**Thierry Dubois** Lyon

**A**s travel restrictions relax, will passenger demand return? Carriers and aircraft manufacturers worry that people's fear of coronavirus infection may prevent the desire for travel from growing back to profitable levels. Industry players can therefore be expected to do everything they can to boost passenger confidence.

In fact, action taken by civil aviation authorities, such as the European Union Aviation Safety Agency's (EASA) passenger management guidelines, already sets high screening and hygiene standards. EASA's health safety protocol notably deals with thermal screening at the airport and the use of face masks. Add the existing air conditioning systems onboard, which include hospital-type filters, and passenger health can arguably be seen as taken care of.

Nevertheless, carriers may want to show passengers they are going the extra mile to protect them. If perception is reality, how passengers feel will dictate a carrier's revenues. Hence

the business case for the numerous technologies cabin equipment suppliers are pitching.

Safran suggests seats could be fitted with transparent partition walls. Each "ringfence" wall would leave half an armrest to each passenger, says Quentin Munier, Safran Seats executive vice president for strategy and innovation.

A lighter design includes removable partitions that could be installed by passengers at head level. They could be made of single-use, flexible textile. Removable seat covers could also be single-use.

To avoid multiple hand contacts with a single item, pedals could control seat recline and tray table position.

Where antimicrobial materials would be used, such as armrests and tray tables, QR codes would enable the passenger to gather information on the surface's hygienic properties, says Munier.

Safran Seats launched a challenge for rapid application development, which yielded 120 ideas in two weeks, says Munier. "These are ideas, not

Safran suggests seats could be fitted with partition walls, single-use covers and recline-control pedals.

products. We have studied feasibility and, depending on customer feedback, we will prioritize developments. While they cannot be done overnight, we are well aware time is of the essence."

A codesign scheme, dubbed "Create with Safran Seats," is being offered to carriers for customized solutions.

Meanwhile, the Interspace padded semipartition is to be made available for premium-economy seats this summer. Since it gives a conventional seat a cocooning factor, it was initially developed for passenger comfort. In the context of the COVID-19 pandemic, it is now hoped to provide some degree of airflow separation, although the impact on air cleanliness has yet to be measured, says Munier.

Acro Aircraft Seating is exploring a collaboration with Addmaster, a supplier of additives for materials. The idea is to incorporate the Biomaster antimicrobial technology, which has been in service with London's public transportation for five years, into aircraft seat parts such as armrests.

"Biomaster is proven to inhibit the growth of microbes by up to 99.99%, and it has been proven to be highly effective against viruses on porous surfaces such as textiles and paper," says Al Roots, Acro's head of industrial design. "When microbes land on an untreated textile or surface, they multiply.

When they land on the antimicrobial protected surface, silver ions prevent them from growing, producing energy or replicating, therefore they die.”

Silver-ion technology can already be found on Tapis Corp.’s Promessa synthetic leather, which Acro uses for some of its products.

Biomaster can be added at any stage of production. “It performs best if added at the raw material stage, [then] it will last the life of the product,” says Roots. If sprayed on a textile, it can undergo up to 80 cool washes.

Biomaster should be seen as a complement to regular cleaning, Roots emphasizes.

Tests for Biomaster have yet to be conducted in two domains—retention of the materials’ physical properties and effectiveness against COVID-19. The material must be shown to keep its characteristics for anti-inflammability and resistance to cleaning agents, for instance. Otherwise recertification would be required.

The effectiveness question is more challenging. “There is no commercially available method by which it could be tested,” says Roots. But microbiology studies are encouraging, suggesting that tests conducted against the norovirus and feline coronavirus will be valid for the COVID-19 virus.

The industry ought to standardize such trials, notes Safran’s Munier.

An intermediate step for in-service aircraft would be spraying a coating on components such as tray tables and armrests. “The cost-effective solution will be available in the near future and in a quick turnaround time,” says an Acro spokesperson.

Initial antiviral test results have been deemed positive. “Durability testing is underway and we are expecting results in the middle of the third quarter,” says the spokesperson. The coating can also be applied to new seat parts.

“This will go some way toward helping airlines provide much-needed reassurance to cabin crew and passengers and ensuring a heightened feeling of safety and wellness,” she says.

Another challenge is in describing the products that can be characterized as “antimicrobial” because they act against bacteria and mold. However, U.S. regulation will not allow calling them “antiviral,” says Roots.

Cabin hygiene could be helped by light, too. Aveo Engineering, a special-

ist in LED lighting, is promoting the use of visible violet and ultraviolet (UV) light for disinfection purposes.

“The 405-nanometer light is the disinfecting component of sunlight. A violet light can run all the time and be masked by normal white light. We use these lights to keep galleys and lavatories clean,” says Georg Hartl, Aveo’s quality and certification administrator.

UV-C light (at a 275-nanometer wavelength) is for intense disinfection, but humans cannot safely be exposed to it. It can be used for disinfection between flights.

“Both violet and UV-C light are known for being effective against bacteria, viruses and fungi,” says Hartl.

Confirming the attractiveness of

Simulation specialist Ansys points out that UV-C disinfection works only under the “line-of-sight” principle. This means a surface, to be disinfected must not be masked from the light source. The right energy setting against COVID-19 stands at 600 milliJoule/cm<sup>2</sup>, Ansys adds.

These technologies will be used in addition to high-performance ventilation systems.

Cabin air is a mix of fresh air from outside the aircraft and recirculated air, according to Jean-Brice Dumont, Airbus executive vice president for engineering. Recirculated air flows through high-efficiency particulate air (HEPA) filters, such as those used in medical environments. “They



### **Aveo Engineering, a specialist in LED lighting, and Honeywell are promoting the use of ultraviolet light for cabin disinfection.**

UV-C, Honeywell announced a partnership with Dimer, designer of the GermFalcon cabin disinfection device. The size of an aircraft beverage cart, it has UV-C-light arms that extend over the top of the seats and sweep the cabin. Honeywell will market and produce the system, renamed the UV Cabin System. It is said to be able to treat an aircraft cabin in less than 10 min. for less than \$10.

“As the travel industry begins to recover, we know hospital-grade technology will ease passenger concerns, and that’s what we’re providing with this system,” says Elliot M. Kreitenberg, cofounder and president of Dimer. Results vary based on UV dosage and application, and testing has yet to be done specifically on protection against COVID-19.

block at least 99.9% of viruses and other microbes,” says Dumont.

The air flows downward at 1 m/sec. (3.3 ft./sec.) from top vents and flows out at floor level. Every row has its own vents. That the air flows vertically, not horizontally, limits the probability of virus dissemination.

“If you sneeze, droplets will be sucked away and in 1 min., there will be nothing left around you,” says Dumont.

A computational fluid dynamics model by Ansys analyzes the example of a passenger wearing a mask and sneezing. It shows that few droplets make it through the mask and barely come close to any other passenger.

Despite the already high performance of HEPA filters, Dumont considers also requiring more frequent maintenance checks. ❁

# New Research and Technologies Fuel Single-Pilot Operations Debate

> EU-FUNDED PROJECT SETS ONE CREWMEMBER AS THE GOAL

> NASA RESEARCH ADVOCATES FOR HUMAN CONTRIBUTIONS TO SAFETY

**Thierry Dubois** Lyon

**T**he reduction in cockpit crewmembers has long seemed inevitable. But the divergent view that a minimum of two human beings should remain on the flight deck is gaining traction. Bolstered by recent research, some safety experts are now more comfortable with that conclusion or at least urge further study.

The existence of the two conflicting approaches means a potential move to single-pilot operations is unlikely in the near future and will be preceded by continued debate. In other words, the jury is still out on how many seats will be occupied in future commercial aircraft cockpits. Regardless, a positive outcome of the dialog may result: a better understanding of human performance under adverse conditions.

Airbus has been a longtime proponent of cutting—possibly to zero—the number of pilots in the flight deck. The stance taken by the airframer’s safety experts is that more automation results in fewer accidents.

However, without changing their minds, company officials have been increasingly careful about the use of automation, also emphasizing for almost a decade that piloting skills should be retained.

Airbus has been working on a “disruptive cockpit” (DISCO) project within the framework of Europe’s Clean Sky technology initiative. Its aim is clearly stated: “We are working toward single-pilot operations, and that means we need to develop all the necessary core enabler technologies,” says Sebastien Dubois, acting head of unit for the Clean Sky 2 program. Under the research project’s objectives, technology will manage the functions and operations that are more suited to automation, freeing the pilot to “focus on tasks where human judgment, experience and piloting skills add better value,” he says.

Despite the adjective “disruptive” in DISCO, Airbus executives are relatively cautious in their wording, probably to avoid upsetting pilot unions. “We believe the time will come for a

future cockpit to be operated by a single pilot while ensuring that today’s unprecedented levels of aircraft safety are continuously raised,” says Pascal Traverse, general manager for autonomy thrust. “We always work on technologies that give time to pilots and provide them with information in the best way possible for them to analyze the situation and make a decision.”

For Traverse, the reason to move to single-pilot operations would essentially be to address pilot shortages. It is seen as one of the key challenges of the future, along with “enhancing operations,” he says.

For carriers, enhancing operations may translate into cutting operating costs. This is the motivation for reducing the number of crewmembers, according to Bertrand de Courville, a flight-safety consultant. A retired Air France captain, Courville is a member of the Toulouse-based Air and Space Academy and the International Society of Air Safety Investigators.

“The airframer who could offer a cockpit with such capability would have a competitive edge,” he says.

A number of technologies are being studied under DISCO. The schedule calls for reaching the proof-of-concept stage, or technology readiness level (TRL) 3-4, by early 2021. A maturing phase, up to TRL 4-5, would last until 2023, according to Dubois.

Work on single-pilot operations under Clean Sky began in 2014.

A key aim of DISCO is to minimize pilot interruptions—such as dealing with failure management or adverse weather conditions, says Dubois. The project more generally aims to reduce pilot workload by taking advantage of technologies such as artificial intelligence (AI), voice recognition and digitalization. The pilot’s role may thus evolve from flying an aircraft toward managing a mission, he says.

A higher level of automation during the landing and taxiing phases is envisaged. New ground-collision avoidance systems are being developed to con-



firm a runway or taxiway is free from obstacles, says Dubois. The weather radar may help.

An instrumental tool for situational awareness may be a head-worn display with see-through-aircraft-skin synthetic vision capability.

A lidar-based sensor may improve speed measurement by making it independent from possible icing conditions. The sensor may have other applications, such as cloud description, wind shear detection and icing-conditions warning. Flight testing is planned for this year.

For communication with air traffic control, tools may include voice recognition and voice-to-text conversion.

Single-pilot operations entail detecting pilot incapacitation or problems such as high workload or stress. Input to gauge those may come from eye-tracking cameras, a pulse sensor or body temperature sensor, says Dubois. Some of the devices could be integrated into the seat to avoid being intrusive.

What if the pilot, alone in the cockpit, is incapacitated? Avionics



S. FRAUENR/ARBUS

tion system this past December and January in Toulouse. On April 24, Airbus conducted the first fully automatic vision-based taxi, takeoff and landing in a single flight.

At the heart of the system are a camera, image processing algorithms and a control law. The system detects converging vanishing lines and deduces the runway's centerline.

ATTOL's software uses machine learning, an AI process that is not yet certified. In a future cockpit, "conventional algorithms may run in parallel, and the outcomes of the two would have to correlate," says Traverse.

The European Union Aviation Safety Agency in February released the first edition of its "Artificial Intelligence Roadmap," a document that begins to answer OEMs' questions on how to certify an AI-based system. The road map focuses on machine-learning techniques, which are data-driven and so cannot be assessed through a conventional approach. They lack predictability and explainability.

In single-pilot operations, a more capable autopilot would be needed. It would have to be permanently available, even in conditions such as crosswinds or an out-of-order instrument landing system says Traverse. Reliability would have to be raised to the same level as fly-by-wire controls.

Pilots would have to trust future systems even more than they do current ones. So designers may have to rethink the way a system presents calculation results. Thales' in-development PureFlyt flight management system (FMS) will better "explain" its actions. It can share low levels of calculation, to an extent to be determined with the airframer.

Traverse emphasizes DISCO is not only about systems. "In human-machine interfaces, an equation will not give us the right ergonomics," he says. "We rely on humans—test pilots, instructors, airline pilots and our human factor experts, who assess pilot behavior."

He sees single-pilot operations as first becoming a reality for relatively short flights up to 2.5 hr. "In some instances, such as complex missions, poor weather and aircraft entry into service, two pilots would still be required," he adds.

Despite repeated requests, Boeing did not reply to Aviation Week's questions.

### While Airbus is making progress in reduced-crew operations technology, human performance is being reassessed.

manufacturer Garmin has designed an emergency autoland system for business aircraft that is now being installed in light turboprops.

A guarded red button has been added to the flight deck layout, within easy reach of passengers. When pushed by anyone—including the pilot—it activates the autoland function.

Fred George, Aviation Week's chief aircraft evaluation editor, has tried it (*AW&ST* Nov. 11-24, 2019, p. 40) and says: "This is essentially a virtual, digital co-pilot that can take over control of the aircraft, evaluate winds, weather and fuel reserves, then select a suitable divert field and fly the aircraft to the best runway at the landing facility." The feature uses GPS for navigation.

Would it be relevant to use a comparable system in a commercial aircraft? The short answer is yes, according to Dubois and Traverse.

"The system does not have the required level of integrity, but a com-

parable function may be used," says Dubois. "To make such a system compatible with commercial aviation's standards, data fusion would have inputs from the GPS, weather radar and inertial reference systems." DISCO includes such work.

In a commercial aircraft (as opposed to a small business turboprop), the pilot would have the final say, such as choosing not to land in a hostile country.

Traverse sees an application for a technology Airbus has been demonstrating. "In principle, the use of a system [comparable to Garmin's Autoland] is relevant. However, we are targeting a level of safety that requires [combining] GPS and image recognition," he says.

Airbus has been testing an Autonomous Taxi, Takeoff and Landing (ATTOL) system. A modified A350-1000 performed automated takeoffs and landings using an image recogni-

Before embarking on development of a single-pilot commercial aircraft, the cost of the required additional systems would have to be evaluated (*AW&ST* Nov. 11-24, 2019, p. 44).

In the meantime, how about deeper studies on what a pair of pilots do well? That is the focus of a NASA research paper, published in November 2019, which aims to document human performance contributions to safety in commercial aviation.

The countless correct judgments pilots and controllers perform every day are often the difference between an accident and a nonevent, says lead researcher Jon Holbrook. “Ironically, data on these behaviors are rarely collected or analyzed,” he says.

On the contrary, large volumes of data are collected on the failures and errors that result during infrequent incidents and accidents. This is like trying to understand the key to a successful marriage by studying divorces, as the saying goes in the academic world.

The whole issue is increasingly critical, as a growing number of projects focus on increased automation and autonomy and decreased human involvement, including at NASA, says Holbrook. “Without understanding how humans contribute to safety, any estimate of predicted safety of autonomous capabilities is incomplete and inherently suspect,” he says.

To explore “positive” behaviors that contribute to resilient performance in commercial aviation, Holbrook’s team examined a range of existing sources of data about pilot and controller performance, including interviews with domain experts and aircraft flight data records. These subjective and objective data were used to identify strategies that support resilient performance.

Defining safety in terms of “things that go right” enabled new methods of exploring existing data. Operators (pilots and controllers) were able to reflect on and provide specific examples of resilient behaviors, according to the paper. Evidence of the use of operator strategies that promote resilient performance were identified in objective data.

Among the identified strategies was predicting when the current context inhibits the normal use of a procedure, regulation, policy or norm.

“To improve safety, system designers should understand what

humans do well and create systems with this understanding in mind,” say Holbrook and his team. “Systems can be designed to ensure the ultrasafe airspace system is not unintentionally made less safe due to loss of resilient properties that are provided by human operators and are not well-understood.

“Things do not go well because people follow rules and procedures,” he says. “Rather, things go well because people exhibit performance variability and make sensible adjustments and adaptations in response to interpretation of what is happening and the demands of the situation.”

This is also consultant Courville’s point, an emphasis on the strong points of human performance. “It

### A human attribute often seen negatively may help: Fear.

A pilot may see a threat and fear its consequences.

can be summarized as a cognitive tradeoff,” he says. That term describes how a human can find a solution rather quickly—but with a risk of poor assessment or misunderstanding. “The capacity to adapt has two aspects: We are fast, we get to the heart of the matter, but sometimes we make mistakes. These are two faces of the same coin. This is normal in human activity,” he says.

