FLYING THE
KC-390

Aircraft Interiors Innovations
Counter-UAS Conundrum
Pilots Weigh In on MAX Fix
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**ON THE COVER**

Aviation Week’s Evaluation Pilot Tim Wuerfel and Senior Editor Guy Norris flew the Embraer KC-390 as flight tests continue toward Brazilian military certification. Wuerfel’s pilot report begins on page 30, and Norris’ accompanying program update starts on page 54. The multi-role tactical transport and air refueling aircraft is due to enter service later this year. Embraer photo.

Aviation Week publishes a digital edition every week. Read it at AviationWeek.com/awst
WHAT TO WEAR?
All the discussions about getting back to the Moon by 2024, including “Trump’s (Quasi) Kennedy Moment” and “Baby Steps to the Moon” (April 8-21, pp. 16 and 18), respectively, have been focused on politics, appropriations, budgets, schedules, launch vehicles and test flights.

A few perceptive writers have even mentioned that we need a new lunar landing vehicle, but I have read nothing about developing appropriate space suits for the mission.

A study some years ago noted the incredibly abrasive characteristics of the lunar regolith, but that was all.

To my knowledge, there has been no contract issued to actually design, manufacture and test new lunar suits.

Bill Pohnan, Jr., Streamwood, Illinois

CERTIFICATION STRONG-ARMING
Throughout my career, I’ve been a chief test pilot for Avros in the UK, a technical member of the UK Civil Aviation Authority and a member of the UK Air Registration Board.

As to the sad state of affairs related to the Boeing Maneuvering Characteristics Augmentation System (MCAS) situation (April 8-21, p. 5), I believe that as test pilots we would never have agreed to such a powerful device as the MCAS relying on a single angle-of-attack (AOA) indicator. At that time (and I suspect not much has changed), we knew that when we noted an anomaly that could delay certification and delivery, we would find ourselves under terrific pressure from the manufacturer for whom we worked. Our views were often challenged.

In the case of the MCAS, I believe that some time in the future it will be revealed that Boeing’s flight-test department did indeed query the choice of a single-AOA indicator.

Tony Blackman, London, England

MCAS—ANOTHER ANGLE
As to the MCAS situation, all eyes appear to be on Boeing and the FAA. But it might also be interesting to ask why Boeing Commercial Airplanes is not AS9100-certified (a standard of aeronautics, space and defense organizations), which it requires of its suppliers and subcontractors.

Its chief competitor, Airbus, is EN 9100-certified for all its aircraft.

Indeed, this standard requires risk management for all activities, from design straight through to post-delivery activities, and the company is audited at least annually by an independent body to maintain its certification.

Christian Masson, EN 9100 certification consultant, Aussonne, France

ROOT CAUSE: CREW ABILITY
The daily pillorying of Boeing regarding the 737 MAX MCAS both in print and on social media is grating. The tone of the interrogation by members of Congress is pure showmanship, displaying little understanding of the issue or the common sense to seek out appropriate experts to educate them.

Yes, there is a problem with Boeing’s MCAS, which, by improperly activating the stabilizer trim motor, became the probable cause of two recent crashes and 346 deaths.

But the significant contributory cause is the elephant in the room that few dare to mention: Crew error. Both crews were at fault for not immediately turning the STAB TRIM switches to CUTOFF, a memory item for any aircraft with electronic stabilizer trim motors.

To imply or even state that had the crews been informed and trained on the MCAS system this would have prevented the crashes is not supported by the primary rule of flying: Maintain aircraft control.

Then, and only then, would knowledge of all the details of the new system have been helpful to analyze to determine the cause of the malfunction—after regaining aircraft control, of course.

The multiple complaint write-ups by pilots who experienced the MCAS malfunction causing a runaway trim—and who corrected for it—demonstrates that by following existing procedures the situation can be rectified. Media focus should be on the training of the crews involved in the crashes.

The MCAS modifications that are to come will undoubtedly make the 737 MAX a better airplane, but sullying Boeing’s reputation along the way will do nothing to improve crew competency, which contributed in large measure to the crashes.

Jean-Claude Demirdjian, Los Angeles, California

STRETCHING THE LIMIT
The commercial factors that sent Boeing down the current twisted road are unfortunately still fully in place.

The company appears to be desperate to retain the common type rating for the 737 MAX. The bottom line for the company seems to be: If the MAX loses its common type rating with previous 737s, more training will be required, and the aircraft will have to sell for less.

But beyond the immediate issue of the MCAS, the MAX faces a larger problem. Is the flight-control architecture—designed in the 1960s for the 737-100 and modified with patch-es and fixes—still fit for purpose on the 737 MAX family?

The proposed MAX 10 will be 86% heavier and 55% longer than the original version. When is a stretch a stretch too far?

Guy Wroble, Denver, Colorado
HONORS & ELECTIONS

David Davenport, FlightSafety International co-CEO and president for commercial, has been elected president of The Wings Club Foundation.

The British Business Aviation Association has given Infite Jet Center CEO Penny Stephens the Michael Whealley Award for outstanding services to general aviation.

Warren Kroeppe1l, chief operating officer of Sheltair Aviation, has received the New York Aviation Management Association’s William F. Shea Award for significant contributions to New York state’s aviation community.

The Aeronautical Repair Station Association has presented the Legislative Leadership Award to Rep. Sam Graves (R-Mo.) for his support of the aviation industry.

To submit information for the Who’s Where column, send Word or attached text files (no PDFs) and photos to: whoswhere@aviationweek.com For additional information on companies and individuals listed in this column, please refer to the Aviation Week Intelligence Network at AviationWeek.com/awin For information on ordering, telephone U.S.: +1 (866) 857-0148 or +1 (515) 237-3682 outside the U.S.
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- Implication of additive manufacturing when implementing advanced manufacturing
- How can innovation around manufacturing contribute to job creation and workforce diversity

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Delta Air Lines is “very interested” in Boeing’s proposed new midmarket airplane (NMA)—but only if the price is right. That is the word from CEO Ed Bastian, who told Aviation Week’s MRO Americas conference and exhibition that the NMA could be a “perfect candidate” to replace many of the 200 Boeing 757s and 767s the airline plans to retire during the coming decade. “We have an interest in being one of the launch customers,” Bastian said in an onstage interview at the event, which drew more than 15,000 attendees to Atlanta. But Delta, the second-largest U.S. carrier, is cautioning Boeing not to overengineer the NMA. “We want it to deliver the type of range and expectations you see currently in our 757/767 fleet,” Bastian says. “Obviously, you want to take the latest technology and drive greater fuel efficiency, economics and range, but don’t overbuild it and price us out of the market.”
km (84 mi.) east of Misawa when it disappeared.

**Groupe Dassault wants to sell** its 96.85% stake in SABCA, less than two months after acquiring GKN’s 43.57% holding in the Belgian aerospace company, which supports European F-16s.

**AVX Aircraft and L3 Technologies** have revealed a coaxial-rotor, ducted-fan compound helicopter design for the U.S. Army’s Future Attack Reconnaissance Aircraft prototyping competition.

**OBITUARIES**

**NASA Skylab and space shuttle astronaut**
Owen Garriott died April 15 at his home in Huntsville, Alabama. He was 88. An electrical engineer and U.S. Navy veteran, Garriott was selected as a scientist astronaut in 1965. He launched in 1973 on the 59.5-day Skylab 3 mission, participating in three spacewalks. He launched again in 1983 on the 10-day Spacelab-1 shuttle mission aboard the orbiter Columbia. Garriott retired from NASA in 1986.

**Aviation pioneer Geraldyn “Jerrie” Cobb**
ever got a chance to test her space legs, though she, along with 12 other women, qualified for flight in 1961 when NASA scouted for its first class of astronauts. The corps was not open to women then. Four decades later, the National Organization for Women and others lobbied NASA to fly her after John Glenn returned to space on the shuttle, ostensibly for medical research for the aging. But it was not to be. She returned to missionary work in the Amazon. Cobb, 88, died March 18 at her home in Florida.

Brazil has the largest military aircraft fleet in Latin America. Despite political and economic challenges, it is proceeding with several ambitious modernization programs, including Embraer KC-390 tanker-transports, replacement of F-5 fighters with Saab JAS 39E/F Gripenes and the triservice X-HBR program to indigenously manufacture Airbus H225 helicopters.

*For more information about Aviation Week’s Military Fleet Discovery Database, go to [pgs.aviationweek.com/FleetDataServices](http://pgs.aviationweek.com/FleetDataServices)*

Brazil: Latin America’s Major Force

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<tr>
<td>Northrop F-5 48</td>
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**Rotary-Wing**

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**Transport & Tanker**

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<tr>
<td>C4ISR 14</td>
<td>130</td>
</tr>
<tr>
<td>Trainer 130</td>
<td>506</td>
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</table>

**Total:**

- **In Service:** 738
- **On Order:** 110

*Source: Michael Tint and Michael Wang/Aviation Week Intelligence Network*
This pithy precept appears at the top of page 1 of *The Last Warrior*, an intellectual history of Andrew Marshall, the furtive, 42-year director of the Pentagon’s Office of Net Assessment (ONA), who died in March at the age of 97. So often was the maxim repeated in appreciations of Marshall that it has me wondering about the “right questions” we should be trying to answer today.

Those who do not recognize the name can rest assured that even Marshall’s colleagues would refer to him as “the most influential man you’ve never heard of.” His resistance to celebrity notwithstanding, I have known of Andy Marshall for a very long time, and not because we knew one another.

His name has figured as a leitmotif in the development and practice of my own thinking about strategy. From seeing Graham Allison’s effusive acknowledgement of Marshall in the pathbreaking 1971 book *Essence of Decision* to chumming with a clique of Marshall acolytes at the Center for Naval Analyses during my tenure there in the immediate post-Cold War years, I came early to admire the gravitas of Andy Marshall. Even my current practice in business strategy echoes Marshall, who in 1992 famously invited a group of business strategists from IBM, AT&T, Sun Microsystems and Xerox to lead an offsite on innovation before a reluctant group of admirals and generals accustomed to themselves being at the front of every room.

Until recently, amplifying mere admiration with actual knowledge of Marshall’s oeuvre has been a privilege accorded few outside the brotherhood of ONA alumni dubbed “St. Andrew’s Prep.” Marshall’s self-effacing temperament, combined with the secret classification and exclusive distribution of nearly everything he wrote in government service, had lent an aura of mystery to the chief priest’s actual views and analyses.

While ONA’s assessments remain locked away, Marshall’s retirement coincided with publication of several magazine profiles, academic assessments and *The Last Warrior* (the latter by proteges Andrew Krepinevich and Barry Watts), all of which give credit to Marshall’s early identification of three insights that decisively shaped the Pentagon’s outlook: Long-term economic weakness would undo the Soviet Union; the advent of advanced information technology married to precision guidance would revolutionize warfare; and China would rise to compete with the U.S. for global leadership.

Taking Marshall at his word, one presumes these early-warning insights were derived from analyses he commissioned after carefully determining the right questions to ask about the strategic challenges of the late Cold War, post-Cold War and early 21st century, respectively. According to Krepinevich and Watts, what Marshall called “strategic management” required developing insights about “one or two of the most pressing problems or attractive opportunities in a given competition, and [doing] so early enough for the defense secretary to make decisions about them that would influence their outcome.”

How better to honor this man and his legacy, therefore, than to take up what I will call the Marshall Maxim and propose three questions whose answers may help illuminate choices about the strategic management of the nation, its defense establishment and the industry which serves it:

■ How will America’s role in the world change when the tectonics of national power—wealth, technology and demographics—are no longer tilted in our favor? We will need a new grand strategy by which to create power.

■ How do we deter, defend against and defeat adversaries in a world where kinetic power is depreciating? As information progressively trumps lethality as an instrument of war, we will need to organize and equip our military forces differently.

■ What is the business model of the next great defense company? The Aerospace Industries Association’s recent report, “Vision 2050,” affirms that “established A&D players are finding their existing operating and investing paradigms may need to change.”

These may not be the best “right questions,” and I offer them with the abject modesty befitting their inspiration. But now as much as at any time over Marshall’s career, we who share his unbounded curiosity about strategic management should be laboring to discover the right questions for which decent answers are needed.

Contributing columnist Steve Grundman is the principal of Grundman Advisory and Senior Fellow at the Atlantic Council.
commentary

GOING CONCERNS
MICHAELO BRUNO

A STRANGE THING HAPPENED
after Boeing announced on April 5 that it would slow production of new 737 narrowbodies to 42 aircraft a month from the current rate of 52 by the middle of April: Nobody else in the supply chain did the same.

Despite what amounts to a 19% cut in production at the top, every major supplier—from aerostuctures giant Spirit AeroSystems to engine-maker CFM International—says they are continuing at or near their current rates.

“Spirit and Boeing have agreed to work together to minimize the disruption to Spirit operations and the supply chain,” says Spirit AeroSystems CEO and President Tom Gentile. The Wichita-based company, Boeing’s most important supplier by far in terms of work

content and dependence, will maintain its production at rate 52 and store accumulated MAX shipsets at its facilities until they can be sent to Boeing under the slowdown plan.