“Therefore, seeing the existence of mistakes as regrettable is wrong,” says Courville. “We [make] mistakes because we are otherwise good. The idea of eliminating mistakes, such as in a ‘total war on error,’ is a bad one. If we accept errors, we can better deal with them and build defenses against them. Otherwise, we lose key human qualities.”

Threat and error management is a valuable part of a preflight briefing, says Courville. The crew discusses the most likely errors and how to detect and correct them. “We must accept, detect and mitigate errors,” he says.

Taking into account human factors is critical in system design. An incorrect weight input into the FMS can cause a problem at takeoff. “The mistake should be detected by the FMS,”

notes Courville. “A system designer must accept that there will be errors. Interfaces have yet to progress in robustness.”

Before considering single-pilot operations, should not team work in the flight deck be more valued? “In safety, we are getting close to a sort of optimum. . . . We have made good progress in the way two crewmembers make decisions and correct errors,” says Courville. “There are examples in other industries where people do not make decisions on their own.”

Airbus’ Traverse notes that the airframer does measure crew performance: “Of course, we [must] first understand where humans are relevant, what they are capable of and how we should help them. Our aircraft have two-pilot crews. We analyze incidents in operation and have a large database about what’s happening with our aircraft.”

There may also be value in making a decision onboard, as opposed to a choice made by an operator on the ground. The crew can assess risks in real time, including ending a dangerous situation by choosing to go around or divert.

“A person working remotely, or an algorithm, will find it more difficult to cope with a complex situation in limited time,” says Courville. “As a pilot, when you are in flight, you have great independence—no one will reproach a pilot [for] making a diversion. Will this independence be the same on the ground, where influences could be different?”

Moreover, to advance safety, the human being in the cockpit can be seen as a sensor, he adds. This role is all the more important in feedback processes, as there are fewer and fewer accidents to learn from.

In addition to error, another human attribute that is most often seen negatively may help: fear. A pilot may see a threat and fear its consequences, says Courville. “You cannot put numbers on fear and risk perception. People who are never afraid are dangerous.”

Courville nevertheless sees some automation features as progress. On the A350, the automated emergency descent feature in case of depressurization is a benefit, he says. “The sequence is always the same: The workload and the level of stress are high, and there is the risk of losing consciousness.”

# SIMPLE APPROACH

> SIMPLIFIED DESIGN IS OPTIMIZED FOR RELIABILITY

> INITIAL MISSION IS MANUFACTURED ORGAN DELIVERY



The ALIA eVTOL has a high-aspect-ratio wing for cruise efficiency.

Graham Warwick Washington

ERIC ADAMS

**W**hen secretive Beta Technologies had to move its new prototype to a more expansive location to begin flight testing, the U.S. startup decided concealment was not an option. So its ALIA electric air taxi was introduced to the world on June 12 with a spectacular helicopter airlift across Lake Champlain.

The winged all-electric vertical-takeoff-and-landing (eVTOL) aircraft was transferred by air from Beta's home base at Burlington International Airport in Vermont, where it had completed taxi and tethered-hover testing, across the lake to Plattsburgh International Airport in New York.

Operating from what was once a Boeing B-52 bomber hangar at Plattsburgh, Beta plans to conduct flight and transition testing from the sprawling former Strategic Air Command air base, where the single 12,000-ft.-long by 200-ft.-wide runway sees only a handful of commercial airline flights a week.

With four lift rotors on twin booms for vertical flight and a 50-ft. wingspan and pusher propeller for forward flight, the piloted aircraft is one of three full-scale engineering prototypes being built by the startup. The 6,000-lb. gross-weight eVTOL vehicle is designed to carry 200 ft.<sup>3</sup> of cargo or six people.

The ALIA is being developed with funding support from United Therapeutics, which wants a vehicle able to deliver manufactured organs for human transplants. It requires a vehicle able to fly two people 250 nm on a single battery charge and recharge in under 1 hr.

Demonstrating the 250-nm range objective with the engineering prototype on available batteries is a key goal of flight testing from Plattsburgh, says Beta team member Tom O'Leary. The range target is close to that provided by an equivalent 6,000-lb. helicopter, he notes.

Beta is also working for the U.S. Air Force's Agility Prime program office under a small business innovation

research contract. Under the current phase, the startup will deliver a flight-test report on the ALIA prototype. Negotiations are underway on a follow-on contract involving additional prototypes. In addition to support from United Therapeutics and Agility Prime, Beta has funding from private investors, O'Leary says.

Beta previously flew the Ava XC eVTOL technology demonstrator. This was a modified Lancair ES kitplane fitted with a wing and four pairs of tilting coaxial rotors. But the goal with the ALIA was to simplify the design to provide reliability for organ delivery, says O'Leary.

The lift rotors are optimized for vertical flight and the pusher propeller for forward flight, to avoid performance compromises. All are fixed-pitch for simplicity. The performance of the lift rotors in flight testing is one of the key areas of interest for Beta, he says.

The four lift rotors are powered by dual-wound electric motors, with redundant inverters and batteries for safety. The lift rotors stop and align longitudinally in forward flight to reduce drag. When stopped, the rotors are tilted up about 3 deg., which is their minimum-drag alignment, O'Leary says. The batteries are housed below the cabin, to lower the center of gravity and improve flight stability.

The aircraft has a sailplane-like high-aspect-ratio wing for cruise efficiency. Control in vertical flight is via the lift rotors. In forward flight, control is provided by ailerons on the wing, elevators on the horizontal tail, and rudders on the vertical fins at the tip of the horizontal tail—which is connected to the wing by the twin booms.

Based on flight testing of the engineering prototypes, Beta will build further production-conforming aircraft for FAA certification flight testing. The startup is not providing a timeline for certification and production, but O'Leary says 2023 "is not unrealistic." 🛩️

# NOT SO FAST



- > USAF PROGRAM ONE YEAR LATE, 39% OVER BUDGET
- > FOCUS SHIFTS FROM SCHEDULE TO PRODUCTION READINESS
- > AIR-LAUNCHED OPTIONS SEEK TO MAXIMIZE LOAD-OUT

TIERSON/SHUTTER

**Steve Trimble** Washington

**B**y the stroke of a pen on May 3, 2017, Lisa Disbrow, then-acting Air Force secretary, ushered the U.S. military into the weaponization age of hypersonic flight by authorizing development of the Air-Launched Rapid Response Weapon (ARRW).

The key word in that name is “weapon.”

In each of the previous seven decades, the Defense Department had tested hypersonic vehicles but only as X-planes and demonstrators. This time, it was different. After Russia and China had established a clear lead over the U.S. in a series of breakthrough flight tests staged between 2014 and 2016, the Air Force decided to start fielding a new set of maneuvering hypersonic weapons.

In 2020, the Pentagon’s portfolio of offensive hypersonic programs has metastasized with an annual budget averaging about \$2 billion, which spans air-, land- and sea-launched missiles using two different forms of propulsion.

Not that everything has gone strictly according to plan.

In April, the Air Force canceled the second air-launched missile program, which was called the Hypersonic Conventional Strike Weapon (HCSW). Meanwhile, DARPA planned to fly the Tactical Boost Glide (TBG) demonstrator in 2019, but it still has not flown yet.

TBG and ARRW share a common design, so the early operational capability (EOC) milestone for ARRW also is delayed by at least a year, to September 2022. The delays increased the costs for the ARRW program, which the Air Force partly offset by canceling HCSW.

The delays are also a result of a new strategy. The original plan focused on ushering operational prototypes through the flight-test phase as quickly as possible, allowing the services to declare an EOC with a handful of left-over spare missiles. A new strategy, adopted since 2019, accepts a lengthier schedule for the air-launched missile flight-test programs such as ARRW in exchange for design changes and supply-chain decisions, thereby shortening the production cycle.

“I would say that some of the changes you are seeing are coming from the fact that we said, ‘We want both of these programs to roll into actual production systems,’” says Mark Lewis, the Defense Department’s director of research and development for modernization. “So we’ve been thinking

**The Lockheed Martin AGM-183A represents the most advanced—and risky—hypersonic missile configuration: an air-launched weapon with a high lift-to-drag-ratio glide body.**

through what things we need to do with these DARPA programs to maximize the return on investment.”

Specifically, DARPA’s TBG program is the risk-reduction program for two different versions of ARRW. The first ARRW design scheduled to become operational is the Lockheed Martin AGM-183A. But Raytheon is developing a different design to meet the ARRW requirement, which the company says will be more advanced.

Likewise, DARPA selected Lockheed and Raytheon versions of a scramjet-powered cruise missile. Both versions of the Hypersonic Air-Breathing Weapon Concept (HAWC) were expected to enter flight testing in 2019 but fell behind schedule. Most recently, the Lockheed version of HAWC was destroyed during a captive-carry flight test that is now under investigation.

“The question now across the board over all our hypersonic programs is, how do we maximize the utility of these [DARPA] programs so they give us the information we need?” Lewis asks. “Our goal is delivering hyper-

sonics at scale, and that can change the nature of your program. If you're doing an exploration program for exploration's sake—and I'm not taking anything away from those programs at all—that's somewhat different than if I'm doing a program that's feeding data into a follow-on effort with specific goals and requirements.

"So we are looking at our programs and saying, if the data from program X leads to the follow-on program Y, then how do we make sure that all of the data we get out of program X is of value to program Y? And conversely, if it isn't, then we need to rethink the investment. That's the mindset we are applying across the portfolio," Lewis says.

For ARRW, the impact of the philosophical shift has been dramatic. In March 2019, a set of "changing program circumstances" increased costs by 39%, to \$1.16 billion, the Government Accountability Office (GAO) reported in June 2020. The GAO did not elaborate, but the percentage increase implies an original budget of about \$836.5 million.

The road to an EOC milestone by the end of fiscal 2022 now includes little margin for error. The Air Force originally called for Lockheed to achieve the EOC milestone in August 2021, or 36 months after the contract award. But the schedule delays have pushed the first of four planned flight tests of the Lockheed version of ARRW to October 2021, with the fourth sortie now scheduled for September, the last month of fiscal 2022.

Adding to the schedule pressure for ARRW is the sheer technological ambition of the program.

To be sure, each of the weapons in the Pentagon's hypersonic weapons portfolio face challenges. The Common Hypersonic Glide Body (C-HGB) seeks to build a common airframe with intermediate range that can be launched from a submarine under the Navy's Conventional Prompt Strike (CPS) program and a mobile ground launcher under the Army's Long-Range Hypersonic Weapon (LRHW) program. The Air Force's planned operational follow-on to DARPA's HAWC program will attempt to transition scramjet propulsion from experimental to operational status.

The C-HGB and HAWC programs, however, are building on successful flight experiments. The Air Force successfully tested the scramjet-pow-

ered Boeing X-51A in 2013, flying for 210 sec. and achieving a top speed of Mach 5.1. The C-HGB is a derivative of the Army's Advanced Hypersonic Weapon (AHW), which itself was based on the Sandia Winged Energetic Reentry Vehicle Experiment.

The latter completed three successful flights in 1979-83. The Army revived the project in 2006, leading to a successful test of the AHW in 2011 and a failed test in 2014 due to a booster malfunction. The Navy adapted the AHW for ship launching and staged another successful test in 2017. Three years later, this past March, the Block 0 version of the C-HGB completed another successful flight, allowing the Army and Navy to proceed with developing a Block 1 All-Up Round.

By contrast, TBG and ARRW have no experimental flight-test record to build upon. Although these air-launched missiles share the rocket-boosted glider configuration of the C-HGB, there is a crucial difference. The C-HGB is based on a biconical, axisymmetric design, which rotates on its axis during flight to dissipate heat. The designs for TBG and ARRW are more advanced wedge-shape gliders. While the C-HGB achieves a lift-to-drag ratio of about 2.4-2.6, TBG and ARRW are expected to fall into the 3.0-3.3 range.

The only recorded attempt to test a hypersonic glider with a lift-to-drag ratio as high as ARRW ended in failure. During two flights staged in 2010 and 2011, DARPA's Hypersonic Test Vehicle (HTV)-2 successfully separated from the booster, but the onboard flight-termination system commanded both gliders to self-destruct after they lost control.

With HTV-2, DARPA sought to demonstrate a global hypersonic weapon with ultimate performance. By comparison, the Army's axisymmetric AHW seems modest. The AHW was designed to demonstrate a maximum speed of Mach 8 and a range to target of 3,500-5,000 mi., including a cross-range capability of 1,200-1,700 mi., according to a 2014 analysis by Sandia National Laboratories, the manufacturer of the glide vehicle. DARPA set a goal for the HTV-2 to fly faster than Mach 20, with a range to target of 10,000 mi., a cross-range capability of 3,300 mi. and an accuracy of 10 ft. or less.

At those speeds, the HTV-2 would have glided for an extended period



U.S. AIR FORCE

## Tactical Boost Glide/ Air-Launched Rapid Response Weapon Timeline

The most advanced air-launched hypersonic weapon in development currently is a joint effort between the DARPA Tactical Boost Glide (TBG) and the Air Force Air-Launched Rapid Response Weapon (ARRW).

**March 2014** DARPA launches Tactical Boost Glide (TBG) program.

**Sept.-Nov. 2014** DARPA awards TBG Phase 1a contracts to Boeing, Lockheed Martin and Raytheon.

**April-May 2016** DARPA eliminates Boeing from TBG competition, awards Phase 1b contracts to Lockheed and Raytheon.

**May 9, 2016** DARPA selects Lockheed for the TBG Phase 2 contract, eliminating Raytheon.

**May 3, 2017** U.S. Air Force approves requirement for TBG-derived Air-Launched Rapid Response Weapon (ARRW).

**Aug. 13, 2018** Air Force selects Lockheed to develop AGM-183A ARRW.

**March 2019** DARPA selects Raytheon to develop second TBG demonstrator.

**March 2019** Air Force cancels Hypersonic Conventional Strike Weapon, diverts funding to cover new, 39% ARRW cost overrun.

**June 2019** Air Force performs first captive-carry test of Lockheed TBG/ARRW all-up round.

**2020** DARPA plans first TBG flight test in 2020.

**Oct. 2021** Air Force expects first of four flight tests of AGM-183A ARRW.

## U.S. Hypersonic Programs

	Launch Mode	Configuration	Contractor	In-Service Date	
<b>OPERATIONAL PROTOTYPES</b>					
	AGM-183A Air-Launched, Rapid Response Weapon (ARRW)	Airborne	Single-stage booster, glider	Lockheed Martin	Fiscal 2022
	High-Speed Air-Breathing Weapon Concept follow-on	Airborne	Single-stage booster, scramjet-powered missile	Undecided	Unknown
	Long-Range Hypersonic Weapon	Land	Two-stage booster, glider	Lockheed Martin	Fiscal 2023
	Conventional Prompt Strike	Sea	Two-stage booster, glider	Lockheed Martin	Fiscal 2025
<b>DEMONSTRATORS</b>					
	Tactical Boost-Glide (TBG)	Airborne	Single-stage booster, glider (same as ARRW)	Lockheed Martin, Raytheon	N/A
	Hypersonic Air-Breathing Weapon Concept	Airborne	Single-stage booster, scramjet-powered missile	Lockheed Martin, Raytheon	N/A
	Operational Fires	Land	Two-stage booster, throttleable upper-stage, TBG glider	Lockheed Martin	N/A

Source: U.S. Defense Department

inside a ball of flame up to 3,500F, requiring the use of expensive materials. DARPA never released the dimensions for the HTV-2, but internal dimensions of the launcher’s payload assembly limit its length to no greater than 50-60 in.

Three years after the second failed HTV-2 test, DARPA launched the TBG program to demonstrate a glide vehicle with a similarly high lift-to-drag ratio but sought a more compact form factor for the all-up round with less overall performance. By 2016, DARPA selected Lockheed to demonstrate the first TBG flight by 2019. At the same time, DARPA officials, including then-Deputy Director Steven Walker, counseled the Air Force to wait until after the first flight of TBG before launching the development of an operational air-launched missile.

The Air Force decided seven months after Walker’s warning that it could not wait any longer, leading to Disbrow’s go-ahead decision for the ARRW in May 2017.

“I think people underestimate the importance of this decision of the Air Force,” says Mike White, director of hypersonic programs for the Pentagon’s research and engineering branch.

“For the hypersonic community, we’ve always been kind of stuck in the [research and development] realm,” White says. “The Air Force, in 2017, [was] the first service that said, ‘Hey, we want hypersonic weapons.’”

The Army and Navy took longer to decide to weaponize AHW but not by much. In November 2017, the Navy completed a successful flight test of an AHW modified to be launched from a submarine or ship in Flight Experiment-1. The Army and Navy agreed on a plan to convert AHW into the C-HGB for LRHW and CPS with a two-stage, 34.5-in. booster stack. The Air Force’s short-lived HCSW also planned to use the C-HGB but with a 32-in., single-stage booster.

“Once we flew the FE-1, the interest started to peak,” White says. “Then we got service interest in transitioning [experimental hypersonic technology into operational weapons].”

The green light to begin developing the ARRW and C-HGB front ends also launched the development of a family of new booster rockets. To field operational weapons, services could no longer rely on the hand-me-down booster rockets employed for the Army’s AHW and DARPA’s HTV-2, which used derivatives of a retired Polaris missile and a Peacekeeper missile, respectively. Less is known about the size and performance of the boosters, but White confirmed a 34.5-in.-dia., two-stage booster stack for the C-HGB. The diameter of the single-stage rocket for ARRW has not been released, but it is smaller.

“When you live in the technology world, you can kind of pick and choose

boosters that are off the shelf,” White says. “But when it comes to fielding a real weapon, you have to integrate with launch platforms. You would like to maximize performance within the weight and volume constraints of the launch platform.”

The load-out volume for an aircraft has emerged as a key issue. The HCSW cancellation freed up funds to cover the fiscal overrun on ARRW and launch the development of an operational prototype of HAWC, but the decision also reflected a move by the Air Force away from larger hypersonic weapons.

“HCSW weighs 12,000 lb. and the front end is about 10% of that,” White says. “So you have to figure out, OK, what can I fit on a B-52?”

For HCSW, the answer was “not enough.” But the smaller ARRW offers more flexibility for the Air Force’s launch platforms while providing similar trajectory options for a rocket-boosted glide vehicle. The Air Force plans to install six AGM-183As externally on each B-1B bomber, and service officials hope to keep it small enough to launch from a fighter such as a Boeing F-15EX. In February, Boeing provided a clue about the limits of the F-15E’s weapons load-out. A model of the F-15EX displayed at the Air Warfare Symposium included a surrogate hypersonic all-up round on the centerline weapon station, with a length of 270 in. and a mass of 7,300 lb.

Models, renderings and rare glimpses of captive-carry tests remain the only sightings of the Pentagon’s air-launched hypersonic weapons portfolio. The successful Flight Experiment-2 staged in March shows the Army’s LRHW is on track to enter service as scheduled in 2023, followed by the Navy’s CPS in 2025. The Air Force’s turn to enter the flight-test phase is next, with the delayed rocket-boosted TBG and scramjet-powered HAWC launches still planned for this year.

“We’re really very confident,” Lewis told reporters during a March news conference. “I don’t want to misrepresent the fact there’s still development underway. But we have tremendous confidence in the ability of this technology to perform as expected.”



**Check 6** Aviation Week editors discuss hypersonic technologies pushing the laws of physics and budget limits: [AviationWeek.com/podcast](https://www.aviationweek.com/podcast)



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DARPA

## U.S. Hypersonic Defense Plan Emerges, but Cash Does Not

- > SPACE-BASED HYPERSONIC TRACKING IS POSSIBLE IN 2023
- > NEW, SEA-BASED INTERCEPTOR MAY BE READY BY MID-2020s

**Steve Trimble** Washington

**A** U.S. hypersonic defense system has evolved from wide-open concept studies two years ago into a densely layered architecture populated by requirements for a new generation of space-based sensors and ground-based interceptors.

Over the next two years, the first elements of the Defense Department's newly defined hypersonic defense architecture could advance into operational reality if all the pieces can overcome various challenges, including the Pentagon's so far ambiguous commitment to long-term funding.

The Space Development Agency (SDA), with assistance from the Missile Defense Agency (MDA) and the Defense Advanced Research Projects Agency (DARPA), next year will start launching satellites into orbit with new forms of tracking technology optimized to perform the challenging task of remotely targeting hypersonic missiles as they maneuver in the atmosphere hundreds of miles below.

At the same time, the MDA and DARPA will soon begin demonstrating a new class of kinetic and nonkinetic interceptor technologies. In addition to solving the guidance and thermal challenges posed by hypersonic flight, this new class of missile defense weapons must be guidable by satellites

potentially perched far over the horizon, not by sensors integrally linked on the ground to their launching systems.

Pentagon officials began conceiving a hypersonic defense architecture a year after launching multiple offensive weapon programs in 2017, seeking to close gaps in the ballistic defense system that missiles now fielded by adversaries are designed to exploit.

With the ability to maneuver hundreds of miles off a ballistic trajectory, hypersonic glide vehicles (HGV) and cruise missiles are designed to evade the MDA's network of stationary ground-based and slow-moving sea-based radars dotted around the globe. By gliding or powering through the atmosphere against the warm background of Earth, the same missiles appear 10-15 times less luminous during the midcourse phase than the boost-phase, exoatmospheric objects that the MDA designed the Space-Based Infrared System (SBIRS) satellites to detect, according to Michael Griffin, the undersecretary of defense for research and engineering.

Closing those gaps will require serious investment. Despite plans to infuse more than \$10 billion to field at least three different rocket-boosted HGVs by 2025 as offensive weapons, the Pentagon's financial commitment to field

### A new space sensor layer planned for 2024 could provide target-quality tracks for hypersonic defense.

a defensive capability is not as clear.

The MDA, for example, submitted a fiscal 2020 budget request in February 2019 that included around \$157 million in hypersonic defense. A month later, the agency submitted an unfunded-priorities list to Congress, asking for another \$720 million for hypersonic interceptors and tracking sensors. Congress met the MDA more than halfway, adding \$400 million to the final appropriations bill.

A similar shortfall then appeared in the MDA's fiscal 2021 budget request. The agency included \$207 million for hypersonic defense but asked Congress to chip in another \$224 million on top of the budgeted amount, according to a March report by the Center for Strategic and International Studies' (CSIS) Missile Defense Project.

Moreover, the Defense Department's long-range forecast for hypersonic defense spending shows an ambiguous commitment at best. The MDA plans to launch a competition to select a Regional Glide-Phase Weapon System (RGPWS) in fiscal 2021 but only if Congress approves the additional \$224 million identified in the unfunded priorities list. At the same time, the new SDA plans to start demonstrating MDA's Hypersonic Ballistic Tracking and Surveillance System (HBTSS) alongside the SDA's own tracking layer in orbit.

But the unclassified version of the Future Years Defense Program, which details the Defense Department's five-year spending forecast, shows declining support for hypersonic defense after next year. If Congress approves the extra \$224 million for MDA, hypersonic defense spending would peak at around \$450 million next year, then average about \$112 million annually from fiscal 2022 to 2025, according to the CSIS data. The implication seems clear: Despite the MDA's public commitment to a hypersonic defense system, the agency prefers to finance the development mainly by annual congressional add-ons.

Although the MDA's long-term funding plan for hypersonic defense is limited, the potential threats are no longer speculative. In December, the Russian government announced it had achieved operational status for the Avangard, a nuclear-tipped HGV

launched by a modernized SS-19 intercontinental ballistic missile.

Two months earlier, Gen. Paul Selva, then-vice chairman of the Joint Chiefs of Staff, explained the implications of an adversary with a nuclear-armed HGV: Imagine if NATO attempted to blunt a move by Moscow to occupy a Baltic state, and Russian strategic forces responded by threatening to launch an Avangard missile. The now-retired general warned that a single Avangard could arc over the Arctic Ocean, and as it reached the northern tip of Hudson Bay, Canada, could change course. It could then veer to target the U.S. East Coast or strike the West Coast, Selva says. U.S. forces currently have no ability to deter or defend against such a capability.

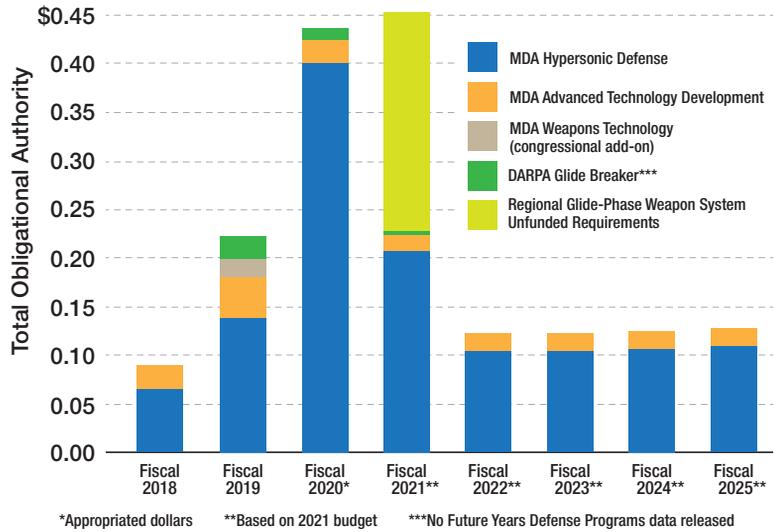
To solve that problem, a new space-based tracking system is needed. The Pentagon's existing satellites are either looking for a more luminous signal than that of an HGV or a hypersonic cruise missile or are using a very narrow field-of-view sensor to minimize background clutter, says SDA Director Derek Tournear, who spoke with Aviation Week during a June 4 webinar.

The first attempt to solve that problem is scheduled for launch in fiscal 2024. Forty satellites in SDA's Tranche 1 constellation in low Earth orbit carry sensor payloads for tracking hypersonic missiles. Unlike the SBIRS or other space-based capabilities, the sensors will neither have a narrow field of view nor be optimized for tracking only during the boost or exoatmospheric phases of a missile's trajectory. Instead, the spacecraft in Tranche 1 will carry a wide-field-of-view infrared sensor.

"However, the jury is still out on whether [the sensors] will be able to form a track that is high enough quality to actually give you that fire control solution so that you can fire [interceptors] on [a] remote [track]," Tournear says.

The backup to the SDA sensor will be demonstrated under MDA's HBTSS program. The MDA is developing what Tournear calls a medium-field-of-view system, which falls between the narrow-field-of-view format of existing satellites and the SDA's wide-field-of-view design for Tranche 1. Ideally, the SDA's wide-field-of-view sensors will detect an HGV or a cruise missile and pass the data in orbit to the HBTSS sensors, which will then develop a target-quality

## Defense-Wide Hypersonic Defense Budgets, 2018-25 (in 2021 U.S. \$ billion)



Source: Center for Strategic and International Studies

track. That data will be passed down to interceptor batteries on the ground.

Within a few years, the SDA will find out how the concept works. By the end of 2022, eight Tranche 0 satellites equipped with the SDA's wide-field-of-view sensors should be in low Earth orbit. A year later, the MDA plans to launch two satellites into low Earth orbit with medium-field-of-view sensors. The Tranche 0 constellation—aided by

catch, however. The launch of the Tranche 1 satellites in 2024 fall within the five-year spending plan but so far remain unfunded.

Shortly after the scheduled Tranche 1 layer is activated, the MDA plans to field RGPWS, the new interceptor optimized for HGVs. If Congress adds the funding, RGPWS could be fielded as early as the "mid-2020s" with the Navy's Mk. 41 vertical launch systems on ships and submarines, followed later by air- and land-launched versions. The design requirements for RGPWS are classified, but it's possi-

### Modified interceptors such as the Terminal High-Altitude Area Defense will augment new kinetic and nonkinetic options to shoot down hypersonic missiles.

ble the interceptor may benefit from an ongoing DARPA program. Glide Breaker, which includes Aerojet Rocketdyne as a supplier, seeks to demonstrate a "critical enabling technology" for a hypersonic defense missile. The MDA also plans to demonstrate an "extreme power" microwave weapon against "very long-range" missile threats within two years.

At the same time, the MDA is adapting existing point defenses against atmospheric threats. Lockheed Martin is studying improved versions of the Terminal High-Altitude Area Defense system, called "Dart," and of the Patriot, called "Valkyrie." In addition to the extreme power microwave, Raytheon also is studying a new variant of the SM-3 called Hawk. 🚀



MISSILE DEFENSE AGENCY

20 communications-relay and data-processing "transport" satellites—will provide a limited operational capability and validate that the sensors work as designed.

The next step comes in 2024, when the SDA plans to launch the 40 satellites in the Tranche 1 constellation. "We would have, in essence, regional persistence of [infrared satellites] over any area of the globe that we choose," Tournear says. There is a

# HYPER HURDLES

> “JURY STILL OUT” ON SCRAMJET ALTERNATIVES FOR LARGER VEHICLES

> FLOW-PHYSICS UNCERTAINTIES AND MATERIALS REMAIN KEY HURDLES

**Guy Norris** Los Angeles

**A**fter decades of promise the age of operational hypersonic vehicles is dawning, and concepts once considered the stuff of science fiction or the fanciful predictions of military planners are about to become reality.

The first generation of U.S. tactical boost-glide and air-breathing strike weapons are in development and will be fielded within a few years. But proponents say much more work still needs to be done before larger, next-generation designs can harness the advantages of flight speeds of Mach 5-plus for broader roles including strike and reconnaissance, high-

speed civil and military transport and even multistage access to space.

In addition to first-order issues such as propulsion type selection and the complex coupled optimization of propulsion and airframes, designers must also contend with challenging changes in flow physics with varying Mach numbers. Added to the continuing quest for exotic materials with such high-temperature resistance that they have yet to be invented, the list of hurdles remains as daunting as ever.

Tests of rocket-boosted hypersonic glide vehicles and early air-breathing scramjet-powered demonstrators have, however, given today’s devel-



opers a solid foundation of the basic high-speed aerodynamics and propulsion requirements. “The good news is there is now zero doubt that a scramjet can be built and can produce net positive thrust,” says Mark Lewis, director of defense research and engineering

## Key challenge areas for Air-Breathing Hypersonics





U.S. AIR FORCE

**The X-51A proved scramjets work. Now the challenges include producing robust hypersonic weapons in quantity as well as scaling up the technology.**

the ultimate vision of developing reusable hypersonic aircraft will require a huge effort, says Lewis. “There’s a lot to do there in terms of the engine-airframe integration, particularly the propulsion transition,” he says. “We need a propulsion system that gets us all the way from zero all the way up to Mach 5 or 6 and then back down to zero. That’s one we’re still working on. The big question is, should it be a combined cycle engine or multiple engines? Can I go direct from a turbine to a ramjet/scramjet, or do I need something intermediate?”

As the upper operating limit for turbine engines is around Mach 3 or 4, the focus for developers of air-breathing systems has been on a combination of high-speed turbojets, ramjets

for modernization at the U.S. Defense Department. “That’s all pretty remarkable. We have a keen understanding what the properties of the fuel should be and how to inject it effectively.”