“This staggered production approach allows us and our supply base to better prepare for and support 737 production,” Gentile says. The company stresses that it will minimize any impact to its full-time workforce by reducing contractors and overtime, as well as suspending hiring to backfill open positions.

CFM, a joint venture of General Electric and Safran, likewise has no plans to decrease production of Leap 1B powerplants for 737s. “We have great confidence in Boeing and the 737 MAX and will continue our close coordination on this program,” CFM says.

Indeed, the engine program now should catch up on deliveries to Boeing in 3-4 weeks, the CFM program director told Aviation Week on April 10. Speaking on the sidelines of Aviation Week’s MRO Americas, Kris Shepherd also acknowledged that the 1B remained about two weeks behind schedule in general. “I really want to get caught up!” he says.

The disparity in responses between Boeing and its suppliers seems amazing at first, especially considering the fact that many suppliers were leaning forward to rate 57, which until recently was expected to be announced by Boeing by the Paris Air Show in June. Why would everyone but Boeing keep plowing forward? The answer is because many of them were barely keeping up and could use the extra time.

To that effect, several financial analysts praise Boeing’s decision to slow production, especially as it seems to try to strike a balance between allowing the OEM to address necessary MAX fixes while not risking costlier cutbacks for suppliers. While many now expect a roughly six-month grounding of MAXs flying or being delivered—admittedly twice their original estimates of a 2-3-month grounding—they still do not believe the developments threaten the long-term money-making prospects of Boeing or the industry.

“The productivity story is unchanged in our view but will be pushed out,” say Jefferies analysts.

Indeed, the 737 reduction may not register too much on the bottom line for many suppliers (see table). Triumph Group, which provides landing gear, gearboxes and actuation systems as well as interior components and ducting for the 737 MAX, does not expect any material financial effect. “The program historically has contributed a single-digit percentage of annual revenue,” Triumph says in a regulatory filing. “The company will use the intervening months to de-risk any supply chain areas of concern.”

This is critical, as the supply chain appears to think the breather will not last long, according to Canaccord Genuity analyst Ken Herbert. “Consensus among suppliers seems to be more like August-September,” he says, referring to when the slowdown might end. However, a production increase to 57 new 737s a month probably will not happen until 2020.

Boeing is being held to account for the two 737-8 crashes, the grounding of the MAX fleet and the financial impact on airlines. It will also absorb the costs of the 737 production slowdown, as the rate cut gives suppliers time to catch up in production and position themselves for further rate increases. Hopefully, the supply chain will never get a break like this again—but it also should not squander it.

Last Chance To Catch Up

The MAX production cut means suppliers can catch their breath
EIGHT YEARS AFTER SPACEX unveiled a heavy-lift version of its Falcon 9 rocket, the triple-core booster delivered its first commercial satellite into orbit, clearing the way for a U.S. Air Force Falcon Heavy mission this summer that, for the first time, will add the military as a customer for reusable rockets.

Acknowledging the progress SpaceX and other companies have made in reusable rocket technology, Congress last year directed the Air Force to drop the word “expendable” from its launch services procurement program. In March, the Evolved Expendable Launch Vehicle program was officially reborn as National Security Space Launch.

Space Test Program 2 (STP-2), scheduled to fly on a Falcon Heavy no earlier than June, will be the military’s first run with a reusable rocket since the U.S. stopped flying military satellites on NASA's space shuttles in December 1992.

SpaceX stuck its first Falcon landing in December 2015 and has since successfully recovered 37 vehicles. The tally would have been 38, but the center core from the Falcon Heavy that launched on April 11 could not be secured after touching down on a drone ship in the Atlantic Ocean due to high seas.

"With 8-10-ft. swells, the booster began to shift and ultimately was unable to remain upright,” SpaceX noted in a statement four days later. “While we had hoped to bring the booster back intact, the safety of our team always takes precedence. We do not expect future missions to be impacted.”

SpaceX fared better retrieving the Falcon Heavy's payload fairing, with both halves plucked from the ocean by recovery ships shortly after they splashed down. The fairing will be reflown when SpaceX launches the first batch of its operational Starlink low-Earth-orbit broadband satellite network in May, CEO Elon Musk noted on Twitter.

But it is the Falcon Heavy’s side boosters that most interest the Air Force. The pair successfully landed at Cape Canaveral AFS after helping to deliver the 14,250-lb. (6,464-kg) Arabsat-6A satellite into orbit on April 11.

Falcon Family Grows

SpaceX’s heavy-lift launcher enters commercial service

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“We're looking forward to using these side boosters again on STP-2,” the Air Force Space and Missile Systems Center wrote on Twitter.

The loss of the Falcon Heavy center core due to rough seas will not affect STP-2 preparations since a new center core was already earmarked for that mission.

More than a year after its February 2018 flight test, the first operational Falcon Heavy lifted off from Kennedy Space Center Launch Complex 39A at 6:35 p.m. EDT on April 11 to deliver Arabsat-6A into a geostationary transfer orbit stretching as far as 55,900 mi. from Earth.

Built by Lockheed Martin, the satellite is designed to provide TV, radio, internet and mobile communications services to customers in the Middle East, Africa and Europe.

In addition to STP-2, the Air Force plans to fly two classified missions on Falcon Heavy rockets in 2020-22. Additional Falcon Heavy commercial customers include ViaSat and Sweden's Ovzon.
A VIATION WEEK & SPACE TECHNOLOGY / APRIL 22-MAY 5, 2019

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AVIATION WEEK NETWORK
Boeing on March 27 provided the first large-scale overview of Maneuvering Characteristics Augmentation System (MCAS) modifications to industry. The meeting was the de facto start of a global campaign by the embattled U.S. aerospace giant to convince regulators that the changes and related training are sufficient to clear the MAX for revenue flying.

The campaign encompasses a series of simulator demonstrations and briefings at multiple training sites throughout the U.S., Europe, Asia and Australia. More than 40 of the 50 MAX operators “have had the opportunity to see the update in action during simulator sessions,” Boeing said April 17.

The outreach comes as Boeing attempts to manage an unprecedented situation. Because the MAX grounding started with a Chinese mandate and spread to other countries before the FAA followed suit, the company says it is imperative to build a caucus of international regulators willing to lift MAX operations bans that have been in place since mid-March.

Most affected airlines are preparing to be without the aircraft for a while. Many have removed MAXs from flight schedules into August at least.

The FAA, which usually sets the standards for U.S.-built aircraft, is also shifting gears. The agency has set up a Joint Authorities Technical Review (JATR) to review certification of the aircraft’s automated flight-control system. Chaired by former NTSB Chairman Christopher Hart, the JATR team comprises FAA, NASA and international aviation authorities.

While the FAA seeks global consensus, the agency also is doing its own due diligence. On April 12 it hosted representatives from the three U.S. MAX operators—American Airlines, Southwest Airlines and United Airlines—as well as unions that represent the carriers’ pilots. The 3-hr. meeting included reviews of the two fatal MAX 8 accidents—Lion Air Flight 610 on Oct. 29, 2018, and Ethiopian Airlines Flight 302 on March 10—that triggered the MCAS changes and fleet grounding. Boeing’s progress on the upgrades and proposed training was also reviewed.
While neither the final software nor the MCAS training curriculum have been presented to the FAA for certification, the agency has been working with Boeing for months. Confident of Boeing’s progress, an FAA official told the April 12 gathering that late May or early June is a target date for approving Boeing’s proposed changes, a source with knowledge of the proceedings tells Aviation Week. The FAA would then mandate the upgrades, clearing the way for U.S. MAX operations to resume—perhaps without consensus from other regulators. The return-to-service time line is not set in stone, the source adds.

Participants also discussed a recent FAA Flight Standardization Board (FSB) pilot-training and qualification review that determined MCAS training—like the rest of transition training from a 737 Next Generation (NG) to a MAX—can be accomplished without simulator time or an aircraft training device. FSB participants, including 737 pilots and FAA engineers, conducted trials on March 25 using 737-800 and MCAS version-12.1.1.-equipped 737-8 full-flight simulators. They also conducted “functional equivalence” and handling-qualities comparison flight tests per the FAA’s FSB guidance.

The pilots detected no handling differences between the 737-800 and 737-8—mirroring conclusions reached by an FSB review conducted in August 2016 by pilots from American, Southwest, and Delta Air Lines and representatives from Transport Canada and the European Aviation Safety Agency. The handling equivalency negated the need for simulator training, both boards determined.

The latest FSB review recommends adding the MCAS to a list of four “special emphasis areas” for 737NG pilots transitioning to the MAX. Already on the list: the MAX’s Elevator Jam Landing Assist feature, landing attitude modifier, gear-handle operation and flight-crew alerting.

“MCAS ground training must address system description, functionality, associated failure conditions” and flight-deck alerts, the draft report adds. “These items must be included in initial, upgrade, transition, differences, and recurrent training.”

The revised FSB review, which will be finalized following a public-comment period that runs until April 30, also adds the MCAS to a list of “master differences” between the MAX and NG. The current 737 FSB report, the document’s 16th revision, does not reference MCAS.

Some regulators and operators are expected to push for mandatory simulator sessions that mimic MCAS failure modes. On April 16, Canada Transport Minister Marc Garneau confirmed his country will be among them. “It’s not going to be a question of pulling out an iPad and spending an hour on it,” he told Reuters.

The FAA could opt to require simulator sessions but will more likely follow the FSB’s recommendation that calls for Level B, or computer-based, training to cover MCAS description and failure scenarios. This would set a minimum standard that regulators or operators could opt to exceed.

Meanwhile, Boeing is close to finalizing the MCAS upgrade. The updated software was put through its paces on a key engineering test flight on April 16. “That was the final test flight before the [FAA] certification flight,” CEO Dennis Muilenberg says. “We’re making steady progress toward certification.” The software has been tested on 120 flights, many of them initial post-production, or BI, flights on MAXs built for customers.

While it works to finalize the new flight-control law logic, Boeing is confident that the global outreach program will lay the foundation for its proposed training package.

Mike Sinnett, Boeing Commercial Airplanes vice president of product development and future airplane development, says the briefings continue to emphasize that the MCAS, which was added to the speed trim system (STS) to standardize handling qualities with those of the 737NG, is neither a stall protection or prevention function. “It is a handling-qualities function. There’s a misconception it’s something [other],” he says. Added to ensure a linear relationship between stick force per G, “speed trim is a function of airspeed, so if you’re going fast it is a low angle-of-attack [AOA], and if you’re going slow it is at higher AOA,” Sinnett says. “The thing you are trying to avoid is a situation where you are pulling back and all of a sudden it gets easier, and you wind up overshooting—that’s going to be a question of pulling out an iPad and spending an hour on it,” he told Reuters.

The MCAS activation during the two MAX 8 accident sequences sparked Boeing’s decision to reexamine how the system operates and modify its software. The work began shortly after the Lion Air accident. The March 27 gathering briefed key proposed MCAS changes to 200 pilots and regulators.

The first of three new main layers of...
Boeing has demonstrated the old and new versions of the MAX’s Maneuvering Characteristics Augmentation System (MCAS) to pilots and regulators in its 737 MAX engineering cab simulator in Seattle. The MCAS is a new flight-control-computer (FCC) function added to the MAX to enable it to meet longitudinal stability requirements for certification.

However, the system is only needed to enhance stability with slats and flaps retracted at very light weights and full aft center of gravity (cg). The aircraft exhibits sufficient natural longitudinal stability in all other parts of the flight envelope without the MCAS to meet the rules. Boeing emphasizes that the MCAS is not an anti-stall or stall-prevention system, as it often has been portrayed in news reports.

The new software load (P12.1) has triple-redundant filters that prevent one or both angle-of-attack (AOA) systems from sending erroneous data to the FCCs that could falsely trigger the MCAS. It also has design protections that prevent runaway horizontal stabilizer trim from ever overpowering the elevators. Boeing showed that the pilots can always retain positive pitch control with the elevators, even if they don’t use the left and right manual trim wheels on the sides of the center console to trim out control pressures after turning off the trim cut-out switches.

Most important, the MCAS now uses both left and right AOA sensors for redundancy, instead of relying on just one. The FCC P12.1’s triple AOA validity checks include an average value reasonability filter, a catastrophic failure low-to-high transition filter and a left versus right AOA deviation filter. If any of these abnormal conditions are detected, the MCAS is inhibited.

Three secondary protections are built into the new software load. First, the MCAS cannot trim the stabilizer so that it overpowers elevator pitch control authority. The MCAS nose-down stab trim is limited so that the elevator always can provide at least 1.2g of nose-up pitch authority to enable the flight crew to recover from a nose-low attitude. Second, if the pilots make electric pitch trim inputs to counter the MCAS, it will not reset after 5 sec. and repeat subsequent nose-down stab trim commands. And third, if the MCAS nose-down stab trim input exceeds limits programmed into the new FCC software, it triggers a maintenance message in the onboard diagnostics system.