But to go beyond rocket-boosted single-use gliders and missiles to fulfill

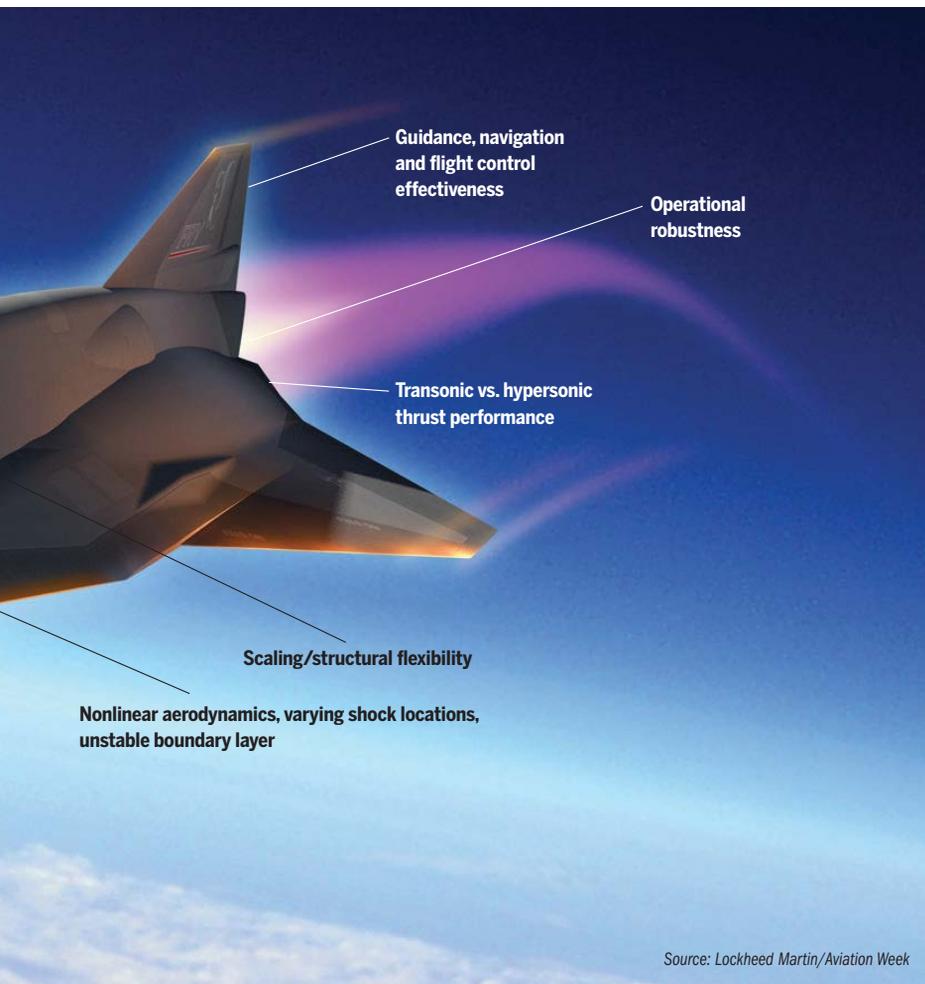
and scramjets—collectively dubbed the turbine-based combined cycle (TBCC)—to accelerate to Mach 5 and beyond. However, despite the pioneering success of the scramjet-powered NASA X-43A and U.S. Air Force-led X-51A vehicles, and tests in 2019 of a 13,000 lb.-thrust Northrop Grumman-built scramjet by the Air Force, there is no definitive consensus on the best path forward for integrated high-speed propulsion.

Part of the reason is that scramjets, while conceptually simple with no moving parts, are complex in terms of operational physics. The mechanical compression of jet engines is replaced by shock compression which, in the form of shockwaves entering the engine, must efficiently compress air within the inlet and isolator before turbulence and chemistry mix and react fuel and air in under 1 millisecond.

Even by the performance standards achieved by the 50-in.-long combustor in Pratt & Whitney’s J58 turbojet of the 1960s, the fastest air-breathing engine ever to see operational use, the task of the scramjet is orders of magnitude more difficult. The J58 traveled at 3,200 ft./sec. at Mach 3.3 and 80,000 ft. in the Lockheed SR-71, while the X-43A’s 30-in.-long combustor traveled at around 9,600 ft./sec. as it flew at Mach 9.7 and 110,000 ft.

“The challenge is designing combustors with optimal overall geometries (area distribution and shape), injector and flameholder geometries, and the spatial distribution of fuel injectors, plus values of other fuel injection parameters,” says Kevin Bowcutt, the chief hypersonics scientist at Boeing who led the X-51A conceptual design. He thinks the hurdles, while significant, can be tackled using a multidisciplinary design optimization (MDO) approach that simultaneously combines aerodynamics, control, propulsion and structural considerations to produce a highly integrated solution.

“This design optimization process will be aided by fast, high-fidelity flow simulation [computational fluid dynamics] tools, good ground test facilities specializing in hypersonic engine testing, and sophisticated flow diagnostic instrumentation for test measurements,” adds Bowcutt, who has previously noted the X-51A was the first hypersonic vehicle to be refined using MDO.



Guidance, navigation and flight control effectiveness

Operational robustness

Transonic vs. hypersonic thrust performance

Scaling/structural flexibility

Nonlinear aerodynamics, varying shock locations, unstable boundary layer

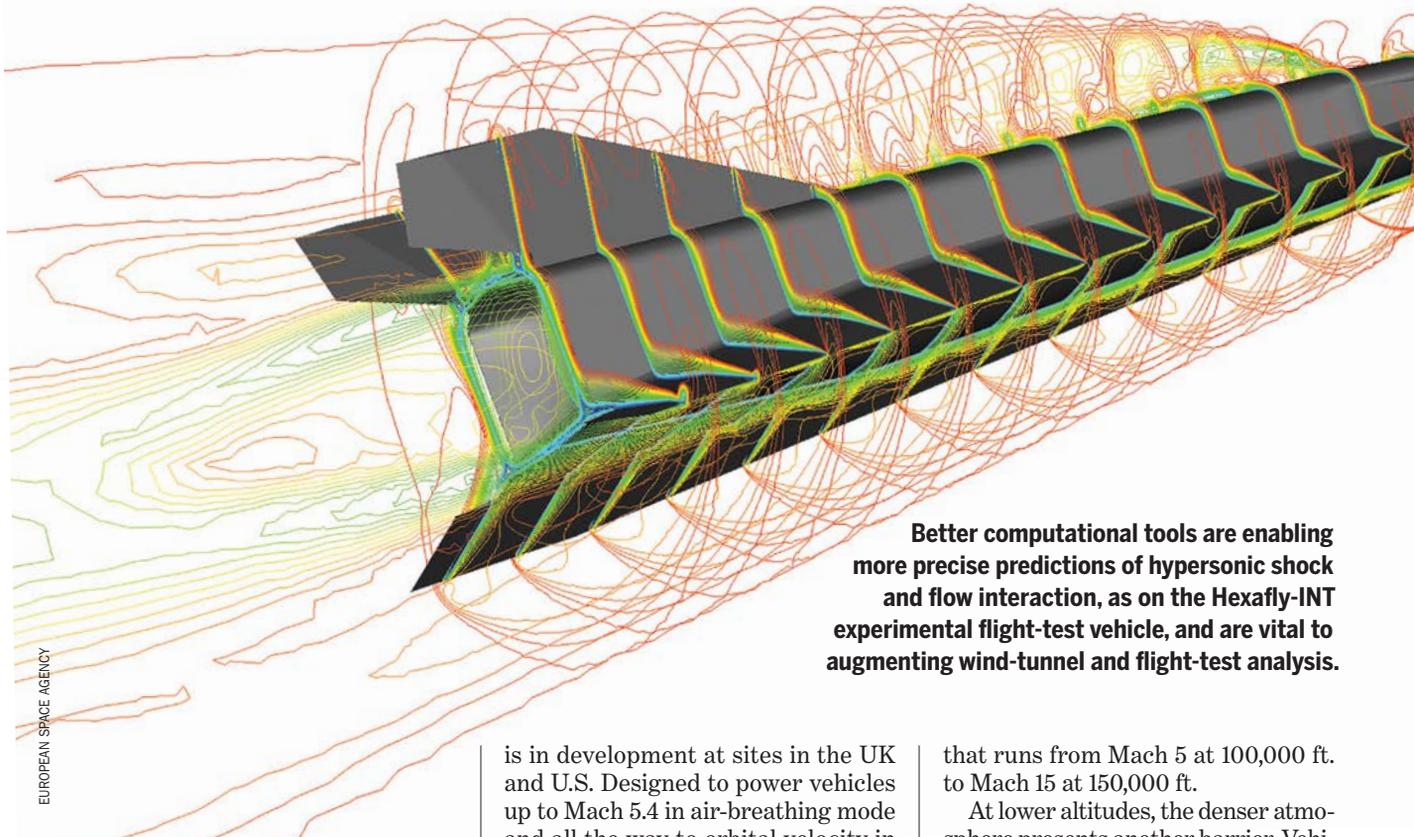
Source: Lockheed Martin/Aviation Week

However, despite decades of scramjet development work, competing propulsion concepts continue to emerge. So are scramjets necessarily still the right answer? “I would say the jury’s still out,” says Lewis. “One of our challenges is to be open-minded enough to think maybe there are other ways to propel ourselves at high speed. I wouldn’t want to narrow down our technology options.”

magneto-plasdynamic engines. Both cycles are being investigated for hypersonic application, the former for potential access to space as part of a pulse detonation rocket-based combined cycle with ejector ramjet, ramjet, scramjet and rocket modes.

Another alternative is the Reaction Engines SABRE (synergetic air-breathing rocket engine), which

increase. Commencing with a take-over speed of around Mach 3, hydrocarbon-powered scramjets hit a fuel thermal limit around Mach 7.5, while hydrogen-powered vehicles reach a performance limit around Mach 14. In terms of altitude, most dual-mode scramjets are theoretically bounded by upper operability limits at a dynamic pressure of 500 psf—a level



EUROPEAN SPACE AGENCY

**Better computational tools are enabling more precise predictions of hypersonic shock and flow interaction, as on the Hexafly-INT experimental flight-test vehicle, and are vital to augmenting wind-tunnel and flight-test analysis.**

**PROPULSION OPTIONS**

A potential wide variety of alternative power cycles beyond the TBCC have also been studied that could speed a vehicle from a standing start to Mach 6-plus, most of which take advantage of the thermodynamic properties of liquid hydrogen as a working fluid for cooling and power. Examples include the ATREX expander air turbo-ramjet studied by JAXA, the Japan Aerospace Research Agency; the Russian-developed ATRDC deeply cooled, air turbo rocket; the KLIN cycle thermally integrated deeply cooled turbojet and liquid rocket engine; and the aspirating rocket engine.

Other air-breathing concepts showing promise include pressure-gain cycles such as rotating and pulse detonation engines and, potentially, even more exotic magnetohydrodynamic/

is in development at sites in the UK and U.S. Designed to power vehicles up to Mach 5.4 in air-breathing mode and all the way to orbital velocity in rocket mode, the engine’s pre-cooler passed a critical milestone test in October when it operated successfully at temperature inlet conditions equivalent to Mach 5.

“The whole idea of a liquid air cycle engine and the deeply cooled cycle is extremely promising,” says Lewis. “I don’t know if at the end, they’ll pan out, but they seem to have some significant advantages for certain classes of vehicles. I do worry that we [must] maintain a sufficiently diverse research portfolio and development portfolio that there is room for a full range of clever ideas.”

**AIRFRAME-PROPULSION INTEGRATION**

Air-breathers must navigate a relatively tight flight-trajectory propulsion corridor as speed and altitude

that runs from Mach 5 at 100,000 ft. to Mach 15 at 150,000 ft.

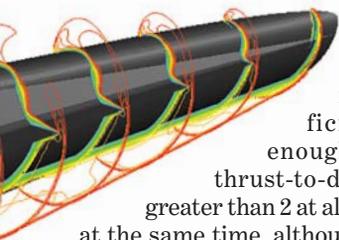
At lower altitudes, the denser atmosphere presents another barrier. Vehicle designers usually target hypersonic flight in the stratosphere to limit the dynamic pressure to below 2,000 psf. The line representing the resulting structural design limit extends from around 40,000 ft. at Mach 2.5 to around 110,000 ft. at Mach 14.

To add to these challenges, design considerations are also complicated by changing aerodynamic behavior with Mach number; finding the optimum wing size to suit varying flight modes; configuring the vehicle for a high propellant fraction; and defining the correct inlet and nozzle size, both of which vary extensively with Mach.

“We also know how to build good inlets,” says Lewis. “But there is still an ongoing question: What is the best inlet design? Under the general heading of ‘perfection is the enemy of good enough,’ we know how to build inlets

that work. However, there are clearly areas for continued development, research and advancement.”

As achieving a high thrust-to-drag ratio is critical for efficient acceleration to Mach 5-plus, propulsion integration is vital and drives the need for increasing air capture with Mach number. Designers have discovered that overall



air capture and engine thrust coefficient must be sufficiently high enough to give a thrust-to-drag ratio of greater than 2 at all speeds. But at the same time, although inlet size and air capture must be relatively large for hypersonic performance, drag from inlets and nozzles must be reduced as the vehicle passes through the transonic region around Mach 1.

“It is very challenging to design inlets that accommodate a very large range of air mass capture (measured as capture area) and contraction ratio with high compression efficiency and flow stability, and low flow distortion and additive (including spillage) drag, across a large range of Mach

shapes that you know do great at Mach 5, 6, 7, 8, but they have no hope of punching through Mach 1. There’s a slight disconnect there. With the weapons applications we have an easier task because we are usually punching through Mach 1 with a rocket, for example. But this shows that low-Mach-number performance becomes critical.”

The extreme challenges of bringing together a closely coupled airframe and propulsion system are further magnified by the need to then minimize the weight, power and size requirements of the subsystems inside the vehicle. The need for a highly integrated flight architecture, made possible through MDO-type approaches, is “absolutely a key area,” says Lewis. “We knew 35 years ago that a hypersonic vehicle would have to be a fully integrated system, and today everything that we’ve learned has reinforced that,” he says.

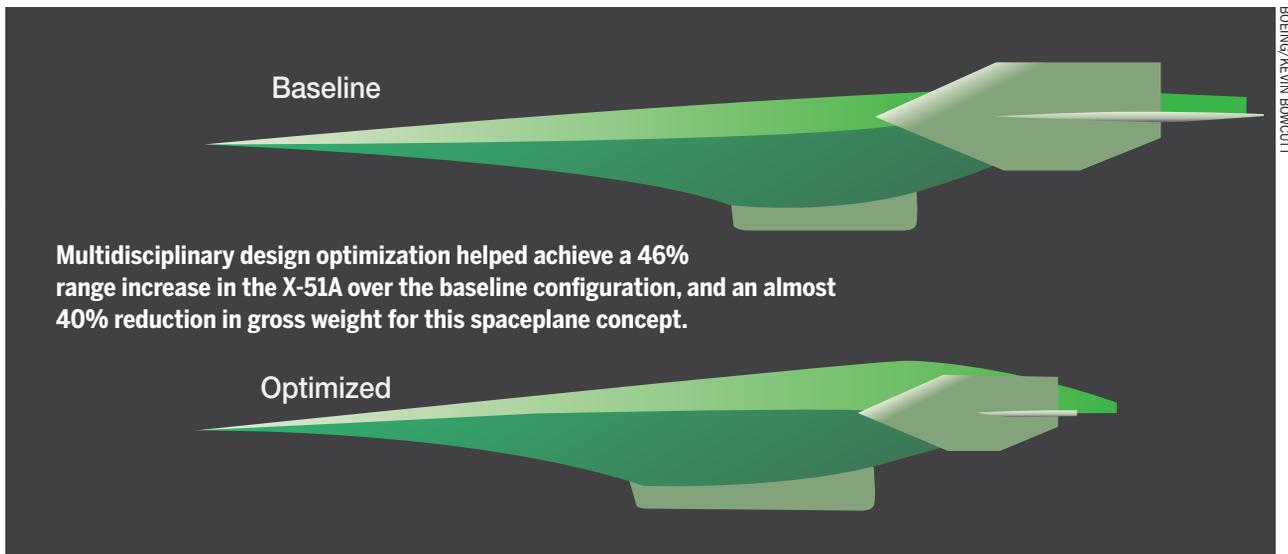
### SCALING AND FLOW PHYSICS

Challenges also differ, depending on size. “Going to the bigger vehicles there’s another coupling that’s really important, in that structures can bend and flex,” says David Van Wie, head of

structurally stiffer, face challenges related to packaging and thermal management. “NASA studies long ago said long slender vehicles had much higher hypersonic lift-to-drag ratios than shorter, stubbier vehicles,” says Van Wie. “And when you go try to make something small, it can’t be long and slender, there’s just no internal volume. It ends up setting what is achievable from an aerodynamic efficiency from a lift-to-drag ratio.”

“There is a challenge there doing all the aerodynamics and propulsion integration with the internal packaging,” Lewis adds. “You must make sure you have room for all the parts inside that you need such as sensors and systems for guidance, navigation and control.”

Another scaling issue, and one that goes to the heart of hypersonic vehicle design, concerns the behavior of the boundary layer, a thin layer near the surface that designers strive to keep laminar for as long as possible to minimize heating and thus reduce thermal protection requirements. At hypersonic speeds, the boundary layer tends to thicken and, in general, become more resistant to disturbances. But when it transitions to turbulent flow it can affect heating, drag and



number, altitude, and angle of attack,” says Bowcutt.

“Over the years I’ve been involved in looking at conceptual design for a number of hypersonic vehicles where the final shape was dictated not by its hypersonic performance but by the transonic performance,” Lewis recalls. “You can design hypersonic

the Air and Missile Defense Sector at Johns Hopkins Applied Physics Laboratory, Maryland. “You just can’t make it rigid enough,” he says. “Flight loads can couple back into the engine and the propulsion systems, and the degree of coupling gets more challenging as you go to larger scales.”

Smaller scale vehicles, though

stability. Pressure increases across shockwaves can also interact with the boundary layer.

Although varying shock positions are in themselves not an issue, shock interactions with boundary layers produce friction drag and in some cases can magnify aerodynamic heating as much as eight times higher than lam-

inar flow. As shock locations change, so will interaction zones. “Therefore, areas of enhanced aeroheating will move around, requiring enhanced thermal protection or management over a greater area of the vehicle (increasing weight and cost),” explains Bowcutt. “Being able to accurately predict boundary layer transition is important. Developing and using means to delay boundary layer transition could also be important if they could be developed.”

Although advances in computational codes have recently enabled more accurate predictions of flow physics, further improvements in narrowing down boundary layer transition zones will help build robustness into hypersonic vehicle design, says Lewis. “We’ve learned to design around what

we know we don’t know,” he says. “We realized we’re never going to know exactly when the boundary layer transitions from laminar to turbulent, so we have to design around that.”

Conversely, scramjet engine developers face the challenge of encouraging turbulent, rather than laminar, boundary layer conditions in inlets for better operability. “A turbulent flow is less susceptible to boundary layer separation where shocks interact with the boundary layer,” says Bowcutt.

Recalling lessons learned from working as a student on the National AeroSpace Plane (NASP) program of the 1980s, Lewis says a very senior lecturer warned that if the vehicle’s boundary layer was turbulent instead of laminar, then it would never fly. “Among the things I’ve learned is, if

our vehicle designs are that sensitive, then they’re not going to fly and we need to be designing robust configurations,” he says. “That’s the hard part.”

Maturing hypersonic vehicles into operational systems remains a major hurdle, agrees Van Wie. “Improving our knowledge of how to actually build vehicles and get them to operate robustly in the environment is, I think, one of the bigger challenge areas right now,” he says. “You want to be able to fly it in a way where you don’t have to thread the needle and follow, for example, a given experimental flight profile. I want to fly it like any other aerospace vehicle.”

Interaction of the shockwave around the leading edges of the vehicle with the boundary layer is another challenge, particularly for

## HYPER ACTIVITY

> BOLT MACH 7 FLIGHT TEST TARGETED FOR AUGUST

> EARLY 2021 FOR INITIAL USAF X-60A TEST FLIGHT

**Guy Norris** Los Angeles

**T**esting remains a key challenge for U.S. hypersonic developers, particularly those looking to produce the next generation of larger vehicles, despite a recent wave of reinvestment in government, academic and industrial ground-test facilities.

“We can’t test at all the conditions I want,” said David Hunn, director of technology at Lockheed Martin Missiles and Fire Control, speaking at a Royal Aeronautical Society hypersonics conference in London in November. Of the basic test conditions—enthalpy, heat flux, pressure and oxygen content—there is no test site open to U.S. developers where all four can be evaluated simultaneously. This inevitably puts a greater focus on flight tests for qualifying vehicles, backed up by ground tests and the addition of margin for uncertainties.

The “wind tunnels in the sky,” as Hunn described previous U.S. tests such as those of the X-43A, X-51A and DARPA-led HTV-2 Falcon, have produced invaluable data. The HTV-2 reentry vehicles, for example, tested in 2010 and 2011, generated 540 sec. of data at around Mach 16. “We got very interesting aerodynamic and materials data on those vehicles before they came to their untimely end,” he said.

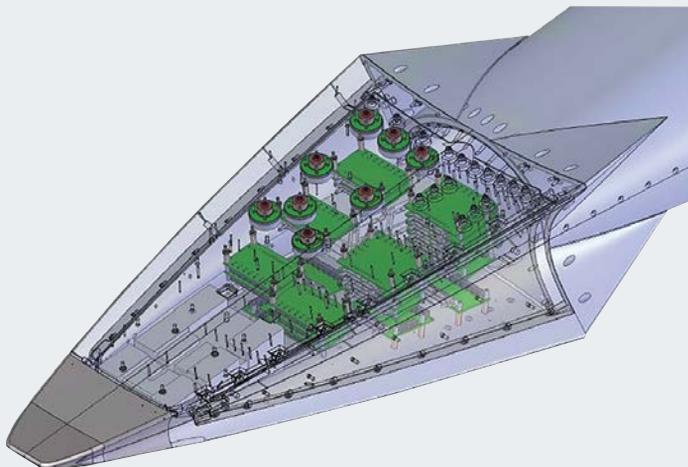
A flying testbed planned for the near term is the U.S. Air Force Research Laboratory’s (AFRL) X-60A, an air-launched liquid oxygen/kerosene-powered rocket that is designed to test payloads at hypersonic speeds from Mach 5-8. The expendable vehicle, which will be dropped from a modified Gulfstream business aircraft, is configured with wings for maneuverability and an onboard flight telemetry

system for data capture. Developed by Generation Orbit Launch Services, the X-60A is now expected to make its initial test flight out of Cecil Spaceport, Jacksonville, Florida, in spring 2021.

Another impending AFRL hypersonic flight test, this time led by the Johns Hopkins University Applied Physics Laboratory, is the Boundary Layer Transition (BOLT) flight experiment—a rocket-launched payload designed to evaluate flow characteristics over complex geometries. Building on the results of earlier tests as part of the successful U.S.-Australian HIFiRE flight series, the experiment will measure boundary layer transition on a low-curvature concave surface with highly swept leading edges—a shape more relevant to future large-scale vehicles.

Boosted by a sounding rocket to just over 280 km (174 mi.)

### Boundary Layer Transition Flight Experiment



slender-shaped boost-glide vehicles at higher altitudes and sharp-nosed reentry bodies. The degree to which flow-interaction effects, or leading-edge viscous interaction, can occur is influenced by the Reynolds (Re) number, a nondimensional scaling metric that is the ratio of inertial forces to viscous forces. In the upper atmosphere with lower Re, the thickness of the boundary layer increases and interacts with the adjacent flow. At even the very sharp leading edges of a hypersonic vehicle in very low Re, the growth of the boundary layer effectively changes the shape of the leading edge, making it seem blunter to the oncoming flow outside of the boundary layer.

The effect changes the air distribution at the leading edge, which in turn

affects the behavior of the boundary layer and creates viscous interactions with potentially damaging impact on lift/drag. Similar effects can cause trouble in other shock/boundary layer interactions such as inlets and on inlet ramps. "That's a significant factor in the behavior of leading edges, but it introduces a scale," says Lewis. "So if I take a given shape that flies hypersonically with a certain performance, and I photographically reduce it. I could suddenly pick up entirely different physical behavior because of the way these interactions scale."

### HIGHER-TEMPERATURE MATERIALS

Another significant challenge is in materials. Despite the seven decades of research that led to the develop-

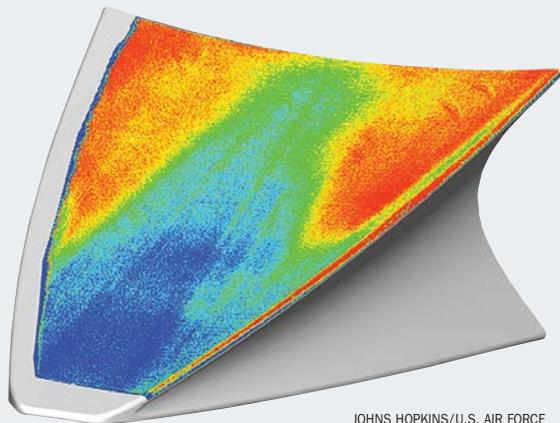
ment of thermal protection systems (TPS) and other heat-resistant treatments for spacecraft, ballistic weapons and supersonic aircraft, none of these material systems specifically meet the unique heating challenge of extended hypersonic flight through the atmosphere.

At sustained speeds of Mach 6 and above, the temperatures at the leading edges of hypersonic vehicles can run from 1,600-2,200C (2,900-4,000F), the upper range of which is more than 300C higher than the melting point of titanium and 600C hotter than the melting point of steel. The highest heat flux is focused, blowtorch-like, over a relatively small area, leading to high thermal shock and extreme temperature gradients. At such high temperatures, material prop-

altitude, the heavily instrumented BOLT payload will conduct the first experiment on ascent between Mach 4.7-6, and in the final few seconds of descent, between Mach 6.7-7.4. At an altitude of 15 km the payload will be separated from the booster to allow it to enter a flat spin—slowing its velocity before impact and enabling it to be inspected after recovery. The test, which was delayed from May by the COVID-19 pandemic, has been rescheduled for August with a backup date in early 2021. It will be conducted at the Swedish Space Corp.'s Esrange near Kiruna, Sweden.

As flight tests of initial hypersonic glide vehicles and cruise missiles accelerate in the U.S., with 40 individual launches planned over the next four years by the Air Force alone, private industry is stepping up efforts to enter the fray. One company, Stratolaunch, has outlined plans to

**The tightly packed interior (left) of BOLT includes tungsten ballast and sensors to gather data from the high-Mach transition zones expected on the vehicle's concave surfaces and highly swept leading edges (below).**



JOHNS HOPKINS/U.S. AIR FORCE

repurpose its huge carrier aircraft—originally designed to air-launch medium rockets—into a platform to support hypersonic flight tests.

Stratolaunch, which aims to resume flight tests at its Mojave, California, base later this year, plans a series of flying testbeds starting with the Talon-A, a fully reusable, autonomous, liquid rocket-powered vehicle targeted at flight speeds up to Mach 6. This will be followed by the Talon-Z, targeted at test conditions up to Mach 10, and the longer-term "Black Ice" spaceplane.

Another private venture, Atlanta-based Hermeus, has completed scaled static and high-speed laboratory tests of a prototype turbine-based combined-cycle (TBCC) engine up to Mach 5, and is working on near-term plans to test the transition between engine modes. The company aims to develop a high-speed transport for entry into service around the end of this decade based on existing and near-term airframe, materials, systems and propulsion technologies.

DARPA, together with the Air Force, is meanwhile conducting individual ground tests of elements of a TBCC system called the Advanced Full-Range Engine (AFRE). Designed for future runway-based reusable hypersonic vehicles operating up to Mach 5, the AFRE combines an off-the-shelf turbine and dual-mode ramjet/scramjet (DMRJ).

The engine uses mass-injection precompressor cooling to close the gap between the maximum speed of the turbine and the takeover speed of the ramjet. The water injection element at the heart of this, together with the common turbine/DMRJ inlet, combustor and common nozzle will be integrated later this year into the complete TBCC assembly. Free-jet testing of the engine is set to occur in 2021.

NASA's long-running Hypersonic Technology Project also continues to study a TBCC concept, and in June announced it will work with GE Aviation to develop high-temperature ceramic matrix composite materials for component parts. NASA also selected GE's F101 turbofan for analysis as part of studies of a TBCC-powered concept vehicle. ☛

erties can change during the flight, while oxidation and catalysis effects are also possible.

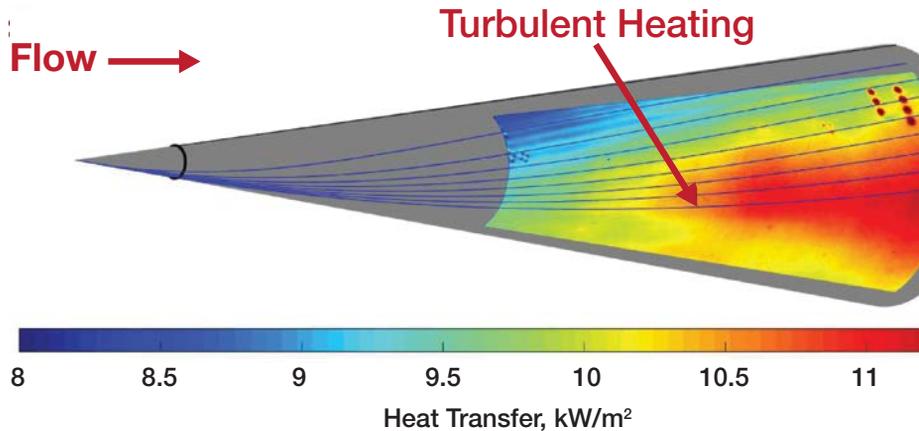
“It is an area where there’s a lot of opportunity for invention,” says Van Wie. “As the leading edges become sharper, they want to get hotter. That’s one of the main materials issues out there: How sharp do you want to go, and that fundamentally translates into the highest temperatures they can be operated at. The answers are influenced by whether it’s a reusable vehicle or a one-use weapon system. But this is an active area of research.”

“[Higher-temperature-resistant materials] would allow you to design vehicles with sharper leading edges, which would give you a higher lift-to-drag ratio for better performance. Or it would give more margin by allowing flight at higher speeds and altitudes,” says Van Wie. “It is a one of the challenge areas where there’s a lot of room for improvement.”

Another significant, related hurdle is the changing thermal environment with varying vehicle size. “People still don’t understand how the material challenges scale with size,” says Lewis. “It’s another avenue that requires continued investment and development. For example, if I try to make a given hypersonic configuration smaller by just photographically reducing it, then I wind up with much sharper leading edges. And then those get much hotter. So I end up with this tradeoff going on for blunt leading edges that create more drag and have less aerodynamic performance.

“So that’s a pretty active area, especially as we’re talking about delivering hypersonics at scale. And for doing it in large numbers, we realized we had to be very careful extrapolating that if something works on a certain scale, it doesn’t mean that we can take that same configuration and apply it across the range of systems that we’re looking to develop,” he adds.

As a vehicle passes through the atmosphere at Mach 5-plus, the air itself can change. “Your temperatures become such that the chemical composition of the air flowing around the vehicle begins to change,” says Lewis. “You start to disassociate oxygen. Then at even higher temperatures eventually you can start disassociating nitrogen. This chemical dissociation affects the behavior of the flow over the vehicle.” The dissociation of diatomic oxygen



into oxygen radicals takes place at temperatures around 1,700C, while that of nitrogen is at around 3,700C.

Disassociation, plasma formation at higher Mach numbers and aeroh heating effects pose a major challenge for communicating with hypersonic vehicles as well as for guidance, navigation and control (GNC). “It makes the hypersonic calculation somewhat challenging. Where do you put your sensor, and how do you put in an aperture or window of some sort that you can blend with the rest of the vehicle?” asks Lewis.

Research and development into tackling the GNC hurdles is active across the hypersonic enterprise, with current study work ranging from new sensors and avionics for missiles and transatmospheric vehicles to advanced designs for semiautonomous/autonomous missile guidance systems and development of new guidance laws for high-speed vehicle trajectory optimization. Other areas of study include the application of data fusion for target discrimination and tracking algorithms, as well as development of new adaptive control algorithms and novel actuation systems.

Materials represent the “first and foremost” challenge to successful hypersonic vehicle development said David Hunn, director of technology at Lockheed Martin Missiles and Fire Control, at a Royal Aeronautical Society hypersonics conference in London in November. “I’m having to adjust my trajectory and performance based on the limitations of materials systems that are available now.”

“We are in regimes that have rarely been explored in the past. So how do we handle that?” he asked. The options range from internally cooled structures with circulating coolant to insu-

lated structures with passive, ablative or semiactive TPS. But overall, the radiation cooled/hot structure approach is preferred. “[It] is simple, there are no moving parts such as pumps, and it is predictable and stable,” he said. “Arguably it also offers the minimum space, weight and power.”

**COATING CHALLENGES**

With metals incapable of withstanding the required heat flux, material choices currently are focused mainly on carbon-fiber and carbon-matrix composites as well as ceramic composites.

“We have a hope here that there are material solutions out there but—and there is always a but—we have to understand that these carbon-based materials oxidize,” said Hunn. “So in the air, I have to worry about chemical catalytic reactions breaking the air down into its base elements and recombining that with the airframe—and that would be an endothermic reaction adding more heat to it. I also have to worry about heat emissivity. If it is too low, it gets really hot. Fundamentally, no matter what the airframe materials, the chances are we will have to develop protective coatings to work in these atmospheres.”

Work on new coatings for temperatures in excess of 1,700C are focused on novel ceramic materials such as tantalum and hafnium carbide, and zirconium and hafnium borides. “Some are ceramic-based materials, which are pretty good oxygen barriers, so there’s a lot of research looking at some of these novel coatings on some of these advanced composite materials as near-term solutions for current hypersonic airframes,” said Hunn.

However, to advance hypersonic vehicle development to the next level, he said, “The answer really is

**Advanced heat-resistant coatings and materials are required to handle intense thermal loads on hypersonic vehicles, particularly in areas of laminar to turbulent boundary layer transitions as illustrated in this temperature-sensitive paint-related test.**

11.5

SANDIA NATIONAL LABORATORIES

that we are going to have to sidestep Mother Nature and invent our own materials.” Work at a fundamental level is underway at universities and research labs; it is focused on using computational power and a road map from the periodic table to “come up with some novel new materials that have the characteristics needed to roll into hypersonics,” he said.