According to a pilot who was shown the changes in a simulator session, the demonstration begins with the original MCAS software load. During a normal takeoff, at rotation, the left AOA indication moves to its maximum reading—as seen from the flight data recorder in the Ethiopian Airlines accident. Pilots currently do not expe-
ever activates a second time, pilots really want it to activate,” says Sinnett. The third layer of defense ensures pilots always retain some control-column authority to counteract MCAS nose-down stabilizer commands. “The column itself will always provide at least 1.2g of maneuvering capability,” he says. “So you don’t just have the ability to hold the nose level, you can still pitch up and climb.”

Sinnett says pilots seem satisfied that the three main layers of protection now added to the MCAS will prevent any potential repeat of the circumstances detected in the tragic Lion Air and Ethiopian accidents. “The most compelling thing is that the AOA failure case turns into a run-of-the-mill AOA failure case [one] might have on any other airplane.”

### AOA Disagree
The red-and-white stall-warning tape on the airspeed indicator is well below the aircraft’s indicated airspeed.

### New MCAS Control Law

<table>
<thead>
<tr>
<th>MCAS Changes</th>
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<tr>
<td>1. Both AOA Sensors Compared: the MCAS is inhibited if sensors vary by ≥5.5 deg., there is a sudden spike-up in AOA or if the AOA change rate is unreasonable.</td>
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<tr>
<td>2. Elevator pitch authority exceeds MCAS stab pitch authority; the MCAS is disabled if the command limit is reached.</td>
</tr>
<tr>
<td>3. The MCAS will activate only once for each elevated AOA input. There is no 5-sec. reset after pilot trim inputs.</td>
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### Abnormal PFD Image at Takeoff Due to Erroneous AOA
The updated PFD display indicates angle-of-attack sensing errors as illustrated by the “AOA disagree” icon at lower right along with the red-and-white stall-warning tape extended well above indicated airspeed.

### MCAS Changes

- **Triple AOA Validity Check**
- **Limited Stab Trim Command**
- **Stab Trim Command Limit Exceedance Disable**
- **Pilot Trim Input NO Reset of MCAS**

**Horizontal Stabilizer**

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**AVIATION WEEK & SPACE TECHNOLOGY/APRIL 22-MAY 5, 2019 17**
titude. This is accompanied by the illumination of annunciators on both PFDs that warn of disparities in the IAS and altitude between the left and right displays. As part of the MCAS redesign, Boeing also is upgrading the MAX with AOA-disagree-warn- ing annunciators on the PFD as standard; AOA dial indicator displays are an option.

After the high-AOA indication, pilots then follow the checklist for “airspeed unreliable,” which assures that auto-pilot, auto-throttles and flight directors are turned off. They then pull back power to 80% fan speed, set 10-deg. nose-up pitch attitude and climb to 1,000 ft. above ground level. At that point, they lower the nose, start accelerating and begin retracting slats and flaps at 210 kt. indicated airspeed. When the slats and flaps are fully retracted, the MCAS kicks in.

“It’s a good thing we knew what to expect,” the pilot who saw the changes says. “Otherwise tunnel vision from the ‘airspeed unreliable’ event could have blinded us to the subsequent MCAS nose-down trim input. When I noticed the trim wheels racing, I grabbed the left wheel. It was easy to stop the trim with hand pressure, but I knew in advance what was happen- ing. We followed the checklist for runaway stabilizer, checking again for auto-pilot off and auto-throttle off. We turned off both trim cut-out switches and cranked the ‘frisbees’ [manual trim wheels on both sides of the center con-

The only change pilots will notice with the upgraded MCAS will be angle-of-attack-disagree symbology availability on the primary flight displays.

deviations on PFDs and have not had to deal with continuous stall-warning stickshaker distractions. They also note that they have never been re- quired to fly the aircraft from the point at which a runaway stab trim incident occurred all the way to landing using only the manual trim wheels. “We’re just checking boxes for the FAA,” says one Seattle-based pilot.

A full aerodynamic stall with the MCAS inoperative is another exercise pilots experienced in the MAX engineering cab simulator. “We reduced thrust at 5,000 ft. and slowed the air- craft at about 1 kt. per sec. We were at a midrange cg with gear, slats and flats up. We trimmed until we reached 30% above stall speed and then just continued to ease back on the control wheel,” one of the pilots says.

“Pitch feel was natural, progressively increasing as airspeed decayed. Somewhere between the audible low airspeed warning and stickshaker, I felt the slightest lightening on control pressure in my fingertips,” he contin- ues. “Quite candidly, if I had not been watching for it, I don’t think I would have noticed any difference between the MAX and the Next Gen [NG] models. I kept pulling back through stickshaker, then buffet, then elevator feel shift [a function that doubles the artificial control feel forces near stall] and finally until the yoke was buried in my lap. The nose just flopped down gently at the stall and I initiated recov- ery as I would in most other airplanes I’ve flown.”

During design of the MAX, Boeing added two more leading-edge vortilons [generating vortices over the top of the wing at high AOA] in 2018, for a total of six per side, and also lengthened and raised the inboard leading-edge stall strips to assure stall behavior would be as docile as that of the NG.

Repeating many of the same maneuvers in the engineering cab simulator with the new software load would have been academic at best, as the triple-re- dundant AOA validity checks assure that the MCAS will not be trig- gered by erroneous AOA inputs in the future. But FCC P12.1 changes do not protect against erroneous AOA caus- ing stickshaker or large-scale distortions in indicated airspeed and altitude values. Those malfunctions still can cause distraction and disorientation, especially when flying at night and/or in instrument conditions.

The new MCAS protections built into the P12.1 software load preserve its essential role in enhancing the MAX’s longitudinal stability, while virtually guaranteeing that it will not be triggered by erroneous AOA. And when it does activate, its nose-down stabilizer trim command authority will be limited to assure the pilots always can control aircraft pitch with the elevators.

However, the FCC software up- grades are not the only critical chang- es needed to boost safety margins for operators. Pilots who underwent the demonstration also say the sessions underscored the need for additional simulator training for dealing with compound emergencies involving AOA and runaway trim failures.
737 MAX Crisis Raises Questions About NMA Timing and Definition

> GROUNDING AFTERMATH DELAYS BOEING NMA CUSTOMER TALKS
> MAX REPLACEMENT WILL BE NEEDED SOONER, ANALYSTS SAY

Jens Flottau Frankfurt

The MAX crisis is affecting Boeing in myriad ways. Most important, 346 lives were lost in the two recent 737-8 accidents. As a consequence, the company’s approach to aircraft development and safety is being publicly scrutinized, leading it to establish an internal review board concerning its processes.

Boeing’s public image is tarnished beyond anything seen in recent memory. Because of the global grounding, it cannot deliver its highest-volume product. The financial and industrial impact will be painful now that it has cut its production rate. But the crisis is also reviving a debate about the proposed new midmarket airplane (NMA).

Before the March 10 crash of Ethiopian Airlines Flight 302, Boeing was widely expected to seek authority to offer the NMA to airlines soon and to use the Paris Air Show in June to present more details of its latest project, planned to be positioned between the traditional narrowbody and widebody segments.

However, some industry observers believe a change in course is now imperative. “The cold commercial reality is that an already pressuring need to replace MAX soon has now become all but unavoidable,” writes Nick Cunningham, managing partner and analyst at London-based A&D research company Agency Partners. He believes the NMA as currently planned would be the wrong aircraft for the job.

Vertical Research Partners analyst Rob Stallard is raising questions as well. “A number of investors are starting to consider longer-term, strategic issues,” he says. “For example, does this push back Boeing’s plans for another 737 rate increase and the launch of the NMA? And does this in turn bring forward a next-gen Boeing narrowbody?”

Cunningham maintains that, unrelated to the accidents, the MAX loss of market share against the Airbus A320neo has worsened recently “and is now unrecoverable.” Boeing lost most of that share at the top end of the narrowbody segment. “[That is] driven by the technical inadequacies of the 737 MAX—it is low to the ground, so it has a smaller fan, thus less power and worse fuel economy than the Neo,” he says.

The way the engines have been installed on the MAX wings—forward and more upward—led Boeing to develop the now infamous Maneuvering Characteristics Augmentation System (MCAS), with the aim of bringing MAX flying characteristics more in line with the 737 Next Generation. Untimely MCAS activation played an important role in both the Ethiopian and the Oct. 29, 2018, Lion Air accidents.

In the short term, the loss of market share that has been visible for some time will likely worsen, given Boeing’s decision to cut rates to 42 aircraft a month, from 52. Rates were about to go up to 57 aircraft per month after this year, so by then the gap will be 15 aircraft per month if planned production is not reinstated quickly. Given that high costs are incurred in short-notice rate cuts and recovery is difficult, Cunningham considers Boeing’s decision very surprising.

That is unless “Boeing is expecting to deliver fewer MAX aircraft, not temporarily, but permanently,” he says. There could be two main reasons for that. First, bringing MAX deliveries back could take longer than originally expected because of lengthy software upgrades, and an exhaustive global certification process in which regional and national airworthiness authorities do not automatically follow the FAA. Second, airlines could be indicating to Boeing that they want fewer of the aircraft.

So far there is little public evidence to support the latter point. Only Garuda Indonesia, Lion Air and possibly Ethiopian have expressed a wish to cancel existing orders. That does not necessarily mean that other carriers will not follow suit.

Here is where NMA definition is key. “We have long suspected that NMA may really be a cover for a much wider program to replace MAX, starting at the top end,” Cunningham writes. “It would have been necessary to hide the program because making it public would immediately damage MAX sales. That is now much less of a consideration and was already headed that way, given that long backlogs were already impacting orders.” He says worries that orders might be lost to a new aircraft are irrelevant, in the sense that if Boeing delays a MAX replacement orders will be lost anyway.

A 2018 joint Aviation Week-Bank of America Merrill Lynch survey showed that a large number of airlines want an aircraft that looks like a 737 replacement, not the larger, more capable NMA concept Boeing has pursued so far. They did like the idea of a small widebody, though, which is seen...
JetBlue’s London Plans Advance Its Mint Strategy

> JETBLUE PLANS TO SERVE LONDON IN 2021
> FLIGHTS WILL BE WITH AIRBUS A321LRs

Sean Broderick Washington

JetBlue Airways’ plans to enter the highly competitive transatlantic market in 2021 represent a new chapter for the 19-year-old airline, but it is not a completely unfamiliar one. Judging by the success of its U.S. transcontinental market-focused Mint offering, betting against the carrier’s success would be unwise.

The New York-based airline on April 10 confirmed what many in the industry have long expected: It plans to start serving Europe from the U.S. East Coast. Details are scant, however. JetBlue says it will operate multiple daily services between London and its “focus city” airports—New York John F. Kennedy and Boston Logan—and it is “evaluating” which London airport to use.

Heathrow is the most attractive London airport, but gaining access—to takeoff and landing slots—is difficult. A London-based source tells Aviation Week that JetBlue has acquired two slots for Boston services—enough for one daily round trip. If it does not secure more, it will serve London Gatwick Airport instead. JetBlue declined to comment.

The routes will be flown by Airbus A321LRs, which the airline will acquire by converting 13 of its 85 outstanding A321neo orders. The A321LRs, which will become an ETOPS subfleet, will be configured with a revamped version of its highly successful Mint two-class product, which JetBlue created for high-demand transcontinental routes and has expanded to other markets. The carrier’s 35 Mint-configured A321s have 159 seats, including 16 lie-flat premium seats. The A321LRs will have more than 16 premium seats, JetBlue says.

With JetBlue’s London launch still two years off, accurately gauging the market it will face is challenging. A Bernstein Research analysis notes that the largest threat may be to low-cost, long-haul operator Norwegian, which is shifting from a rapid-growth strategy—it launched 35 new routes in 2018, many connecting the Europe and the U.S.—to one focused on making money. The change has led to cost cutting, including scrapping some U.S.-Europe routes.

While changes are inevitable, it is a safe bet that JetBlue’s primary London competition will be the joint venture linking British Airways, American Airlines, Finnair and Iberia, and a similar cooperation between Air France-KLM, Virgin Atlantic and Delta Air Lines. The two groups control 70% of transatlantic seats between Europe and North America, Bernstein calculates, and 75% of business-class seats. Looking at routes between London and the two U.S. cities JetBlue is targeting, the concentrations are even higher: 80% for transatlantic seats and 88% for business class.

Looking at the big picture, JetBlue’s capacity additions, assuming twice-daily frequencies in each market, will be minimal. Bernstein’s analysis shows the carrier will boost daily seats less than 3% and will add about 2% to business-class inventory. Filling them with U.S. passengers figures to be less challenging than selling to European customers. JetBlue’s brand is strong in the U.S., and the joint ventures have the advantage of tailoring their marketing to the brand that makes the most sense geographically while offering each partnership’s entire package.

“In the joint ventures, each airline markets the entirety of the joint venture in its home markets,” Bernstein says. “While JetBlue will have a sales presence and established corporate contracts in the U.S., building those in Europe . . . will be tough.”