Reviews of Chinese and Russian research work indicates “that they are really advancing the state of the art in designing new materials and tailoring them for the hypersonic environment,” said Hunn. Scientists from Moscow’s National University of Science and Technology, for example, recently revealed tests of a new ceramic compound they claim will withstand the typical 2,000C thermal loads of a sharp leading edge or nosecone of a

hypersonic vehicle. The melting point of the new material, called hafnium carbonitride, is not yet known but has already been demonstrated to be beyond 4,000C, say the scientists, who add that further tests are planned at hypersonic conditions.

The corollary of the external heating issue creates an engineering and design challenge for the densely packed interiors of hypersonic vehicles—both gliders and powered. “You have an outside surface that wants to be hot and you have electronic systems inside that you can’t allow to get hot,” says Van Wie.

The problem is compounded by the insulation built into the vehicle to prevent heat transfer from the exterior. “So what do I do with the internally generated heat flux?” asks Van Wie. “There’s nothing magical about that problem—it’s just an engineering system challenge. There’s a whole variety of different ways of attacking it, but you have got to take a look at it from a system perspective and what makes sense for a particular vehicle type and a particular mission.”

### READYING THE RAMP-UP

A final and more urgent challenge, particularly for the first-generation U.S. weapon systems developers, is establishing the industrial base to support the planned production ramp-up. Earlier this year the U.S. Defense Department’s acquisition

leadership established a “war room” in the Pentagon to assess the areas of strength and vulnerability in the industrial supply chain.

Propulsion specialist Aerojet Rocketdyne, which provided the scramjet for the X-51A, is actively engaged in a series of offensive and defensive hypersonic efforts, ranging from DARPA’s Glide Breaker and Operational Fires programs to the Advanced Full Range Engine TBCC propulsion system and the hypersonic air-breathing weapon concept (HAWC) with Lockheed Martin.

“We’re focused on executing the programs we’ve got and then having the capability and capacity to do what’s needed when the time comes,” says Tyler Evans, senior vice president of Aerojet Rocketdyne’s defense business. “The X-51 was a propulsion demonstrator that demonstrated that we could tame the science of supersonic combustion, and it did that. And so, 10 years later, we’re focused on making scramjets practical, making them repeatable, making them affordable.”

As part of the readiness ramp-up the company also acquired Florida-based additive manufacturing specialists 3D Material Technologies, a move designed to support lower production costs across its range of solid and liquid rockets as well as scramjets. Additive manufacturing is “integral to our solution,” says Evans. ☒

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# Hypersonic Strike Weapons Projects Accelerate Worldwide

> RUSSIA HAS FIVE KNOWN OFFENSIVE HYPERSONIC PROGRAMS

> CHINA IS DEVELOPING AN EXPANSIVE HYPERSONIC TECH BASE

**James Bosbotinis** London

**T**here is growing international interest in the development of offensive hypersonic weapon systems, particularly following the deployment by Russia and China of nascent hypersonic strike capabilities. France, India, Japan and the UK all are seeking to develop a hypersonic strike capability too.

Beyond Russia's Avangard hypersonic glide vehicle (HGV) and Kinzhal air-launched ballistic missile (ALBM), and China's DF-17 HGV, both nations are developing additional hypersonic weapon systems. Russia, for example, is working on the Zircon hypersonic cruise missile (HCM) and related technologies, while China is developing an expansive technological base and infrastructure for the development and production of hypersonic systems for military, commercial and space applications.

Given the technical challenges and costs inherent in developing hypersonic weapons, particularly in areas such as propulsion, airframe design, guidance and thermal management, what roles will such weapons undertake? The speed, maneuverability and flight characteristics of hypersonic weapons makes them challenging to detect, track and intercept, reducing the warning time available and window for interception.

Hypersonic weapons thus provide advantages for the prosecution of time-critical, mobile or relocatable targets, or in the face of adversary missile defense capabilities. Maritime strike is also a key projected role for hypersonic missiles under development or being deployed by Russia, China and Japan. In the conventional precision-strike role, hypersonic weapons will require a robust set of supporting intelligence, surveillance, target-acquisition and reconnaissance capabilities, in particular for the prosecution of mobile/relocatable targets.

France is developing its fourth-generation air-launched nuclear missile, the ASN4G, which will be scram-

jet-powered and is due to enter service in the mid-2030s, replacing the current ASMP-A. It is also developing an HGV demonstrator, the "Vehicule Manoeuvrant Experimental," or V-MaX, which is due to make its first flight before the end of 2021. India is similarly pursuing two hypersonic weapon projects, the BrahMos-2, developed by the BrahMos joint venture between India and Russia, and another HCM project. The BrahMos-2 is intended to be an HCM capable of speeds of Mach 5-7; HCM development is supported by the scramjet-powered Hypersonic Technology Demonstrator Vehicle (HSTDV). An attempted test flight in June 2019 failed due to a technical problem with the Agni-1 serving as the launch platform for the HSTDV.

Japan has outlined plans for two hypersonic weapon systems; the Hyper-Velocity Gliding Projectile (HVGP) and a Hypersonic Cruising Missile. Japan outlined in its Mid-term Defense Program (fiscal 2019-23) plans to strengthen the defense of "remote islands in the southwest region," including through the establishment of HVGP units. The HVGP is intended to be a tactical HGV, capable of delivering a penetrating warhead for targeting, for example, aircraft carriers, or delivering a "high-density EFP" (explosively formed penetrator) warhead for "area suppression."

An initial variant will be deployed in the 2024-28 time frame, with an improved variant following in the 2030s. The Japanese HCM will be a scramjet-powered missile, armed with the same warheads as the HVGP, and intended to provide a standoff capability to counter "ships and landing forces attempting to invade Japan." The HCM will be deployed in the late 2020s/early 2030s, with an improved variant following later in the 2030s.

The UK is exploring options for the development of a hypersonic strike capability, including potentially as part of the joint Future Cruise/

Anti-Ship Weapon project with France to replace the Storm Shadow/SCALP standoff cruise missile and the anti-ship Exocet and Harpoon from 2030. In July 2019, Air Vice Marshal Simon Rochelle, then chief of staff capability, announced that the UK sought to deploy an affordable, air-launched hypersonic weapon by 2023.

Moreover, as Aviation Week disclosed, a joint U.S.-UK study, Thresher (Tactical High-Speed, Responsive and Highly Efficient Round), is being conducted by the U.S. Air Force Research Laboratory and UK Defence Science and Technology Laboratory (AW&ST April 6-19, p. 14). It is due to be completed in 2022 or 2023.

With the notable exception of the UK's intention to rapidly acquire a hypersonic missile by 2023, the majority of known programs are not likely to deliver weapon systems until the second half of the 2020s or 2030s. This period

is also

likely

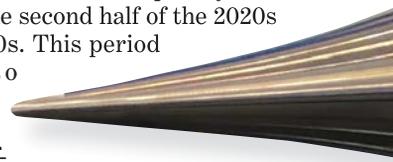
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icant expansion in Russian and Chinese hypersonic strike capabilities.

Russia possesses a nascent hypersonic strike capability following the initial deployment in December 2017 of the Kinzhal ALBM and in December 2019 of the Avangard HGV system. The Kinzhal and Avangard were both announced by President Vladimir Putin in his state of the nation address on March 1, 2018, and reflect Russia's long-term efforts to develop hypersonic weapons, particularly as a response to U.S. missile defense efforts.

Although seeming to catch the U.S. public by surprise, the development of the Avangard can be traced back to the Albatross project started in the late 1980s as part of the Soviet response to the U.S. Strategic Defense Initiative. NPO Mashinostroyeniya performed several tests of the Yu-70 prototype in 1990-92, until the program was put on hiatus amid the dissolution of the Soviet Union, says Markus Schiller, founder of ST Analytics and a Germany-based consultant on hypersonic technology. The Yu-70 project was revived shortly after Putin assumed power in 2000,



leading to a series of test flights in 2001-11. The Avangard HGV is based on an improved version known as the Yu-71, which performed a series of tests in 2013-18, Schiller says.

The development of hypersonic weapons also reflects Russia's interest in developing a robust conventional long-range precision-strike capability as part of its wider military modernization efforts. It is developing and deploying both nuclear and conventionally armed hypersonic weapons, including dual-capable systems, to undertake tactical and strategic roles.

In addition to the Avangard and Kinzhal, at least three more development programs are underway: the Zircon, GZUR (from the Russian for "hypersonic guided missile") and an air-launched weapon to arm the Suk-

Mach 9, have a range in excess of 1,000 km and operate in the land attack and anti-ship roles. The Zircon will be compatible with existing launchers capable of launching the Oniks supersonic cruise missile, such as the UKSK vertical launch system. It is due to enter service in 2022. A Zircon was successfully test-fired from the new frigate Admiral Gorshkov in February 2020.

Following the collapse of the Intermediate-Range Nuclear Forces Treaty, Putin announced the development of a ground-launched Zircon variant. The GZUR is reported to be an air-launched missile capable of a speed of Mach 6, a range of 1,500 km and sized to fit within the bomb bay of a Tupolev Tu-95MS Bear. It may enter service in the early 2020s. In this regard,

March, U.S. Air Force Gen. Terrence O'Shaughnessy, commander of U.S. Northern Command and the North American Aerospace Defense Command, stated that China is testing an intercontinental HGV. It is likely that the DF-41, China's new ICBM that also debuted at the October 2019 National Day Parade, would be armed with the new HGV. O'Shaughnessy's testimony appeared to echo public statements from 2014 by Lee Fuell, who was then in Air Force intelligence and linked China's HGV development program to plans for that country's nuclear arsenal.

China is developing the technologies required for HCMs. For example, in May 2018, a scramjet test vehicle, the Lingyun-1, was publicly exhibited for the first time in Beijing, while in August 2018 China successfully tested a hypersonic waverider test vehicle, the XingKong-2, which attained a speed of Mach 6. Notably, in April 2019, Xiamen University successfully flew the Jiageng-1 test vehicle, which employed a "double waverider" configuration. Interest in developing an air-launched hypersonic strike capability has also been noted.

China is also believed to be developing two ALBMs, which would provide China with a near-term air-launched hypersonic strike capability.

The new CJ-100, which also debuted at China's 2019 National Day Parade, warrants mention. Aside from the statement that the weapon offers "long range, high precision and quick responsiveness," no technical information on the CJ-100 has been officially released. *The South China Morning Post*, citing the Chinese publication *Naval and Merchant Ships*, suggests the CJ-100 has a cruising speed of Mach 4 and top speed of Mach 4.5, adding that it employs a two-stage configuration utilizing a rocket booster and ramjets. Given China's progress in developing hypersonic technologies, the possibility that the CJ-100 is a hypersonic cruise missile cannot be dismissed.

In a further indication of China's progress in the development of hypersonic technologies, in January 2019 it was reported that an indigenous Turbine-Based Combined-Cycle engine had completed its design and development phase and was proceeding to the aircraft integration test phase. ☛



### China is evaluating air-breathing options such as the Lingyun-1, a scramjet test vehicle that was publicly exhibited for the first time in Beijing in 2018.

hoi Su-57 Felon. The Avangard is an ICBM-launched HGV, initially equipping the UR-100N, a modernized version of the SS-19, and might equip the developmental SS-X-29 Sarmat (Satan 2). The Avangard is reportedly capable of attaining speeds in excess of Mach 20, can maneuver laterally and in altitude and travel intercontinental distances.

Although principally intended as a nuclear system, the Avangard can reportedly also be used in the conventional strike role. The Kinzhal is a dual-capable, air-launched derivative of the Iskander-M tactical ballistic missile, with a range of 2,000 km (1,250 mi.) and a speed of Mach 10. It is being deployed with a modified variant of the Mikoyan MiG-31, the MiG-31K, and may be integrated with other aircraft, including reportedly the Tupolev Tu-22M3 Backfire.

Russia is also developing a scramjet-powered HCM, the 3K22 Zircon, which will be capable of speeds up to

Russian media reports in May noted the testing of a new hypersonic missile from a Tu-22M3 that is intended to arm the modernized Tu-22M3M. Another hypersonic missile is reported to be under development and intended to equip the Su-57.

China has thus far confirmed only one hypersonic weapon, the DF-17. Its pursuit of hypersonic weapons is driven by the requirements to counter U.S. missile defenses and acquire a robust precision-strike capability as part of its wider efforts to develop "world-class" armed forces. The DF-17 is a conventionally armed medium-range ballistic missile (possibly derived from the DF-16), equipped with an HGV, with a range of 1,800-2,500 km. When it debuted at China's National Day Parade on Oct. 1, 2019, it was announced as being intended for "precision strikes against medium- and close-range targets."

In testimony before the U.S. House Armed Services Committee this

# PATHFINDER PROGRESS

- > THE XB-1, LIKE THE CONCORDE, RELIES ON VORTEX-GENERATED LIFT AT LOW SPEED
- > THE DEMONSTRATOR'S GE J85 ENGINES WILL HAVE FIXED-GEOMETRY INLETS

**Guy Norris** Los Angeles

**S**eventeen years after the retirement of the Concorde, a small fighter-like aircraft nearing completion in Colorado is set to blaze a trail toward development of the first purpose-built civil supersonic airliner of the 21st century.

Boom Supersonic's XB-1 is a one-third-scale demonstrator for the Overture, a follow-on 75-seat airliner it aims to introduce into commercial service later this decade. Although inspired by the Concorde, the XB-1 displays key technology differences that Boom believes will enable the Overture to operate economically and sustainably at Mach 2.2—targets out of reach when the pioneering Anglo-French airliner left the drawing board more than a half century ago.

The XB-1 shares some Concorde-like features, including a slender nose, elongated forward fuselage and graceful ogival delta wing. But unlike the Concorde, the wing is mounted on the upper fuselage and predominantly made of lightweight carbon-composite materials rather than special aluminum alloys. The XB-1 is also a trijet, and its tail-mounted engine is fed by a dorsal inlet, marking another significant departure from the Concorde's twin-podded quad-engine configuration.

Despite a slowdown caused by the COVID-19 pandemic, progress continues toward final assembly of the demonstrator inside Boom's Centennial Airport facility in Denver. "The first upper skin is going onto the fuselage, and we are in the process

**Despite its 61.5-ft. length, the mostly composite XB-1 will have a maximum takeoff weight of only 17,400 lb.**

of closing that out," says CEO Blake Scholl. "The vertical tail is in structural testing, and the landing gear is getting drop-tested. So we're basically testing every single component as it goes onto the aircraft and then doing integrated testing as well."

Once complete, the aircraft will be officially unveiled later this summer before being prepared for system checks and ground tests—including initial slow-speed taxi trials—at Centennial. "Sometime around the end of the year, possibly early next year, we'll be taking it down to Mojave, Cal-



BOOM SUPERSONIC CONCEPT

ifornia. And we are still looking to be in the air next year," he says. Testing will be undertaken with Mojave-based Flight Research Inc. (FRI) a training, service and support company with which Boom announced a strategic partnership in January. FRI's supersonic T-38 will provide pilot proficiency training and will also be used for chase support during XB-1 flight tests.

"For safety, we have to have a long and wide runway and be based close to test airspace, so it makes a lot more sense to do flight tests in Mojave," says Scholl. Under the



**The XB-1, pictured with its virtually complete tail fin and titanium aft sections, prior to upper-skin closeout.**

BOOM SUPERSONIC

agreement with FRI, Boom is also subleasing part of the company's flight line facility for an XB-1 simulator, a flight-test control room and hangar space for maintenance and support of the demonstrator.

"The XB-1 is very much informing the design of the Overture," says Scholl. "The goal is mainstream supersonic flight for as many people as possible in as many places as possible. So we started out with a sketch of what the Overture looked like and then said, 'OK, let's put that on the backburner; let's go shrink it down about one-third scale, and then go through the design, build, fly and learn cycle.' We did this knowing that when we went through that process, we'd shift our attention back to the Overture to take everything we've learned from the XB-1 and use it to update and improve a richer design. So that's exactly what's going on."

With a wingspan of 21 ft. and overall length of 61.5 ft., the XB-1's proportions are similar to the slightly shorter Lockheed F-104 Starfighter and the

longer Douglas X-3 Stiletto supersonic research aircraft of the 1950s. The aircraft's slender, low-drag delta wing is designed for supercruise performance and at lower speeds will generate vortex lift to allow an acceptable angle of attack for landing and takeoff.

With its small wing and complete absence of lift-augmentation devices, Boom estimates the XB-1 will have a sporty final approach/reference landing speed of around 185 kt. To handle high runway speeds, the nose landing gear is strengthened to withstand descent velocities in excess of 13 ft./sec., while the titanium main landing gear bulkheads are built to withstand impact forces of 112,000 lb. Loads will be transmitted into the composite fuselage structure, the largest part of which is a 47-ft.-long fuselage skin section.

Two-dimensional, fixed-geometry supersonic inlets are mounted close to the fuselage beneath the wing and, together with the center inlet, transition flow through subsonic diffuser duct sections to the three closely

grouped General Electric J85 engines in the tail. The center inlet, which is mounted on a prominent boundary layer diverter above the aft fuselage, feeds air through a longer S-duct.

For the Overture design, which will be firmed up within 24 months, the engines will have variable-geometry inlets and be mounted farther outboard while, according to current renditions, the tail engine will feature a divided inlet with openings on either side of the aft fuselage.

The three XB-1 engines, which collectively generate 12,300 lb. thrust in afterburner, are housed in an aft-fuselage assembly made completely from heat-resistant titanium. Small movable horizontal tails are attached to the lower aft engine nacelles to provide pitch control. Boom confirms that the horizontal tail will not feature on the Overture, which will be designed with a chine and a larger, conventionally mounted delta wing. An elongated conical tail cone extends aft of the vertical fin to reduce afterbody drag, particularly during transonic flight.

Even though the XB-1 is still months from completion, Boom says the experience of designing, wind-tunnel testing and building the demonstrator has already helped guide design refinements to the Overture. “There’s a tremendous amount we have learned about aerodynamic optimization,” says Scholl. “In particular, how you balance low-speed and high-speed performance, how you trade your high-lift devices into the wing and how you balance high-speed efficiency with the ability to meet noise rules for takeoff and landing. We have better ideas on that now than we had a few years ago.”

With the design of the XB-1 finished and assembly underway, “the engineering center of gravity at Boom is shifting from the XB-1 to the Overture, which is due to begin flight tests in the mid-2020s,” Scholl says. “And with that we’re taking a second pass with the overall vehicle design with the Overture.” Although he declines to be more specific about potential changes, Scholl adds: “There’s just a lot you can do to make the Overture better, but it will be a little while before we’re ready to unveil what’s to come.”

Major configuration choices—such as adoption of a trijet layout—are “absolutely still on the table,” says Scholl. “That’s one of the real advantages we have with the XB-1. We will not be completely finalized with the Overture until we have flown the XB-1, and the calibration data we get from that deletes a lot of uncertainty. It is an enormous benefit to have flown a similar configuration demonstrator aircraft: You’ve learned where your assumptions are right and where they are wrong, and you’ve got data that you can carry forward to make sure you develop Overture the first time around,” he adds.

“The XB-1 is a critical step toward mainstream supersonic travel,” says Brian Durrence, senior vice president of Overture development. “It’s going to provide, and is providing, key technologies to help us move to safe, efficient and sustainable supersonic travel. There’s really nothing like flying hardware to take designs and working knowledge to the next level.

“For example, the design tools that we utilize for the XB-1 are the same tools we’re planning on utilizing for the Overture. For critical parts of the aircraft, such as the inlet, it will be great

to be able to get advanced information on that and get a direct match of that performance. Then maybe we will know if we need to adjust our tools and methodology slightly in order to maximize the efficiency,” says Durrence.

Flight testing will, for instance, verify Boom’s methods of controlling wave drag and shockwaves. “It is a very important piece of the puzzle to make sure that we have the strongest tools and methodologies available and that these are backed and verified with test data,” says Durrence. “Every piece, not just the design part, of the XB-1 program is a valuable learning experience for Boom.”

Unlike NASA’s X-59 low-boom experimental aircraft, under assembly by Lockheed Martin, or the AS2 supersonic business jet in development by Aerion—which aims to use an atmospheric phenomenon known as Mach cutoff for boomless overland flight—the Overture remains point-designed for unrestricted operations over water. “The strategy remains the same,” says Scholl. “We’re focused on transoceanic routes where we can offer a big speedup for as little cost as possible with proven technology and the shortest possible development timeline.”

Scholl concedes that low-boom technology has a future. “[But it will be] a long time before anyone knows how quiet is quiet enough,” he says. “The last thing you want to do is make a big investment in it, and then miss it by a decibel and then all is for naught. You also give up efficiency for quiet. So we are still more convinced than ever that there’s a meaningful market for transoceanic [travel] where the most important thing is efficiency and low-boom doesn’t really help you.”

Instead, as part of its drive for environmental sustainability, Boom’s noise aspiration is to meet International Civil Aviation Organization Chapter 14/FAA Stage 5 landing and takeoff noise standards with margin, which it believes will also meet the FAA’s proposed standards for new supersonic aircraft. As proposed for initial designs with a maximum takeoff weight no greater than 150,000 lb. and a maximum cruise speed up to Mach 1.8, the standards—known as Supersonic Level 1 (SSL1)—do not cover the larger and faster Overture. However, Boom expects to work with the FAA using the SSL1 standards as a starting point

for establishing an individual certification basis for the Overture.

“Overture will be the first new commercial aircraft to have been built with environmental and economic sustainability in mind from Day 1,” says Scholl. “[That includes] everything from the engines being designed to accept a wide variety of alternative fuels through looking at how to design the aircraft for recycling.”

Boom’s plans to work with California-based Prometheus Fuels on a carbon-neutral fuel received a boost in June when the startup received an investment from the venture-capital arm of carmaker BMW. Boom partnered with Prometheus in 2019 for the supply of fuel for the XB-1, which will be produced using a process in which CO<sub>2</sub> is captured from the air and converted into a liquid fuel using renewable electricity.

However, hurdles still face Boom’s fuel plan. “The biggest challenge we have with respect to sustainable fuel is that we just can’t get enough,” says Scholl. “There are a lot of promising concepts out there, but nothing that reaches industrial scale.”

Another key challenge is the selection of engines. “We’ve narrowed things down a little bit, but we’re still looking at a couple [of] options,” he says. Although no details have been released, Boom is discussing medium-bypass, nonafterburning engines based on derivatives of current turbofans. Earlier, the company disclosed it was studying two promising candidates, one based on a military core and the other a commercial one.

Despite the debilitating impact of the coronavirus pandemic and economic slowdown, Boom remains “in a great cash position,” says Scholl. “That’s allowed us to continue and, in many cases, even accelerate what we are doing.” This includes recruiting additional personnel as it shifts gears toward the Overture Part 25 certification design, as well as to open talks with more suppliers. “As Boeing and Airbus have retrenched, it’s created a good hunger in the supply base, and there’s more room for new entrants to actually speed up what they’re doing,” Scholl says. 🗣️

**Check 6** *Aviation Week* editors discuss Boom’s project and have their questions answered by CEO Blake Scholl: [AviationWeek.com/podcast](https://www.aviationweek.com/podcast)

# Take 3

- > LUEDERS TAPPED TO HEAD NASA'S HUMAN SPACEFLIGHT PROGRAM
- > 2024 MOON LANDING IS THE NEXT BIG GOAL

Irene Klotz Cape Canaveral

Last July, NASA Administrator Jim Bridenstine sidelined the 11-year director of the human spaceflight office, Bill Gerstenmaier, saying it was time for new management to rein in budget overruns and steer the agency toward a crewed landing on the Moon in 2024.

Bridenstine lured Douglas Loverro, an innovative and well-respected program architect and manager with Defense Department and national security heritage, to take on the role of associate administrator with the Human Exploration and Operations (HEO) directorate.

But Loverro's maverick ways proved too troublesome for NASA and on May 18, after just five months on the job, he was asked to leave. NASA's Office of Inspector General reportedly is investigating procurement procedures involving Human Landing System development contracts awarded three weeks before Loverro's departure.

This time around, Bridenstine chose from within, tapping the 28-year NASA veteran Kathryn Lueders (pronounced "Leaders") as the new chief of human spaceflight. In that post, she will oversee programs that account for more than \$10.1 billion of the agency's \$22.6 billion fiscal 2020 spending plan.

Lueders has taken over from a troubled former boss before. She stepped in as manager of the Commercial Crew program in October 2013 after former manager Edward Mango was reassigned following a personnel issue.

On May 31, Lueders and her team marked the successful docking of the first Commercial Crew vehicle to carry astronauts to the International Space Station (ISS), a flight test that remains ongoing.

That milestone, 10 years in the making, pales in comparison to the challenges Lueders now faces. The Trump administration wants NASA to land a pair of astronauts on the south pole of the Moon in 2024, a goal that not only will require two flight tests and the first operational mission of the long-delayed Space Launch System rocket and Orion capsule but also a commercially developed human landing system.

Asked if NASA can meet that milestone, Lueders told reporters on June 18: "We're going to try. . . . If things come up along the way, where technically it takes us longer, then we'll go figure it out. But right now, the team is trying."

"If you're asking me if we're going to land on the Moon in 2024, I'm going to tell you, yes, we can do it," adds Bridenstine. "We know it's hard. We know that there's bound to be challenges. . . . but it is absolutely possible."

Efforts by three previous administrations to move NASA's human spaceflight activities beyond low Earth orbit have failed to gain traction among lawmakers.

Lueders, who joined NASA in 1992, has lived through it all.

"The hardware . . . has been successful, even through all the administration changes and different levels of support," says Lueders. "The good thing is that NASA has bipartisan support . . . and the value we provide for the nation has national support. I'm hoping that will continue."

Lueders' career with NASA began 28 years ago at the White Sands Test Facility in New Mexico, where she managed the operational needs of the shuttle fleet's orbital maneuvering and reaction control systems. Lueders advanced to the ISS program, overseeing planning for U.S. commercial and international cargo launches to the ISS, as well as Russian Soyuz crew missions. She became deputy manager of the fledgling Commercial Crew Program at NASA's Kennedy Space Center in Florida in February 2013.

She became acting manager during a stressful time following the retirement of the space shuttles, budget shortfalls in the Commercial Crew Program and a respected former boss facing a felony conflict-of-interest charge for intervening in a personnel matter in which Mango had a financial stake. He pleaded guilty and was fined \$2,000.

Lueders holds a Bachelor of Business Administration in finance from the University of New Mexico as well as



JOEL KOMSKY/NASA

**NASA's Commercial Crew Program Manager Kathryn Lueders, cheering the docking of SpaceX's Crew Dragon at the International Space Station on May 31, was promoted two weeks later to associate administrator of Human Exploration and Operations.**

a Bachelor of Science and Master of Science in industrial engineering from New Mexico State University.

Commercial Crew Program Deputy Manager Steve Stich succeeds Lueders as the head of the program.

Lueders is the first woman to head NASA's Human Exploration and Operations Mission Directorate. "What's been amazing to me over the last few days is seeing all the tweets, Snapchats, Instagrams, all the notes from all the girls out there," she says. "That really helps me realize the power of my being first [and what] that means to them."

"I think when we can see ourselves in the people that are out there, it makes us realize we can do it," Lueders adds. "That's very, very important for not only girls out there, but for all groups of people." 🌟

—With Mark Carreau in Houston

# New Agreement Enables Use of U.S. Launchers From British Spaceports

- > UK-U.S. PACT SOLVES CONFLICT WITH TECHNOLOGY TRANSFER RULES
- > FIRST UK VERTICAL SATELLITE LAUNCH EXPECTED IN EARLY 2020s

**Tony Osborne** London

London and Washington have signed off on security arrangements that will pave the way for U.S. cubesat and small-satellite launchers to be lofted into low Earth orbit from UK spaceports.

Two years in the making, the Technology Safeguards Agreement (TSA), signed in Washington on June 17, permits U.S. companies to operate from UK spaceports and eases the export of space launch technology between the two countries.

technology is not transferred . . . [and to make] sure it is handled in an appropriate manner," Kuh adds.

The agreement is not without precedent. The U.S. and New Zealand also have a TSA in place that has allowed U.S. launcher company Rocket Lab to conduct launches from its North Island Mahia Peninsula launch site.

"There are implications for how people operate on the ground. There will be security checks in place and both countries have an understand-

ted to conducting the UK's first vertical satellite launch through its UK Spaceflight Program. "This agreement was necessary for any company looking to bring U.S. rocket technology to the United Kingdom," says company spokesman Chip Eschenfelder.

Christopher Ford, U.S. assistant secretary of state for international security and nonproliferation, says: "This TSA sets a strong missile non-proliferation standard for how responsible nations should protect sensitive technology in the conduct of satellite and rocket launches."

Before launches begin, the TSA needs to be ratified by the British Parliament. It also must approve the UK's new Spaceflight Regulations, which are expected to move to public consultation this summer. The regulations will build on the UK's regulatory framework for aviation and will confirm how licenses will be granted for spaceports, launch vehicle operators, and for the provision of range and control services.

While U.S. companies may undertake the first launches from the UK, several British satellite launch companies such as Orbex and Skyrora are waiting in the wings to join them. Canada-based launch company C6 Launch Systems Inc. has said it wants to use the planned Shetland Space Centre, a vertical launch site planned for Saxa Vord in the Shetland Islands.

The company tells Aviation Week that it does not expect any export restrictions for its launch vehicle, although the UK/U.S. TSA will help with the export of the engines.

The UK is seen as an attractive launch location for access to polar and sun-synchronous orbits. Much of the focus is on Space Hub Sutherland, where development is gaining pace (*AW&ST* July 30-Aug. 19, 2018, p. 45). Highlands and Islands Enterprise (HIE), the regional development agency leading the project, submitted plans for the construction of the vertical launch site in February. If the application is approved, construction could begin later this year, says HIE, enabling launches as early as 2022.

Britain wants to be able to launch satellites as part of its strategy to grow the country's domestic space industry and capture 10% of the global commercial space market by 2030, equivalent to around £40 billion. ☼

—With Jen DiMascio in Washington



The TSA, allowing U.S. launchers to be lofted from the UK, will benefit Lockheed Martin.

LOCKHEED MARTIN

While it is not unusual for one country to want to launch satellites from another, transferring the launch systems is wrapped in complexity—due in part to counterproliferation rules such as the Missile Technology Control Regime (MTCR), to which the UK and U.S. are both signatories.

"Space launch vehicles are technically indistinguishable from weapon delivery systems, so transferring a space launch vehicle from one country to another is caught by the MTCR," Andrew Kuh, head of international spaceflight policy at the UK Space Agency, tells Aviation Week. Kuh has been closely involved in the negotiations.

"The TSA sets out how the U.S. and UK will work together to ensure that

ing how things will be managed," he says. "We are also getting maximum flexibility for the operators."

A clear beneficiary of the TSA is Lockheed Martin, which secured £31 million (\$39 million) in funding from the UK Space Agency in July 2018 to set up launch operations from Space Hub Sutherland in northern Scotland with U.S.-developed launchers. Company officials had previously suggested they could use the Electron launcher, leaning on a partnership with Rocket Lab.

The agreements also smooth the way for Virgin Orbit, which received funding to support horizontal launch operations from Cornwall Airport Newquay in England.

Lockheed Martin says it is commit-

# Building a Spaceport 'Network'

## > FAA SEEKS INDUSTRY ADVICE ON SPACEPORT DEVELOPMENT

## > AIR FORCE PLANS THE TRANSITION OF FEDERAL LAUNCH RANGES

Bill Carey Washington

The FAA is developing a spaceport infrastructure grant program and at the same time seeking advice on a U.S. Air Force plan to commercialize the service's Eastern and Western space launch ranges.

There are now 12 FAA-licensed spaceports in the U.S. and 12 more being planned, creating pressure on the agency to better organize and support those facilities to match the growth of commercial space activity. Into the mix, the Pentagon is developing a "National Spaceport" construct to integrate commercial space launches at Cape Canaveral AFS, Florida, and Vandenberg AFB, California, respectively the Eastern and Western ranges.

Addressing a June 22 online meeting of the Commercial Space Transportation Advisory Committee (Comstac), FAA executives said the agency is seeking industry guidance on supporting spaceports through infrastructure funding and accommodating the Air Force's vision for the federal ranges.

Pam Underwood, appointed as director of the FAA Office of Spaceports in March, said the agency is already developing an "internal plan" for a spaceport infrastructure grant program in advance of Congress appropriating funds.

"It's important for us as the Office of Spaceports to make sure that we're ready and have a plan together to facilitate and implement that as it is funded," Underwood said. "[I]nfrastructure improvements are going to be needed as we go forward to maintain the pace of the industry."