Delta and Virgin Atlantic, already well-established between London Heathrow and both New York Kennedy and Boston Logan, intend to make it even tougher. The partners announced plans to add flights from both U.S. airports and London Gatwick, which Delta has not served in nearly a decade. The flights will start in 2020.

asperent for quick turnarounds in hub-feeding roles.

But others are not so convinced the concept is about to change. And there are still NMA fans, particularly among carriers such as Delta Air Lines that have to replace many 757s and 767s in the coming years. Delta CEO Ed Bastian said at Aviation Week’s MRO Americas conference in early April that an appropriately designed product remains high on Delta’s wish list.

“We are very interested in the NMA and have talked to Boeing at some length,” he said. “We’ve given Boeing our expectations. You can rest assured we are spending time in Seattle talking about that.”

However, Boeing’s focus on the MAX crisis has diverted attention from the NMA, Bastian confirmed, leading to a slowdown in dialog with potential customers, including Delta.

“It’s understandable that they’ve been distracted. I expect them to be able to reengage in some conversations in the not-too-distant future,” he said.

Time is of the essence, as many believe Boeing needs to have the NMA available by 2025-26 at the latest to meet the 757/767 replacement cycle. Otherwise it risks losing further ground to the Airbus A321LR or XLR once that derivative is launched.

Industry analyst Kevin Michaels said at the conference that while the MAX situation may have made it a little less likely Boeing will move forward, he still thinks there is an 80% chance it will build the NMA. He noted that Bastion was on stage practically begging for a new aircraft.

Canaccord Genuity analyst Ken Herbert said at MRO Americas that “it is difficult to determine what impact this will have on the NMA, or even the [KC-46A tanker].” Ongoing issues with the U.S. Air Force’s acceptance of the tanker have been overshadowed by the MAX grounding. “But to us it sounds like the NMA decisions are slipping to the right,” he says, adding: “I would not be surprised to see eventual changes at [Boeing Commercial Aircraft] management once the MAX is successfully returned to service, but this will likely come much later.”

A change in management now would only create more uncertainty around future product strategy.

—With Michael Bruno, Sean Broderick and Joe Anselmo in Atlanta

as efficient for quick turnarounds in hub-feeding roles.
JetBlue will eventually operate three versions of the Airbus A321.

“We’re sitting in a very good position, we think, with our partnerships in the transatlantic and with our core products and services that will continue to improve over the next months and years,” Delta CEO Ed Bastian says. “As you look at transatlantic capacity, there are always new entrants coming, and there are always entrants leaving... We’ve had a very good couple of years in the transatlantic, and we expect that to continue.”

JetBlue is betting on value to make the new routes work—similar to its 2014 Mint introduction. The carrier rolled out Mint, its first foray into two-class service, to better compete with rivals’ lie-flat offerings between New York and both Los Angeles and San Francisco. Its original plan envisioned 11 Mint-configured aircraft. But the product’s popularity, driven by fares that were up to 50% below comparable premium offerings, has made it a fit in more markets than expected. The key Mint metrics: routes of at least 2,000 nm with premium demand. JetBlue’s Mint network touches 11 destinations from its New York, Boston and Fort Lauderdale, Florida, bases. Mint flying accounts for about 20% of the carrier’s available seat-miles.

JetBlue has 253 aircraft in its fleet: 130 Airbus A320s, 35 Mint-configured A321s, 28 high-density A321s and 60 Embraer 190s. It expects to take delivery of six A321neos this year and to begin replacing its E190s with Airbus A220s in 2020.

Adding the ETOPS-certified A321LRs will give JetBlue a fifth sub-fleet, assuming the 100-seat E190s and A220s are interchangeable. Getting the A321LRs enough work on transatlantic flights may prove challenging, Bernstein suggests, raising the possibility of the aircraft being used on some of the most lucrative existing Mint routes.

“With smaller scale in international operations, the cost of fixed-base operations will be higher and will need to be spread over a narrower-gauge aircraft versus the competition,” Bernstein says. “Additionally, JetBlue will have to pair the international routes with domestic services to achieve sufficient block-hour productivity.”

—With Tony Osborne in London

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**Carbon Buildup May Have Led to Leap 1B Engine Failure**

**Sean Broderick** Washington and **Guy Norris** Los Angeles

**CFM INTERNATIONAL IS MONITORING ITS LEAP ENGINE**

fleet for signs of an issue believed to be tied to the March 26 Leap 1B contained engine failure on a Southwest Airlines Boeing 737-8 and has recommended inspections for a subset of engines.

The issue: carbon buildup, or deposits of evaporated fuel and other material on fuel nozzles, which lead to uneven temperature flow regions within the combustion chamber exit plane and hot spots within the high-pressure turbine (HPT). These hot spots can cause premature wear.

On the Southwest engine, it is believed to have triggered an HPT blade failure. Metallic fragments were found in the tailpipe, a source with knowledge of the ongoing investigation confirms. CFM believes the issue may be linked to the carbon buildup, or coking, that it has been monitoring.

CFM is working to understand both the failure and what is causing the coking. The Southwest 737-8, operating as Flight 8701, experienced the failure about 10 min. into a flight from Orlando International Airport, Florida, to Victorville, California, where it was to join the carrier’s other MAXs in storage due to the aircraft’s global grounding. The two-person crew returned to Orlando and landed safely.

Within hours of the failure, CFM analyzed the engine’s operating history and compared it against data from each of the other 1,560 Leaps in service. Aware of Leap fleet coking, a common issue with gas turbine engines, the manufacturer had set up rotatable pools of spare fuel nozzles to swap out in-service parts at certain thresholds before the Southwest incident. Following the failure, it revised its analytics and reduced those thresholds. Engines exceeding the revised limits were recommended for inspections.

“CFM continually monitors the fleet, and we have a method to detect carbon buildup, enabling CFM and our customers to proactively manage the issue,” GE says. “In the case of the engine on Flight 8701, we learned from the event that our monitoring analytics and maintenance process needed to be adjusted for our Leap engines. This adjustment has been made, and the fleet was assessed within hours, with follow-on actions completed within days.” GE and Safran are joint-venture partners in CFM.

The inspections have turned up issues on about 1% of the engine fleet—all on Leap 1Bs, which is the 737 MAX’s only engine. The Leap 1A is an option for the Airbus A320neo, sharing the platform with the Pratt & Whitney PW1000G-JM.
BRITAIN'S AEROSPACE INDUSTRY BREATHED a cautious sigh of relief following the EU's decision to allow Britain to delay its exit from the pact. Industry was concerned that without intervention, the UK could have crashed out of the EU on April 12, after the British Parliament repeatedly failed to find consensus on Prime Minister Theresa May's Withdrawal Agreement.

Preparation for a no-deal exit, say analysts, has seen aerospace spend up to £2 billion ($2.6 billion), including the cost of extra stocks in case supply chains are interrupted. Ultimately, those stocks can be used in the production process, but a quarter of that sum—around £500 million—across the industry is unrecoverable, say experts.

“Government and Parliament must use the time they have been granted constructively, by working together to reach agreement on pragmatic solutions to the issues the country faces around Brexit,” says Paul Everitt, CEO of ADS, a UK aerospace and defense trade association.

Everitt says these costs could continue to mount as long as there is a threat of a no-deal exit, an agenda that is still being pushed by some British lawmakers, including ministers, despite the warnings about its potential impact on the British economy.

“The current uncertainty must be put behind us and the needs of businesses, workers and consumers given greater priority in political discussions and decision-making over Brexit,” adds Everitt.

As well as adding cost, figures released by the UK’s Office for National Statistics (ONS) suggest that the Brexit uncertainty has also affected production. The ONS’ Index of Production published in February showed that during 2018, production in the UK aerospace sector declined by 3.9%, despite strong global demand and rising production rates worldwide.

Aerospace Industry Counts the Cost

Tony Osborne London

Aerospace and defense trade association.

Airlines are confident they can keep flying whatever the Brexit outcome.

European Airlines Contend With Ongoing Uncertainty Over Brexit

Helen Massy-Beresford Paris

A n extension of the Brexit deadline until Oct. 31 is good news for those who hope increasing doubts over the process will result in Britain remaining in the European Union (EU) after all. But with Brexit uncertainty already affecting demand for flights, the prolonged confusion may not be good news for airlines already struggling with the short-term economic effects.

While carriers based in Britain and those operating between there and mainland Europe have done much work and spent millions on Brexit-proofing their operations—secur- ing European operators’ licenses and setting up European subsidiaries to protect their flying rights against the dreaded “no-deal Brexit”—they are powerless to do anything about the ongoing drama’s effect on consumers. Carriers have already warned that the lack of clarity is having an impact on their operations, with the weaker pound since the 2016 Brexit referendum—which increases their dollar-denominated costs such as fuel and aircraft leasing—also harming British travelers’ spending power in the Eurozone.

Brexit is by no means the only factor; economic woes in other European countries also are playing a role. But EasyJet warned on April 1 that uncertainty over the issue is curbing customer demand, and it revealed a more cautious outlook for the second half of the year.

The British budget carrier, which in July 2017 set up an Austrian subsidiary to protect its flying rights in the event of a no-deal Brexit, said it was experiencing “softness” in demand across its network due to macroeconomic uncertainty and “the many unanswered questions regarding Brexit which affect customer confidence.”

International Airlines Group, the parent company of British Airways, Aer Lingus, Iberia, Vueling and Level, has expressed confidence that its airlines will be able to keep flying and comply with ownership rules post-Brexit. But CEO Willie Walsh acknowledged at the company’s full-year results presentation on Feb. 28 that the uncertainty was taking an
economic toll. “Whether you are for or against the UK leaving the EU, all the credible forecasts I’ve seen predict that Brexit will have a negative economic impact in the short-to-medium term that is likely to damage consumer confidence and act as a further drag on business investment,” Walsh said. “We need to remain very agile in the months ahead.”

EasyJet is also confident it will keep flying, even in the event of a no-deal exit. That Brexit outcome has become much less likely since the EU granted a delay to the UK’s scheduled departure, but it is still a possibility, albeit a remote one.

While airline executives are confident they can avoid grounded fleets when the Brexit clock strikes midnight, the climate of uncertainty will pile further pressure on prices as carriers seek to persuade nervous consumers to book flights.

“Most airlines managed the uncertainty in the run-up to the planned March deadline, though it took a lot of effort, time and money, for example, in obtaining additional operating licenses,” says John Strickland, director of JLS Consulting. “The October deadline means airlines cannot fully turn back to other aspects of running the business—Brexit is still going to be there somewhat in the background.”

For EasyJet, the lack of clarity is affecting bookings. “Customers in general are wary and waiting to see what’s going to come out of it. We’re seeing a softness in all our core European markets,” CEO Johan Lundgren said April 1.

Virgin Atlantic also reported an annual loss for 2018 on April 10, citing the weaker pound and higher fuel costs, both of which can be linked to Brexit and the referendum’s effects on the economy since June 2016.

Presenting its third-quarter results to Dec. 31 on Feb. 4, Dublin-based low-cost carrier Ryanair warned that despite “reasonable visibility” on its fourth-quarter bookings, it could not rule out further cuts to air fares or its full-year guidance, “especially if there are unexpected Brexit and/or security developments which adversely impact fares for close-in bookings between now and the end of March.”

The airline said it did not share some competitors’ optimistic view that air fares would rise this summer. “Some airlines have reported later bookings due to consumer uncertainty about Brexit,” says Strickland. “Airlines say traffic is buoyant and that forward bookings are in line with expectations but are having to be stimulated by lower pricing further ahead in the year.”

However, looking on the bright side, Strickland says there is a limit to how long Brexit confusion will affect consumer spending patterns. “If the uncertainty continues beyond October, at some point consumers may simply become weary and just start ignoring it,” he says. “We see after events such as security incidents and terror attacks that traffic is typically affected, but it does come back. Even if there are ups and downs on the way to wherever we end up, this will be a temporary situation.”

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Irish Authority Evolves as Europe’s ‘Gateway’

> THE SHANNON AREA CONTROL CENTER IS THE INTERFACE

> FREE-ROUTE AIRSPACE AND DATA LINK ARE INTRODUCED

Bill Carey

A time line from the past to the future runs through the Irish Aviation Authority’s (IAA) North Atlantic Communications Center at Ballygirreen, a townland on the Shannon Estuary in western Ireland.

Originally known as Shannon Aeradio, the station dates to 1936, when a transmitter hut, a receiver hut and a short-wave radio direction-finding hut were built to provide communications by Morse code with flying boats crossing the North Atlantic Ocean between Ireland and Newfoundland, Canada. The experimental flying-boat trials were “a complete success,” paving the way for the future of transatlantic aviation, reads a signpost in front of the station.

The current building, opened in 1952, accommodates 50 radio officers and engineers who provide high-frequency (HF) radio communications for the 500,000 flights that transit the oceanic airspace each year. Under an agreement the UK and Irish governments reached in 1966 to avoid duplication of services, UK controllers in Prestwick, Scotland, provide air traffic control and radio officers at Ballygirreen communications for aircraft transiting the eastern half of the North Atlantic Ocean in the Shanwick oceanic control area—a volume of airspace named from a portmanteau of Shannon and Prestwick.

The joint service agreement between the UK and Ireland most recently was updated in 2004. A newer wing at the station was reached in 1966 to avoid duplication of services, UK controllers in Prestwick, Scotland, provide air traffic control and radio officers at Ballygirreen communications for aircraft transiting the eastern half of the North Atlantic Ocean in the Shanwick oceanic control area—a volume of airspace named from a portmanteau of Shannon and Prestwick.

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Shannon ACC. Controllers there eventually will manage movements at Shannon Airport, which handled 1.86 million passengers and 25,566 takeoffs and landings last year.

In 2006, the IAA was a founding member of the Cooperation between Air Navigation Service Providers (Coopans) Alliance, with Sweden’s LFV and Denmark’s Navair. Austria’s Austro Control joined in 2010 and Croatia’s Croatia Control in 2011.

The purpose of the Coopans Alliance was to standardize the partners’ air traffic management systems on a single platform—Thales’ TopSky—to benefit from common software and synchronized upgrades. “The idea is to develop once and deploy five times,” explains Patrick. In September, the alliance acceptedNav Portugal as its sixth member.

The Shanwick Oceanic Control Area (OCA), in which the IAA provides communications, covers 2.2 million km² (850,000 mi.²) in the eastern half of the North Atlantic Ocean and handles more than 500,000 aircraft movements each year. Iceland’s Isavia, through Iceland Radio, provides services in the northern Reykjavik OCA, which covers 5.4 million km², with 150,000 annual movements.

Isavia and the IAA initiated joint operations in 2007 by sharing a common operating system. The project was expanded in 2015 with the introduction of virtual joint-center operations, allowing the ANSPs to operate independently of each other or jointly using the internet-protocol-based Rohde & Schwarz VCS-4G Voice Communications System for HF, VHF and satellite voice communications at their respective centers in Gufunes, Iceland, and Ballygirreen.

Adoption of the Aireon space-based automatic dependent surveillance-broadcast (ADS-B) system is the IAA’s latest technology advance. The authority became an equity partner in the Aireon joint venture in 2014, joining ANSPs Nav Canada, Navair and Italy’s Enav as well as Iridium Communications. UK NATS joined the company in May 2018.

The IAA will operate Aireon’s Aircraft Locating and Emergency Response Tracking (ALERT) service, providing users with the last known position of any ADS-B-equipped aircraft in distress. Aireon announced that it would offer the service free to registered airlines, ANSPs, regulatory agencies and search-and-rescue organizations in September 2014, after the loss of Malaysia Airlines Flight 370, a Boeing 777-200 that disappeared earlier that year in the Indian Ocean.

Preregistration for the service began last August; as of March, Aireon counted 143 registrants.

Aireon ALERT services will be provided by the watch manager at Ballygirreen, who will have access to a terminal with constantly archived position data from Aireon’s surveillance system. On request by telephone, the manager will provide a 4D report, including the latitude, longitude, altitude and time of an aircraft’s last known position, based on its flight identification code or International Civil Aviation Organization 24-bit address, a unique identifier for the aircraft’s transponder. The IAA will follow up by email with a comprehensive report covering the last 15 min. of the flight.

With Europe’s June 7, 2020, mandate requiring aircraft operators to equip for ADS-B “Out” position reporting soon approaching, the IAA plans to apply space-based ADS-B for surveillance in its domestic airspace. It also has installed a number of terrestrial ADS-B stations.

“It will help us at the peripheries of our airspace, where we are at the limits of our classic [radar] surveillance coverage of 250 mi.,” says Patrick. “We’ll start using it in a fill-in role, augmenting radar in relation to how we operate. It will also give us an increased level of resilience in terms of radar failures.”
Airbus To Offer Enhanced Vision System on HUD

EFVS COULD EXPAND CARRIER OPERATIONS

CHINA TARGETS WIDESPREAD USE IN 2025

Thierry Dubois  
Lyon

A
<br>irbus is developing an enhanced flight vision system (EFVS) that could equip all its in-production aircraft. The idea is to improve airport access, regardless of weather or landing aids on the ground.

The move is part of a commercial aviation trend of gradually adopting military and business aviation technologies to improve pilot situational awareness, such as head-up displays (HUD) and its accompanying symbology. A road map the Civil Aviation Administration of China (CAAC) issued in 2012 has been a factor. More equipment on board decreases the requirement for costly ground aids such as instrument landing systems (ILS), thus multiplying the number of airports into which an aircraft can fly.

An EFVS displays on a HUD an image created from several optronic sensors. Each sensor is suited to a specific range of wavelength, corresponding to the runway's thermal signature or some incandescent lighting, for example.

The picture resulting from the merger of the different inputs will thus provide the pilot with an exhaustive—albeit only two-color—view of the runway and its environment, even when fog, precipitation or darkness prevents natural vision.

Under the FAA's definition, an EFVS operation is conducted when a pilot uses the image provided by an EFVS to operate in the visual segment of an instrument approach. There are major operational benefits, especially under FAA rules, says Airbus test pilot Jean-Michel Roy. Using an EFVS allows an operator to dispatch an aircraft when weather at the destination is below authorized visibility minimums. The crew may fly down to 100 ft. above the runway threshold before switching to natural vision. If the approach has a form of vertical guidance, such as augmented GPS, the EFVS may be used to touch down.

The expected bottom line is a reduced number of flight cancellations and delays.

The FAA has the most advanced set of rules for EFVS operations, and the European Aviation Safety Agency is following suit.

An increasing population of business jet pilots are familiar with such operations because that sector relies on a high proportion of small airports with few landing aids. Military pilots, such as those flying the Airbus A400M transport, have used an EFVS equivalent to land on airstrips without lighting. Regional turboprop manufacturer ATR is closing in on the certification of a similar system (AW&ST Feb. 25-March 10, p. 40).

Airbus engineers will draw from the experience gathered with the A400M and at sister company ATR. They have their own design drivers, however.

Roy suggests Airbus may set the bar higher than ATR. "We want to be certain we meet customer demand; we do not know yet how many sensors we need," he says. The Airbus A320's radome is larger and will thus more easily accommodate the sensors.

While ATR has chosen a wearable display, Airbus favors a HUD for "image quality and reading comfort," says Roy. He would not disclose the names of the potential EFVS suppliers, but Thales and Elbit Systems are two likely contenders. Thales already provides the HUD.

Airbus has started a first EFVS flight-test campaign this year with A320 MSN6101, which the airframer uses as a prototype. Optronic sensors were installed under the radome, just above the weather radar. The campaign will involve "dozens of hours" of trials, says Roy.

Representatives for Chinese carriers may participate in a second series of evaluations. The CAAC's road map for HUD and EFVS equipment targets widespread use in 2025. With the aim of having a greater number of airports reliably served in the country with minimal investment on the ground, the CAAC is incentivizing carriers to install the systems in their aircraft.

"Therefore, some Chinese airlines have asked us to make them available," says Roy.

Onera, France's aerospace research center, has tested the sensors with obscurants such as artificial fog in a weather simulation chamber: "We look at how our sensors can see a light at a given distance," says Roy. An issue is that the aircraft may have to fly through layers of different obscurants.

He believes EFVS will be of interest to markets other than China. "Each operator has to study whether it has a business case," says Roy. FedEx has long used EFVS, he notes. The greater proportion of ILS Category 2- and 3-equipped airports in Europe may make the region slower to embrace EFVS.

Airbus last year began flight-testing an A350 with a head-down synthetic vision system (SVS), which uses a database to represent terrain and obstacles on the artificial horizon. ATR is working on a combined vision system (CVS) that merges SVS and EFVS images. An SVS better represents distant terrain but cannot provide information on a runway incursion. What about a CVS on an Airbus? "We will study this question," Roy answers.

Last October, Collins Aerospace said it had signed an agreement with Boeing to develop an EFVS as a factory option for the 737 MAX. ©
The Trump administration’s call for boots on the Moon by 2024—four years earlier than NASA’s already stressed current schedule—prompted a joke at this year’s Space Symposium: A small lander, chartered under the agency’s ongoing Commercial Lunar Payload Services program, touches down on the lunar surface and unveils its cargo: a pair of astronaut boots.

Without a significant budget boost, that is about as far as NASA will get toward landing astronauts on the Moon by 2024, a timeline that could be a blessing or a curse. Accelerating work by four years to accommodate such a landing basically entails consolidating NASA’s nine-year, roughly $50 billion deep-space exploration budget into five years, for an estimated annual increase of around $5 billion per year, unless cheaper alternatives can be found. Details of the proposal are expected to be delivered to Congress before the end of April.

“NASA has always wanted to have another ‘JFK moment,’ where they’ve got the goal and the resources to go do the job,” Special Aerospace Services consultant Wayne Hale said on the sidelines of the conference in Colorado Springs, April 8-11. “At least three times since then, we’ve had a president stand up and say, ‘I want you to go do this great thing,’ and the resources never come through.”

Lacking a John F. Kennedy-type directive and significant budget hike, NASA’s strategy has been to slowly evolve the ability to sustain astronauts beyond low Earth orbit, paying what it can afford under a budget that has been relatively stable for decades at roughly 0.5% of total U.S. federal spending.

Presidential administrations have come and gone, shifting NASA’s goal to the Moon, Mars, back to the Moon, an asteroid and back to the Moon again, but the agency adapted by maintaining its focus on developing the Orion capsule for deep-space human travel and the heavy-lift, human-rated, Space Launch System (SLS) rocket, wherever they may be needed.

Those projects, along with supporting ground systems, have cost NASA upward of $20 billion, with the SLS debut flight still 20 months away, at best. The first SLS launch with crew
Stratolaunch’s gargantuan twin-fuselage launch vehicle carrier aircraft made a successful 2-hr. 29-min. first flight from Mojave Air and Spaceport on April 13, marking the start of a planned 1.5-year test and certification program.

With an Orion capsule docked, the Gateway also could host crews for several weeks at a time. Interestingly, its core component, a power and propulsion element (PPE) that is slated to launch in 2022, was once the mother-ship for the Obama administration-era asteroid expedition.

“We’ve always said that Gateway was flexible and could be evolved and changed and be part of this open architecture. It was a piece of infrastructure that could be used for a lot of different things, including even Mars activities,” Bill Gerstenmaier, NASA associate administrator for human exploration and operations, tells Aviation Week. “It’s encouraging that we’re now going to get a chance to show that this architecture can really do what it was advertised to do.”

President Donald Trump’s call for NASA to land astronauts on the Moon within his possible second term could translate into a sustained high level of funding to accomplish the deed.

The concern is that the agency would sacrifice its flexibility if fails to meet Trump’s deadline or even if it fulfills it in a way that significantly delays hardware and systems for sustained deep-space operations, risking a repeat of the successful but extremely short-lived 1969-72 Apollo Moon landings.

“If we’re going to change this philosophy of a constant budget wedge, where we do as much as we can, year by year; incrementally getting closer to going back to the Moon—if we’re going to change that, which is what is being proposed here, then it runs the risk of a new administration coming in and saying, ‘No, I don’t want to do that. Let’s cancel all that and start something new.’ That’s kind of scary,” says Hale.

“We’ve had this bipartisan program aboard Orion remains 3-4 years away.

More recently, NASA unveiled plans for a lunar-orbiting outpost, currently envisioned to be some 50 metric tons (compared to the 450-metric-ton International Space Station). The Gateway, as it is known, would serve as a command-and-control module for sorties to and from anywhere on the lunar surface, platform for astronomical observations and remote sensing, assembly node for lunar landers and other space-craft, technology tested for missions to Mars and a small-scale science lab.

Guy Norris Los Angeles

Stratolaunch’s gargantuan twin-fuselage launch vehicle carrier aircraft made a successful 2-hr. 29-min. first flight from Mojave Air and Spaceport on April 13, marking the start of a planned 1.5-year test and certification program.

The six-engine, 285-ft.-long Stratolaunch is the biggest all-composite aircraft ever developed and, as measured by its 385-ft. wingspan, also the world’s largest aircraft. Designed by Burt Rutan and built by Northrop Grumman’s Scaled Composites for Stratolaunch, the aircraft was flown for its first flight by Scaled test pilots Evan Thomas and Chris Guarente, with Jake Riley as flight engineer.

The crew flew from the cockpit located in the right fuselage. The nose of the left fuselage is not occupied but is also pressurized to house launch-related systems for the small- or medium-size payload rockets that will be released from the midpoint of the wing separating the fuselages by 95 ft.

Taking off at 6:58 a.m. Pacific time, the crew conducted basic handling checks at speeds up to 165 kt. (189 mph) and altitudes up to 15,000 ft. The flight
for 0.5% of the federal budget to NASA that’s been pretty stable for decades, and you have a plan that builds out a space program under that,” he adds. “If you come in with a different plan, you run the risk that you’ve upset the bipartisan apple cart, and it will be seen as partisan—and then we’re off to the races.”