The FAA is also working with the Air Force-led U.S. Space Force on the "transition" of the Eastern and Western ranges, Underwood said. The Air Force issued a request for information in September seeking guidance on management concepts for collocated spaceports.

During the meeting, the agency asked Comstac to provide an industry perspective on what the end result of the transition should be.

"The Department of the Air Force is exploring the possibility of converting

the Eastern and Western ranges into quasi-governmental entities similar to a civilian port authority," said James Hatt, the committee's FAA-designated federal officer.

"The FAA seeks Comstac's input on this idea," Hatt added. "How might a National Spaceport Authority focused exclusively on the Eastern and Western ranges affect the commercial space transportation industry? What are the benefits and disadvantages of this concept?"

infrastructure projects at 10 current and proposed commercial spaceports, with a total estimated cost of \$382 million, according to the GSA. "Incredibly, given the importance of space to our nation's defense and our national economy, there is no current federal program that provides financial support for space transportation infrastructure in general, or for spaceports in particular," the report states.

Among possible funding channels are: the Airport Improvement Program, the Space Transportation Infrastructure Matching Grants Program, Transportation Department discretionary grants and a joint FAA/Defense Department infrastructure program, each of which would need to be modified, the GSA says.

The organization suggests the

## Current and Proposed U.S. Spaceports



In advance of the first Comstac meeting under new chairwoman Charity Weeden, representing space debris removal company Astroscale U.S., the Global Spaceport Alliance (GSA) in June released a 44-page report describing a proposed national spaceport policy.

The GSA's National Spaceport Network Development Plan calls for combining current and prospective commercial spaceports with government-owned and privately owned launch and landing sites under the oversight of the Office of Spaceports. The FAA office would be responsible for regulating the network of some 40 sites and distributing funding for infrastructure projects.

There is a need for 44 spaceport

phased creation of a \$100 million per year Spaceport Network Improvement Program. Grants would be paid from a Spaceport and Spaceway Trust Fund derived from a cargo tax on satellites, payloads and experiments, plus a spaceflight participant ticket tax.

The Alexandria, Virginia-based GSA does not favor separate treatment of the Eastern and Western ranges.

"Adopting more commercial practices for acquisition, scheduling and resource management will certainly offer the opportunity for more efficient operations. However, if this is accomplished by creating two taxpayer-supported 'national spaceports,' it would make it very difficult for other spaceports to compete financially," the report states. ☞

## What Is Projected Aircraft Mechanic Supply and Demand in the Near Term?

**We know that going into the COVID-19 crisis, we were facing a major shortage of licensed aircraft mechanics. How do you see supply and demand playing out over the next 12-36 months?**

**MRO Reporter Lindsay Bjerregaard answers:** Despite a downturn in aviation, demand for skilled technical personnel will remain high as we move into recovery mode, particularly because there was such a huge shortage before the COVID-19 crisis.

A major driver of this demand is an aging workforce. In Europe, Airbus has projected that aviation's technical workforce will be badly affected by increasing retirements of baby boomers, and in the U.S., 30% of aviation mechanics are 60 years or older, according to the Aviation Technician Education Council (ATEC).

Industry officials tell Aviation Week privately that the coronavirus crisis has accelerated the wave of retirements. Eric Jones, department chair of Aviation Maintenance Sciences at Embry-Riddle Aeronautical University, sees a similar trend at airlines. And Shonu Bamrah, director of the British School of Aviation, notes that voluntary retirements by older workers are creating open positions, despite some companies imposing hiring freezes.

In the near-term, the pandemic will temporarily reduce the pool of qualified graduates needed for the future workforce. "There is actually going to be a little bit of a shortage right now because of the lower number of graduates this year due to COVID-19, and a lot of the schools in the ATEC group feel that they're going to produce about 20% fewer graduates this year," says James Hall, dean of Aviation Technologies at Wichita State University Campus of Applied Sciences and Technology (WSU Tech).

An audience poll during the Aviation Week Network's "Aircraft Maintenance Training During COVID-19" webinar found that 43% of respondents expected the impact of the pandemic on training and graduation to delay eligible 2020 hires. The poll

results also shed light on a potential industry concern: 28% of respondents believed new hires in the industry would look elsewhere for employment.

There is certainly unease in aviation about potential workers accepting employment in other industries, particularly if aviation is perceived to be a less stable sector after the pandemic. "That airframe and powerplant [A&P] ticket is a valued commodity in

more interest for younger generations and more job opportunities, so he expects there to be robust hiring in the wake of COVID-19.

While restrictions on gatherings during the pandemic have also hindered some STEM initiatives, schools and organizations continue to focus on creating interest in aviation technical careers with younger generations. The recently launched industry



LAKE AREA TECHNICAL INSTITUTE

other industries because [other companies] know what kind of training you received in school," notes Jack O'Callaghan, American Airlines' technical crew chief at Chicago O'Hare International Airport points out. "Disneyland hires A&P mechanics because [they've] got a background in pneumatics, hydraulics and electrics."

However, Bamrah and Hall say interest in aviation technical training remains high—and has even increased at the British School of Aviation during the pandemic lockdown. Jones says the aviation industry's diversification into areas such as commercial space, electric vertical-takeoff-and-landing vehicles and unmanned aerial systems is providing

nonprofit Choose Aerospace is using pandemic-driven advances in online training as an opportunity to promote aerospace career opportunities.

"One of the things we have been doing well is promoting technical education for the last couple of years as a very important career pathway," Hall says. "I think you're going to see that will continue even more so once the group restrictions are lifted." ✪

*The Aviation Week Network invites readers to submit questions to our editors. Answers are published online at AviationWeek.com. To access our answer archive or post a new question, go to: [AviationWeek.com/asktheeditors](https://www.aviationweek.com/asktheeditors)*

*Continued from page 66*

for Ukraine's efforts, providing it with useful reconnaissance footage at the same time.

Since Open Skies photos are not classified and are shared among treaty parties, they can be used publicly, unlike classified spy satellite pictures. Open Skies data collected over thousands of square miles of Ukrainian and Russian territory allowed the U.S. to call out Russia for its destabilizing actions in eastern Ukraine and provide the world community with photos as proof. It is a lot harder for Russia to criticize as fake the photos of military movements when it agreed in a treaty to the method of collection and preservation.

Maintaining the treaty has not been without challenges. I was one of many senior U.S. officials who confronted Rus-

## GIVING UP ON THE TREATY REPRESENTS A SIGNIFICANT LOSS TO THE U.S., DISADVANTAGES OUR FRIENDS AND HELPS OUR ADVERSARIES.

sia about its illegal limitation on flights over Kaliningrad and near the Georgian border. But those grievances, while real, are not worth the consequences of ditching the treaty. Russia is a giant country and has many useful observation targets, especially during military exercises. Giving up the ability to observe 99% of its territory because of a problem with less than 1% is foolish. And we have made good use of this access, conducting missions over Russia three times as often as Russian aircraft overfly the U.S.

But the real insanity, from my perspective, is the continued self-inflicted erosion of U.S. world leadership accelerated by an exit from Open Skies. Our NATO Allies rely on their own Open Skies aircraft to understand what Russia is up to, especially because they have more-limited satellite capabilities. In response to Trump's announcement, 11 allied and partner countries issued a statement regretting the decision and affirming their support for the agreement. Abandoning a treaty that we developed, negotiated and persuaded our allies to join leaves them in the lurch. It also further diminishes our ability to lead the democratic world and produce outcomes favorable to us. If the treaty completely falls apart following a U.S. withdrawal, Russia will have the perfect talking point to persuade other nations that we are an unreliable partner. Russia will also have greater freedom to make trouble in areas we care about.

The U.S. is a powerful country, not because of its weapons but because its ideas have been attractive to people around the world, helping to build friendships and alliances that make it stronger, more prosperous and safer. Abandoning this leadership role, together with the arms control agreements that have kept Americans safe since the Cold War, truly is insane. 🇺🇸

*Greg Delawie, a retired foreign service officer and former ambassador to Kosovo, was deputy assistant secretary of state for arms control and was responsible for the Open Skies Treaty from 2012 to 2015.*

China and others and involved upward of 120,000 troops.

Also of concern, the U.S. director of national intelligence noted recently: "For years, Russia has used the Open Skies Treaty to collect intelligence on civilian infrastructure and other sensitive sites in America, posing an unacceptable risk to our national security." Exiting the OST will put a stop to this.

The latest OST provocation is Russia's decision to designate an airfield in illegally annexed Crimea for Open Skies purposes. Its intention? To propagandize—through the treaty—that the Crimean Peninsula is a part of Russia rather than Ukraine.

Cost is also an issue. The U.S. Air Force's two Open Skies OC-135 aircraft are old and need to be replaced. In addition to the annual operating costs, replacing the OC-135 with newer airframes could cost some \$200 million.

Plus, it is also fair to assert that the photographic imagery taken on OST missions, while releasable to all OST member states, has been superseded by high-tech satellite systems that provide potentially better information more quickly.

To its credit, despite clear-cut Russian violations, the Trump administration undertook a months-long, inter-agency review of the costs and benefits of continuing in the OST. The administration also consulted closely with OST allies and partners before making its final decision. It of course has made its concerns known to the Russian side over time, which chose to remain in breach of the treaty protocols despite protests.

In the end, the Trump administration judged that Russia is willfully breaking, even abusing, the OST. The openness, transparency, cooperation and trust that uphold military confidence- and security-building measures cannot happen unless both sides abide by them.

In addition, as a general principle, there must be consequences for noncompliance with a treaty. Continuing to ignore OST violations could encourage additional Russian bad behavior in arms control—and potentially elsewhere. Moreover, Moscow's violations of the OST only add to deep-seated concerns about Russian belligerence in Europe, including violations of and participation in other international security treaties.

It is important not to forget Russia's material breach of the Intermediate-Range Nuclear Forces Treaty, its suspension of participation in the Conventional Armed Forces in Europe Treaty and its defiance of the Chemical Weapons Convention.

The Trump administration is open to remaining in the treaty if Russia comes back into compliance. "But," Trump said, "Russia didn't adhere to the treaty, so until they adhere, we will pull out. But there's a very good chance we'll make a new agreement or do something to put that agreement back together."

The White House is well within its rights to initiate a withdrawal from the OST—and that decision is completely justified by the Kremlin's longstanding and unending violations of the spirit and letter of this treaty. 🇺🇸

*Peter Brookes is a Heritage Foundation senior fellow and a former deputy assistant secretary of defense.*

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**July 6-Aug. 20**—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations (check website). See [rtca.org/content/upcoming-committee-meetings](http://rtca.org/content/upcoming-committee-meetings)

**July 20-21**—DoD Hypersonic Capabilities Symposium. Mary M. Gates Learning Center. Alexandria, Virginia. See [hypersonics.dsigroup.org](http://hypersonics.dsigroup.org)

**Aug. 1-6**—Small Satellite Conference (SmallSat 2020): Space Mission Architectures. Virtual event. See [smallsat.org](http://smallsat.org)

**Aug. 4-6**—Space and Missile Defense Symposium. Virtual event. See [smdsymposium.org](http://smdsymposium.org)

**Aug. 9-13**—AAS/AIAA Astrodynamics Specialist Conference. Virtual event. See [space-flight.org/docs/2020\\_summer/2020\\_summer.html](http://space-flight.org/docs/2020_summer/2020_summer.html)

**Aug. 12-13**—Civil Avionics International Forum 2020. Chinese Society of Aeronautics and Astronautics. Shanghai. See [galleon.eventbank.cn/event/9th-annual-civil-avionics-international-forum-2020-25450](http://galleon.eventbank.cn/event/9th-annual-civil-avionics-international-forum-2020-25450)

**Aug. 24-26**—AIAA Propulsion and Energy Forum and Exposition. Virtual event. See [aiaa.org/propulsionenergy](http://aiaa.org/propulsionenergy)

**Aug. 31-Sept. 1**—2020 Humans to Mars Summit (H2M). National Academy of Sciences Building. Washington. See [exploremars.org/summit](http://exploremars.org/summit)

**Sept. 2-4**—Inter Airport China. China International Exhibition Center. Beijing. See [interairportchina.com](http://interairportchina.com)

**Sept. 3-4**—Military Space Situational Awareness Conference 2020. Holiday Inn Kensington Forum. London. See [smi-online.co.uk/defence/uk/milspace](http://smi-online.co.uk/defence/uk/milspace)

# Aviation Week Network Events

+1 (800) 722-6344 or [Events.AviationWeek.com](http://Events.AviationWeek.com)

**Aug. 5-6**—CAPA Australia Pacific Aviation Summit 2020. Adelaide, Australia.

**Aug. 11-13**—Urban Air Mobility Virtual. Virtual event.

**Aug. 25-26**—Aerospace Manufacturing Conference. Charleston, South Carolina.

**Sept. 1-3**—MRO Americas. Dallas.

**Sept. 2-3**—Military Aviation Logistics & Maintenance Symposium (MALMS). Dallas.

**Sept. 14-16**—Commercial Aviation Industry Suppliers Conference-Europe. Toulouse.

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

**Sept. 22-24**—MRO Asia-Pacific. Virtual event.

**Sept. 23-24**—Aero-Engines Asia-Pacific. Virtual event.

**Oct. 8-10**—Routes Asia 2020. Chiang Mai, Thailand.

**Oct. 15-16**—CAPA Americas Aviation & LCCs Summit. San Juan, Puerto Rico.

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

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

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# Should the U.S. Exit the Open Skies Treaty?



U.S. AIR FORCE

## **NO** A Withdrawal Hurts Friends, Helps Adversaries

By **Greg Delawie**

**I**n a move former CIA Director Michael Hayden called “insane,” President Donald Trump decided on May 21 to withdraw from a little-known arms control agreement called the Open Skies Treaty. This agreement, negotiated in the early 1990s between NATO and Warsaw Pact countries and brought into force in 2002, provides for cooperative aerial-monitoring flights over 34 member states.

The U.S. and its allies primarily use the treaty to overfly and photograph military installations and exercises in Russia. Giving up on the treaty represents a significant loss to the U.S., disadvantages our friends and helps our adversaries.

These flights are not about espionage; there are Russian treaty experts on a U.S. aircraft when it is photographing their country, just as there are American experts on the Russian aircraft when it is over the U.S. There are also strict limits on the resolution of the aircraft’s cameras and other sensors—they can do no better than “tell a tank from a truck”—and the specialists are there to make sure the limits are not violated. Instead, the Open Skies Treaty is about monitoring, signaling and influencing.

Believe it or not, using aircraft in the satellite age has some advantages. For example, the U.S. has to provide only 24-hr. notice of the flight route for reconnaissance missions over Russia. This means the U.S. can take pictures of exercises and other interesting events that have been planned to avoid observation by spy satellites—since Russia knows where the satellites are and when they will come into view, and it can use this information to hide things from observation.

When Ukraine, defending itself from Russian-supported military action in its east, asked for U.S. Open Skies flights, numerous missions were conducted to signal U.S. support

## **YES** Russia’s Cheating Has Made It Moot

By **Peter Brookes**

**D**espite objections both in the U.S. and abroad, the decision by the administration of President Donald Trump to withdraw from the 1992 Treaty on Open Skies (OST) is fully justified for a number of rock-solid reasons.

For the past decade, Russia has been deliberately violating the 34-nation confidence- and security-building treaty, which allows unarmed aerial observation flights over member states’ territory in the interest of military transparency.

Using onboard cameras, OST missions—if conducted as the treaty envisions—potentially provide early warning of military aggression, observe ongoing exercises and even possibly help verify arms control and other agreements. But that is not happening due to Moscow’s failure to comply.

The list of Russian violations is unfortunately significant. In 2010, Moscow started preventing OST observation flights from approaching to within 10 km (6.2 mi.) of Russia’s border with the Georgian regions of South Ossetia and Abkhazia. While South Ossetia and Abkhazia are within the borders of Georgia, Moscow considers these Russian-occupied areas to be “independent” states and, therefore, not party to the OST. As such, OST missions cannot observe them under the treaty. Or so goes the Russian argument.

Then there is the Kremlin’s restriction on OST flights to 500 km in length over the highly militarized Russian exclave of Kaliningrad, located between NATO members Lithuania and Poland on the Baltic Sea. That transgression goes back to 2014.

In addition, last September, Moscow denied a request for a U.S.-Canada OST flight over the Russian Tsentra-2019 strategic-level exercises. The military drills included

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