NASA learned that lesson the hard way in 2010, when the Obama administration canceled the previous administration’s Constellation initiative, which aimed for a crewed landing on the Moon by 2020.

NASA is looking for options to fulfill all of Trump’s human spaceflight directives, which include a sustained presence around the Moon, partnerships with other countries and commercial companies and, as of March, the first post-Apollo lunar landing before the end of 2024.

“The idea is we’re trying to create an infrastructure that is flexible and adaptable and can change to meet market needs. If we do this right, then we’ve created an enabler. It’s like when the federal government built the Federal Highway System. That became transformative,” says Gerstenmaier.

“This is what we’re trying to do in space, to put in as small a piece as we can from a government perspective, and then have that turn industry loose to go do things.”

When Vice President Mike Pence issued the challenge for a lunar landing in 2024, he told NASA to accomplish the mission by any means possible.

“We’ll get a chance to test and see what that really means,” Gerstenmaier notes. “I think you’re going to get a chance to see how we can essentially restructure the Gateway a little bit or just refocus, where we don’t need the whole Gateway.”

Theoretically, a Moon landing in 2024 is possible, though the short time frame means that only development programs close to producing flight hardware, or hardware already in existence, will fit into the five-year window.

NASA is likely to request both funding and permission for nontraditional contracting arrangements to build a minimalistic Gateway and lunar lander, including a system to travel from the Gateway to the Moon’s surface and an ascent system to launch from the Moon and return to the Gateway, where the crew’s Orion capsule would be docked for the flight back to Earth.

During the Space Symposium, Lockheed Martin presented an early concept for meeting Trump’s deadline, based on repurposing Orion structural components and the propulsion system from its European-built service module.

“This isn’t the only way to accomplish this,” says Lockheed’s Rob Chambers, director of human space exploration strategy. “The objective was to lay out an architecture that moves the needle from ‘Is this possible?’ to ‘How do we do it best?’ It is almost an existence proof that it’s feasible to accomplish this by 2024, maintain a continuity of purpose with an arc toward Mars and then drive out what are those things that have to happen.”

Chambers says the team’s starting point was safety. “Going fast doesn’t mean going recklessly—and it doesn’t have to. . . . But we are going to have to take some mission-success risk,” he notes.

Reusing existing hardware eliminates the time needed for new tooling, qualification tests and unnecessary development efforts. “It is really important to use what you’ve got, only develop what you need to and then get moving,” Chambers says.

Lockheed’s plan begins with the uncrewed Exploration Mission-1 flight of Orion on an SLS rocket around the Moon, a mission NASA hopes to fly in late 2020 or early 2021.

The next step would be to add a docking node or small pressurized habitat onto a commercially provided PPE.

ended with a touchdown at 9:27 a.m. on Mojave’s 200-ft.-wide Runway 30. Commenting after the test mission, Thomas said: “I honestly could not have hoped for more on a first flight, especially of an airplane of this much complexity and uniqueness.”

Powered by six ex-Boeing 747-400 Pratt & Whitney PW4056 engines, the aircraft smoothly rotated at liftoff. “It was definitely ready to fly and climbed out quickly,” says Thomas. After turning the aircraft to the north with its 28-wheel landing gear still extended, the flight crew “got straight into our test cards,” he says. “It flew very much like we had simulated, though we saw a few little things that were off-nominal. Really, for a first flight, it was spot-on.”

The testing focused on airspeed calibration and flight-control system evaluation through a series of roll doublets, yaws, pushovers, pull-ups and steady-heading sideslips. Stratolaunch plans to conduct a launch demonstration of the aircraft with a Northrop Grumman Pegasus XL air launch vehicle.
Beresheet relays a last look at the Moon
before crashing.

NASA expects to announce one or more PPE partnership agreements in May.
Outfitting the PPE with a docking node would enable NASA to turn Exploration Mission-2, a crewed flight test around the Moon slated for 2022-23, into a shakedown mission and docking at the Gateway.

The lander elements, derived from Orion hardware, would fly separately on commercial launchers, or together on an SLS, in early 2024, setting up Exploration Mission-3, launching in late 2024, to become the first Gateway-staged mission to the lunar surface.

“To fly the lander in early 2024, we have to be bending metal next year, which means tooling has to be in-house,” Chambers says. “I hope somebody ordered a bunch of aluminum, because we’re all going to need it pretty soon, no matter what goes into this.”

NASA briefly considered commercial alternatives to the SLS but found nothing that could fly sooner and accomplish the mission. Commercial launchers, however, are expected to play a key role in flying Gateway and lander components as well as crew supplies.

“We’re looking at multiple paths to achieve the same end state,” NASA Administrator Jim Bridenstine told reporters at the symposium. “Redundancy ultimately enables us to move forward, even if something slips. The vice president said ‘by any means necessary,’ so we’re going to put those kinds of redundancies into our plan and then ultimately see the consensus that we can build and whether or not Congress can support it.”

The Trump administration’s call for boots on the Moon by 2024 is part of an overarching effort to speed up deployment of space systems for military, civilian and commercial use, with the aim of growing the U.S. economy and maintaining technical superiority in a changing world.

“It is absolutely the right focus for the nation,” says Wayne Monteith, former commander of the U.S. Air Force’s 45th Space Wing at Cape Canaveral AFS, who now heads the FAA’s Office of Commercial Space Transportation.

“We have to dedicate ourselves to big goals, big missions, big ideas. That is the only way we’re going to maintain our leadership in the world. Whether we actually accomplish a Moon landing by 2024, we have to have a goal or we’ll never get there.”

Israel Leaves Its Mark on the Moon
Irene Klotz Colorado Springs

IT WASN’T THE ENDING SPACEIL HAD PLANNED FOR THE SPACECRAFT

Beresheet, the first privately funded mission to the Moon. On April 11, after a nearly flawless, seven-week journey to lunar orbit, Beresheet—Hebrew for “in the beginning”—began a final, 21-min. engine burn to reduce its speed, drop altitude and land in Mare Serenitatis (Sea of Serenity), near the Apollo 15 and 17 landing sites.

Beresheet did indeed reach the surface, but it was not a soft touchdown. About 6 min. before the scheduled 3:25 p.m. EDT landing, flight controllers reported a problem with one of the spacecraft’s inertial measurement units (IMU), followed by a brief communications dropout and then, most ominously, a problem with the main engine.

By the time communications were restored and commands issued to try to restart the engine, it was too late. Telemetry indicated Beresheet had crashed into the Moon at about 3:23 p.m. “We didn’t make it, but we definitely tried,” Morris Kahn, co-founder of the SpaceIL nonprofit enterprise and a key financier, said during a webcast from mission control in Yehud, Israel.

A preliminary investigation indicated that after the IMU failure, a command was uploaded to the spacecraft, leading to the main engine being turned off, SpaceIL said in a statement.

Two days after the accident, Kahn announced that SpaceIL would begin planning for a follow-on spacecraft, Beresheet 2. “We’re going to build a new spacecraft, we’re going to put it on the Moon, and we’re going to complete the mission,” he vowed.

Beresheet, developed by SpaceIL and Israel Aerospace Industries, originally was to compete in the $30 million Google Lunar X Prize, but the competition ended last year without a winner. The X Prize, however, decided to award SpaceIL $1 million for its technological achievements.

If successful, Israel would have become only the fourth nation after the U.S., the former Soviet Union and China to soft-land a spacecraft on the Moon and the only one to attempt the feat for less than $100 million.
Heavy-Duty Mobile

U.S. MARINE CORPS TRANSPORTER IS A POSSIBLE MOBILE PLATFORM

OPFIRES’ PROPOSED ROCKET IS SIZED FOR LAUNCHING SMALL SATELLITES

By Steve Trimble, Washington

Although classification shrouds many details of the Pentagon’s $10.5 billion, five-year rush to field hypersonic weapons from sea, air and land, only the Army’s launch platform remains a mystery.

The Mk. 41 vertical launch system tubes embedded in the U.S. Navy’s surface vessels and submarines will launch the future Conventional Prompt Strike (CPS) weapon. Boeing B-52s will launch the Air Force’s near-term Hypersonic Conventional Strike Weapon (HCSW) and medium-term Air-launched Rapid Response Weapon (ARRW). In February, a senior defense official said the Army was likely to use a “new” mobile launcher for the future Long-Range Hypersonic Weapon (LRHW) instead of a fixed silo but did not identify the mobile system.

Now a clue has emerged within a Broad Agency Announcement (BAA) draft solicitation published on April 10 by DARPA. Just as the defense agency’s Tactical Boost Glide program is intended to help the Air Force field the advanced ARRW—arguably the world’s most sophisticated hypersonic glide vehicle—on time, DARPA’s OpFires program is focused on helping the Army deploy a second-generation hypersonic weapon in the next decade.

The BAA informs the three bidding teams (Aerojet Rocketdyne, Sierra Nevada Corp., and a Dynetics-led effort) for the Phase 3 contract under OpFires, that the Logistic Vehicle System Replacement (LVSR) is a possible launch platform.

The LVSR is an intriguing option for the Army’s most advanced artillery system. The 10-wheel-drive LVSR is larger than, but comparable to, the Army’s only heavy artillery launcher—the eight-wheel-drive Heavy Expanded Mobility Tactical Truck—that serves as the mobile launch platform for the Army’s exoatmospheric Terminal High-Altitude Area Defense interceptor. But the heavier LVSR is now operated exclusively by the Marine Corps, which uses it as a wrecker and cargo hauler, not a missile launcher.

The possible selection of the LVSR offers new insight into the ground-launched component of the U.S. military’s expanding pursuit of hypersonic weapons. Not only does it suggest a possible Marine Corps role in the Army’s second-generation hypersonic weapons program, the heavy chassis required for OpFires points to a missile with a booster that is large enough for possible space launch applications.

In the near term, the Army plans to deploy the LRHW with a booster and glide vehicle derived from the CPS Hypersonic Technology Demonstrator (HTD). The glide vehicle is a derivative of the Advanced Hypersonic Weapon (AHW) demonstrated by the Army in 2011; the Navy demonstrated an adaptation in 2017. Another version of the AHW glider, which is itself derived from the Sandia Winged Energetic Reentry Vehicle, forms the basis for the Air Force’s HCSW. Meanwhile, the Army and Navy intend to use a common booster for the hypersonic variable-thrust nozzles, pulse motors and reignitable propellants to vary the thrust and range of the booster.

A member of the Dynetics-led-team tells Aviation Week that it has tested a subscale, throttleable rocket motor designed by California-based Exquadrum, whose CEO Kevin Mahaffy, notes: “We can throttle our solid rocket motor (SRM) and turn it off when we reach the right weapon-release conditions. From ignition on, we can throttle the SRM or completely turn it off.”

A rocket motor of that size supports the Army’s objectives for OpFires but could have other military and commercial applications, Mahaffy says, including space launch vehicles.
Tempest Program Attracts International Interest

Tony Osborne  London

As potential foreign partners take a serious interest in British proposals to develop a new-generation combat aircraft, the UK government and industry are quietly working on the technologies that will pave the way for it.

Few details of the Tempest’s progress have emerged in the nine months since British Defense Secretary Gavin Williamson unveiled the UK vision for a new combat aircraft to be ready in the late 2030s.

To get there, the UK is taking a multipronged approach. While the Combat Air Strategy outlined that Britain would stay in the combat aircraft development game, the Future Combat Air System Technology Initiative (FCAS TI), an eight-year, £2 billion ($2.6 billion) program of research jointly funded by government and industry, is examining the technologies that could be needed not only for the future combat aircraft but also to support future upgrades for the Eurofighter Typhoon and Lockheed Martin F-35 Joint Strike Fighter (JSF).

The public face of the FCAS TI is Team Tempest, the joint government and industry consortium made up of the Royal Air Force’s Rapid Capabilities Office, BAE Systems, Leonardo, MBDA and Rolls-Royce.

All these entities feed into an acquisition program within the Defense Ministry that will eventually lead to a platform to replace the Typhoon. An initial business case for that platform will be delivered in December 2020, a full business case in 2025 and initial operational capability in 2035.

“Everything we do is focused on ensuring the UK is ready as a globally competitive combat air enterprise,” Group Capt. Jez Holmes, the Team Tempest program director, tells Aviation Week.

“What we’re trying to do is produce something that delivers credibility in capability terms and also delivers prosperity for the nation by bringing in partnerships,” he says.

Team Tempest’s sphere, in addition to conceiving and developing technologies for the future aircraft, encompasses the educational needs of the program so that skills can be maintained throughout the program’s life.

“Part of the FCAS TI initiative and the industry contribution is about sustaining and building those teams that perhaps have not had a huge amount of demand over the past 10-15 years,” says Clive Marrison, industry requirements director at Team Tempest.

Britain’s last Defense Industrial Strategy, published in 2005, stated that the introduction of the Eurofighter and the JSF meant the UK did not need to envisage building a new fighter for more than 30 years because both were likely to have long operational lives. Upgrade programs for the Typhoon and development of the Taranis unmanned combat air vehicle (UCAV) demonstrator have helped maintain those skills, but the Combat Air Strategy said that without a “clear indication of future requirements,” key engineering skills were placed at “greater risk.”

“Would we have lost those skills?” asks Marrison. “It is difficult to say, but without the investment both from industry and government in research and development over the last 10 years, and now into FCAS TI and Tempest, we would not have been in such a good position to sustain and grow them again.”

In March, Team Tempest held an industry day for potential suppliers to understand the Combat Air Strategy and how they can participate in the program through government and the Team Tempest consortium. The event attracted some 800 delegates from industry and government.

“It is not just about supporting the big four [BAE, Leonardo, MBDA and Rolls-Royce]; it is about supporting as much of the UK industrial and supply base as possible and bringing together as many of the clever minds, clever ideas and clever technologies as we can,” says Marrison.

The team is hoping that the work on the Tempest can ignite interest in aerospace technology in the same way the Concorde did during the 1960s. “Some of the people who will be involved on Tempest, potentially in service until 2080, have not been born yet,” says Holmes.

“Part of our intent here is to engage on a STEM [science, technology, engineering and mathematics] basis across the nation and bring something that gives them an iconic focus,” he adds.

There is no shortage of international interest as well. In late 2018, Sweden’s Saab confirmed it was in a “deepening dialog” with the UK over joining the Tempest program. At the end of last year, the company carried out a 6 billion krona ($650 million) rights issue that CEO Hakan Buskhe said could provide funding for future work, including with the UK. The Italian element of Leonardo said it was actively urging the Italian government to join the British FCAS work. Several influential think tanks in Rome have also pressed Italy’s government to join one of the two European projects, primarily urging it to side with the UK option, arguing that Italy would be sidelined if it joined the Franco-German efforts.

Beyond Europe, the Tempest is one of several options being studied for Japan’s F-3 future fighter requirement to replace the indigenous Mitsubishi F-2, and the British government re-
What results from the UK’s FCAS TI and Tempest work may look very different from the concepts shown so far, but it will make extensive use of locally developed technologies for future unmanned systems.

The UK Defense Ministry and industry, led by BAE Systems, have poured hundreds of millions of pounds into a series of technology initiatives that ultimately led to development of the Taranis UCAV demonstrator and almost paved the way for a joint UCAV demonstrator with France, until the plans were shelved last year.

Many of these underlying technologies for the UAVs and UCAVs are “very transferable across to the system-of-systems approach for FCAS TI,” Morrison says.

Those programs resulted in technologies for signature awareness and control, mission-system architectures, low-probability-of-intercept communications and the ability to rapidly—potentially in real time—upgrade software and mission capabilities and orders.

“None of the areas of development and design and technology that we saw through those unmanned aerial systems—be they at the design, information, mission-system or architecture level—are going to go to waste,” says Morrison.

Like its Franco-German counterpart, the future British combat aircraft will likely end up working with unmanned platforms, perhaps as so-called loyal wingmen or as attritable systems designed to decoy air defenses, such as the swarming systems revealed by Williamson in February and expected to enter service in the early-to-mid 2020s.

In recent years, the UK has been experimenting with adaptable payload bays, advanced materials and new approaches to cockpit development, including the use of augmented reality. It has also invested in cyber-resilience, making software dynamically reconfigurable and more difficult to hack.

Some of the successful technologies that could emerge from the Tempest could also end up in the Typhoon. Rolls-Royce is testing some of the technologies it envisions for a future Tempest powerplant on a Eurojet EJ200, which could result in improvements for the Typhoon. “We are working closely with Typhoon, working closely with the F-35 team as well, so we can spot those opportunities as and when they arrive,” says Holmes.

portedly has also made offers to India, with which it has previously partnered on the Hawk and Sepecat Jaguar.

The FCAS TI is currently focused on 60-70 technology projects, some lasting 1-2 years, others planned to last the full length of the program.

Some of the initial work underway on concepts and requirements is feeding what Holmes calls an “initial gauge,” supporting the opening stages of the acquisition process.

“It will start to deliver them with credible evidence about not only what they need but [also] about what we think we are able to do in an affordable way, with a focus on future adaptability and growth potential, so that we ensure we set ourselves up on a path for success,” says Holmes.

Part of that work is on industry sustainability; others have a more international flavor, such as several projects with France looking at communications and interoperability enabling future platforms to work together in a coalition.

Progress also is being made on development of a comprehensive open mission-system architecture designed to embrace avionics, sensors, connectivity and command-and-control systems. Definition of the architecture and component specifications are close to completion, and components are being built for testing. The architecture will not only underpin the potential for spiral development but also will allow partners or export customers to integrate their own mission-system fits quickly, as it has systematic reuse of software at its core.

With data becoming the currency of the battlefield, and future combat aircraft gathering up information from the electromagnetic spectrum and sensors, any future architecture likely will have to cope with terabytes of information, Holmes suggests.

The challenge will be turning that data into “decision-quality information and presenting it in a useful way,” says Holmes. The ability to do this will depend on how quickly the aircraft’s systems can be upgraded.

“What we’re focusing on in some of our work is how we make that much quicker, much easier and much more affordable,” he says. Such an approach could blur the lines between generations of fighters, Holmes says.

While the Typhoon is considered a fourth-generation combat aircraft and the F-35 as fifth-generation, the Tempest is widely considered to be sixth-generation. However, the aircraft might not be considered as such when it enters service in the late 2030s.

“We have architected our capabilities in the past in such a way that you have to talk in generational terms, because they have a long life, and step changes in capability are more challenging to deliver,” says Holmes.

Nevertheless, Holmes points to the Panavia Tornado, which when it left service at the end of March was an almost entirely different platform from when it entered service. The Typhoon will be the same, he notes.

“What is needed for a future combat aircraft is a regular, constant drumbeat of flexibility and upgradeability, allowing that capability growth to happen much more quickly . . . almost breaking down the generation nomenclature to much smaller, bite-size chunks,” says Holmes.

The UK’s heavy investments in unmanned combat aircraft technologies will also be applied.
Switzerland’s Alpine Fighter Assessments Begin

> THE SWISS PLAN TO SPEND $8 BILLION ON COMBINED FIGHTER AND GROUND-BASED AIR DEFENSE PURCHASE

> THE AIR FORCE IS STEPPING UP ITS AIR POLICING EFFORTS TO 24-HR. COVERAGE IN 2020

Tony Osborne  London

In the coming weeks, some of the West’s most advanced fighters will deploy to Switzerland for evaluations to help determine which will be selected as the Alpine nation’s future fighter.

Eleven years after the last round of trials and five years since the rejection by referendum of the selected aircraft, the Saab JAS-39E Gripen, manufacturers are vying to replace the Swiss Air Force’s dual fleets of Northrop F-5 Tigers and Boeing F/A-18C/D Hornets with a single fleet.

And the need is urgent: Swiss officials are concerned that the Tigers could be easily outgunned by modern opponents, and the Hornets, while still capable, need a life-extension upgrade to see them through to retirement in around 2030.

And the neutral land-locked nation is taking its air defense more seriously than ever. At the beginning of this year, the Swiss Air Force increased its readiness levels, putting armed aircraft on standby for air policing duties for 16 hr. a day, 365 days a year. The next step is to provide round-the-clock coverage at 15-min. readiness by the end of 2020.

The changes are in response to criticism that the service was unable to respond to the 2014 hijacking of an Ethiopian airliner that landed in Switzerland. The embarrassing wake-up call highlighted a dangerous gap in the defense accords.

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needs the low-observable capabilities offered by the fifth-generation fighter.

Being the incumbent could be valuable for the Super Hornet’s chances in Switzerland. This year’s evaluations will also mark the F/A-18E/F’s debut, as Boeing pulled the aircraft from competition prior to the trials in 2008.

Airbus, working with the German government is using British Royal Air Force (RAF) aircraft for the tests because the configuration of RAF Typhoons with the Phase 3 Enhancements package is the closest operational configuration to what Switzerland is being offered. If selected, Swiss Eurofighters would be in the same configuration as the aircraft soon to be ordered by Germany as Tranche 1 replacements, fitted with the new active, electronically scanned array radar.

Dassault is expected to offer its F4 upgraded version of the Rafale, with Switzerland’s Hornets are being given a life extension to enable them to operate until 2030. However, the work is facing delays due to problems with replacement parts not fitting as expected.

Paris leaning on its recent purchase of Pilatus PC-21 trainers and its close relationship with the Swiss government to get an edge.

Armasuisse will initially use the data from the trials to confirm the answers provided by the manufacturers in the first request for proposals (RFP) issued last July. Later, it will be used to make direct comparisons in support of a second RFP planned for 2020. A possible hurdle to this schedule is another referendum, also planned for 2020. Rather than ask whether the government should buy a particular platform, the referendum will likely be more fundamental, officials say, such as asking if the country should modernize its air defenses.

With a green light, contracts would be signed after parliamentary approvals in 2022, and deliveries would begin in 2025-30.
Now that space is becoming part of the national dialog, and American families are discussing the final frontier around the dinner table, the Pentagon is requesting its largest budget for space in recent history, $14.1 billion, to establish a new military service and an agency to focus on a future architecture and modernize a generation of spacecraft.

Pentagon officials have discussed the importance of space before, but the climate is different now. For the first time, a president has called for a separate armed service focused on space operations, commercial industry has developed space technology at a more affordable price point, and the military is looking inward about how to reorganize to purchase equipment at a rapid rate.

The Air Force has spent the last year resetting to move faster, but with commercial industry presenting ever-more tantalizing solutions, the pressure to tap into those innovations is growing. The service must get away from a risk-averse culture focused on large, exquisite high-dollar programs and pivot to more agile execution, says Space and Missile Systems Center (SMC) chief Lt. Gen. John Thompson.

“That sanctuary of space, that benign environment, no longer exists,” Thompson says. “The threats that we have to get after mandate that we go faster and take our acquisition processes and programs further.”

One result of the reorganization was the emergence of a space portfolio architect who focuses on enterprise-wide mission and integration—within the SMC and throughout other national security organizations—as the SMC begins to procure new generations of missile-warning, strategic communication and GPS satellites.

With the Air Force working to speed development and acquisition, there is tension inside the Pentagon about establishment of the Space Development Agency (SDA), because it is looking at alternative architectures for the very same missions. Fred Kennedy, the agency’s director, plans to present the future space architecture to his bosses in September and hopes to have a capability on orbit in 2022—faster than the SMC’s current modernization plans.

“The good news is they get it, and this is a priority inside the Pentagon,” Kennedy says. “One way or the other, it’s going to happen.”

At the 35th Space Symposium here, Kennedy unveiled a notional future space architecture that was informed by eight gaps the U.S. is facing in national security space, targeting, advanced missile threats, an alternative to GPS and a battle management system and creating a military Internet of Things. He warns there may be changes to the next-generation satellite constellation if his experiment is successful.

“This is early days, but I believe there will be a long conversation regarding how the SDA, the Air Force,
the other services and the intelligence community work together as a space architecture,” Kennedy says. “At this moment I can’t tell you what elements of the Air Force architecture will be extant in 2030.”

An industry official predicts the services may continue to hold the heart of the mission, because they have that deep understanding, but they will be able to leverage some of the commercial industry items the SDA matures through demonstrations such as Blackjack, which had been run by the Air Force and DARPA. The services can then begin to use those demonstrated commercial technologies for military missions.

Five or six years from now, if the proliferated low-Earth-orbit (LEO) satellite constellation is successful, it would be appropriate to discuss the correct mix because the Pentagon cannot invest in everything, Kennedy says. “I wouldn’t tell the Air Force to stop planning,” he notes.

For now, the nation needs to keep its options open, says Will Roper, assistant secretary of the Air Force for acquisition, technology and logistics, funding responsive launch, the defense of U.S. satellites in geosynchronous orbit (GEO) and the potential for a proliferated satellite constellation in LEO.

“We’ve done a lot of analysis of different types of architectures and constellations, and we believe we need a mixture,” Roper says. “I think you would find it surprising if we said we have found the silver bullet of space.”

Industry and government officials say the U.S. should place its spacecraft in a mix of orbits—and not rely on just one. Satellites in LEO are attractive because each one is less expensive than a geostationary satellite. But there are downsides to using them. To achieve high revisit rates, they would need to be purchased in bulk. And they can be vulnerable to laser attacks. Even acting Defense Secretary Pat Shanahan told the symposium that China is developing just such a weapon.

Roper says it is important for the U.S. to determine how it can beat that laser, but the solution cannot be too expensive because it would be impossible to distribute throughout the orbit.

Responsive launch is an important option because adversaries will not know what the U.S. has in its arsenal.

“You’ve got to have global space situational awareness to be able to detect,” Roper says. “It’s likely to be expensive, and that represents a vulnerability for us to exploit.”

The U.S. has essentially turned LEO into a time-critical targeting challenge, which is difficult to counter and disruptive.

Other studies have shown that a mix of satellites in GEO and medium Earth orbits (MEO) may be more affordable, as they provide a geographic advantage...
Lockheed has chosen two payload providers, Raytheon and a team of Northrop and Ball Aerospace. The program cleared its systems requirements review in March and is expected to clear its preliminary design review in the next six months. That is “18 months faster than a program of similar size and complexity,” says Col. Dennis Bythewood, director of the Air Force’s remote-sensing systems directorate.

The program is operating under requirements from U.S. Strategic Command and validated by the Pentagon’s Joint Requirements Oversight Council, says Bythewood.

Speeding up the acquisition process did result in a change in how contractors operate: Moving faster means prime contractors are spending money faster than usual.

“[Going fast] front-loads a lot of the activities,” says Kay Sears, general manager and vice president of Lockheed Martin Space. Lockheed is supporting two teams of payload providers, and that competition is driving innovation. “But they both need to spend money to meet their timelines. And we’re at a stage when they need to do some things like [put together] engineering data units, buy materials [and] staff their programs.”

The NextGen OPIR program is seeking congressional authority to transfer funds for fiscal 2019 to budget for those initial activities and keep development on its go-fast schedule for 2025 delivery. It will be tough without congressional approval, Sears says. “I wouldn’t say yet that we can’t make it, but it will be a challenge,” she acknowledges. “We have to recognize that if we are going to go fast, we have to be willing to fund it, and we can’t use historic program spends to say, ‘This is how we are going to do it.’ It doesn’t work like that.”

But this is for the initial block of satellites. A future set may involve a different architecture of the type being studied by the Air Force or the one being explored by the SDA.

The purpose of the SDA, Kennedy says, is to stand up an agency that has appropriate authorities and can actually move at a rapid cadence to get after the threat.

“I can’t point to anybody out there that responds in a timely fashion to these kinds of threats,” he says.

The U.S. has peer competitors coming forward with multiple direct threats to space assets, he points out.

“A distinguishing feature of this agency is that I am not bound by [the Joint Capabilities and Integration and Development System],” Kennedy says.
Positive Reaction

> REACTION ENGINES PRE-COOLER PASSES MACH 3.3 TEST
> FOLLOW-ON TESTS PLANNED FOR MACH 4.2 AND MACH 5

Guy Norris Watkins, Colorado, and Culham, England

It has been decades in the making, but finally, on March 25 in rural Colorado, Reaction Engines achieved what could be a pivotal moment in the advancement of air-breathing, high-speed propulsion when its pre-cooler technology was successfully tested at conditions representative of over Mach 3.

The breakthrough test—conducted at the company’s newly opened TF2 test facility at Colorado Air and Space Port near Watkins—comes 30 years after Reaction Engines was quietly formed in the UK around an innovative engine-cycle concept to enable access to space and hypersonic air-breathing flight from a standing start.

The lightweight heat exchanger (HTX) forms one of the main building blocks of the company’s novel operating cycle and is designed to significantly reduce compressor delivery temperature (T3). This delays the onset of the T3 limit to a higher Mach number, maintaining sea-level conditions in front of the compressor over a very wide range of speeds, thus maximizing net thrust even at high speeds.

The HTX is designed to chill air in the inlet of high-speed turbojets for hypersonic vehicles and, ultimately, will form the basis for the company’s Synergistic Air-Breathing Rocket Engine (Sabre) for low-cost repeatable access to space. In this role, the engine is designed to efficiently extract oxygen for rocket combustion from the atmosphere. In the fully integrated Sabre, the chilled air will be passed from the HTX to a turbo-compressor and into the rocket thrust chamber where it will be burned with sub-cooled liquid hydrogen fuel.

Now, after years of subscale development including the first runs of an operational pre-cooler in 2012, the company’s first large-scale pre-cooler test unit has demonstrated the ability to rapidly chill incoming heated air generated by a donor General Electric J79 jet engine operating at full military power. Tests of the pre-cooler, which is made from 16,800 thin-walled tubes to provide high surface area with low weight, are being conducted under a 2017 DARPA research contract.

“We are adding a dial to the whole engine-optimization equation that you didn’t have control over before, which is the inlet condition—not just the temperature,” says Reaction Engines President Adam Dissel. The test result, which saw gas temperatures reduced from more than 800°F (426°C) to just above the boiling point (212°F), boosts Reaction’s confidence that follow-on tests with the J79 operating in full afterburner will see more dramatic reductions.

With the J79 operating at full power, the pre-cooler is expected to chill the mass flow from over 1,800°F at inlet speeds representative of over Mach 5, to approaching 200°F in less than 1/20th of a sec. The higher-temperature test will stress not only the thermal expansion capabilities of the test rig but also each tube in the HTX, which are joined to an inlet and outlet manifold, thus allowing helium coolant to be cycled through.

“This is the first test ever of our pre-cooler at highly elevated temperatures, and the performance looks to be right in line with predictions, and the data quality exceeded expectations,” says Dissel. The evaluation was particularly significant for an operationally representative system because it “featured a temperature ramp profile analogous to the flight conditions that would be experienced from takeoff and acceleration up to a flight speed of Mach 3.3, the cruise speed of a Lockheed SR-71 Blackbird,” he adds.

Sized to match the mass-flow requirements of a potential flight-test demonstrator engine, the HTX run also was
the first chance to wring out the TF2 facility. “All the various facility and ground support systems performed well during their first fully integrated test setup; this was a great accomplishment, as several systems could not be fully checked out until they were actually operated at high temperature,” says Dissel.

The March 25 evaluation, which also marked the first high-temperature test at the Colorado site, will be followed in coming months by tests at Mach 4.2 and Mach 5. The exact timing will depend on the outcome of test-rig conditioning for runs with the engine in full afterburner. “The last thing we want to do is put an unknown condition into the pre-cooler,” says Dan Larson, Reaction Engines engineering project manager. The connections and piping in the test setup experience thermal expansion of several inches during powered runs and may show even greater movement at higher thrust settings, he explains.

The fully instrumented pre-cooler is “assembled in a manner so that we can deeply analyze the behavior of that unit when it is subjected to hypersonic enthalpies,” says Reaction Engines CEO Mark Thomas. “We will be progressively building up to those extreme test levels. The TF2 is capable of running full simulated missions for the pre-cooler so we can run it effectively in temperature terms from the ground to ultimate flight conditions and back again over a sustained period of time,” he adds.

The facility uses a complex helium circulator and control systems to deliver the appropriate conditions during the simulated flight cycle. “That’s a unique capability; when you think about that volume of hot gas being transferred for that duration. We are not aware of any other facility that could safely do that in any areas we could safely test. So this is a very prized capability, and a lot of investment has gone into it from the UK and the U.S., both private and public,” comments Thomas.

“We are stepping through the test campaign in a progressive manner.

The pre-cooler test unit, visible in the center of the image, contains 16,800 thin-walled tubes.
We are not aware of any other facility showing growing interest in the Sabre concept and the pre-cooler technology at its core. Reaction Engines has raised over $100 million ($130 million) in the last three years from public and private sources. In addition to the UK government, which announced a £60 million commitment in 2013 to assist with the demonstrator engines, BAE Systems made a strategic investment in 2015, while a further £26.5 million was raised in 2018 from other investors, including Rolls-Royce and Boeing’s venture capital arm, HorizonX.

But for now, “it’s fair to say all eyes are on the prize, and the results we achieve in this test campaign,” underscores Thomas. “We are that close to it now that people, in both industry and government agencies, are watching this closely. This is all great because it is exactly where we want to be.”

Test progress in Colorado comes on the heels of a recent positive assessment of the design of the Sabre demonstrator core conducted by Reaction in collaboration with the UK Space Agency and European Space Agency. The preliminary design review clears the way for a follow-on critical design review and the subsequent development and test of the core at Reaction’s newly built facility in Westcott, England, planned for 2020.

The demonstrator core will consist of an axial air compressor driven by a closed-cycle helium loop, with a liquid hydrogen heat-rejection system. Reaction, which is building up the test infrastructure at the Westcott site through the remainder of this year, says the core will be fully representative of the Sabre thermodynamic core cycle. Fueled by liquid hydrogen, the unit will incorporate heat exchangers, combustion and turbomachinery modules. A site for testing the final full-up demonstrator engine has yet to be determined.

Digital Extra Read more about Reaction Engines’ purpose-built TF1 test site: AviationWeek.com/ReactionTF1Site

We’re all on a mission.

Join Apollo astronauts Walt Cunningham, Charlie-Duke and Al Worden, along with government, military and industry leaders in the USA Partnership Pavilion to honor the past and inspire the future of flight! Visit www.parisairshow.com and sign up for “Mission Mail” updates to track the program from launch to landing at Le Bourget, June 17-23, 2019.
Six months ago, few outside the defense community in the UK and U.S. understood what the words “counter-unmanned aircraft systems” meant. But a succession of reported drone incursions at London’s Gatwick and Heathrow airports and Newark Liberty International Airport in New Jersey, which also serves New York City, changed that. Now the need to protect airports and other infrastructure from rogue unmanned aircraft systems (UAS) seems obvious. So, too, does a market for commercial counter-UAS (CUAS).
So far, however, there is no such market. In the U.S. and many other countries, shooting down, disabling or taking control of drones is illegal. There is no liability framework for such operations, no broadly reliable way to detect and identify drones and drone users, and the U.S. has yet to figure out exactly who will have authority to execute CUAS operations.

Potential CUAS buyers lack information and viable solutions. There is no CUAS certification regime and thus no standard against which to measure the relative performance of the systems now offered. Despite a crowd of companies promoting potential products, there are few providers globally with systems ready to field. And outside sporadic battlefield experience, CUAS systems have no real-world track record.

From jamming and cybermanipulation to kinetics and even drone-capturing nets, the handful of active countermeasures now marketed all present potential negative side effects. Ironically, the mitigation portion of the CUAS puzzle requires its own mitigation.

“What this really is,” says Mark McKinnon, an attorney with Washington-based LeClairRyan, “is a chicken-and-egg situation. But you need the chicken and the egg at the same time.”

Airports are not the only land users concerned about drones. Utilities, telecommunications providers, prisons, sports stadiums and even entire cities warily eye their threat potential. However, the safety implications of what airports do should put them at the forefront of counter-UAS advocacy. Or so you would think.

Aviation Week contacted the administration at Hartsfield-Jackson Atlanta International, the world’s busiest airport. The airport’s brief emailed response to a query about CUAS was that we would have to talk to the FAA. For Christopher Oswald, senior vice president for safety and regulatory affairs at the Airports Council International-North America (ACI-NA), Hartsfield-Jackson’s response is not a complete surprise.

“Airports face significant hurdles in getting authorization to use [CUAS] systems. There isn’t a legal framework in which U.S. airport operators would feel empowered to acquire and use them,” he says.

He adds that a July 2018 CUAS guidance letter from the FAA’s Office of Airport Safety and Standards suggests even drone detection is a shaky near-term prospect, likely explaining airports’ reluctance to comment. It repeated an admonishment from an earlier letter from 2016: “It is important that federally obligated airports understand that the FAA has not authorized any UAS detection or countermeasure assessments at any airports other than those participating in the FAA’s UAS detection program...and airports allowing such evaluations could be in violation of their grant assurances.”

The 2018 follow-up urged further caution based on the agency’s own counter-drone study, stating: “The low technical readiness of [CUAS] systems, combined with a multitude of other factors, such as geography, interference, location of majority of reported UAS sightings, and cost of deployment and operation, demonstrate this technology is not ready for use in domestic civil airport environments.”

Among the letter’s assessments was that airport environments have numerous sources of potential radio-frequency interference—“more than anticipated.” Their dense environments made drone detection difficult “and, in some instances, not possible.”

A range of challenges was enumerated: a high level of manpower required to operate equipment and discern false positives, large numbers of sensors needed to achieve required coverage, communication/navigation interference, the deployment of CUAS assets in an environment owned by many entities, prohibitive costs and rapid technological obsolescence.

The FAA will gather more information this year; deploying CUAS systems at five airports to evaluate potential aviation safety risks and efficacy. An aviation rule-making committee is also being established to make recommendations for CUAS standards.

The challenges articulated largely leave aside broader legal questions that must be answered before a meaningful counter-UAS market can develop. Common approaches to detecting and mitti-
gating unwanted UAS run afoul of the Communications Act of 1934, the U.S. Criminal Code and Federal Communications Commission and FAA regulations.

For example, the Communications Act requires that radio transmitters including jammers be licensed. No CUAS jamming system has been licensed, nor has a licensing mechanism been established. Willfully destroying or disabling an aircraft is prohibited by the Criminal Code, as is intentional interference with satellite communications. “The FAA can’t rewrite those laws,” Oswald observes. “Congress has to rewrite them and recognize what would be lawful activity in a drone era.”

With passage of the 2018 FAA Reauthorization Act, Congress has rewritten some of those laws, giving the Department of Homeland Security and Justice Department the right to “disrupt,” “exercise control” of or “seize or otherwise confiscate” drones deemed a “credible threat” without a warrant. The provisions will likely face legal challenges, and they do little to clarify the commercial market for CUAS providers, McKinnon says.

“It’s really tricky because the provisions are generally limited to operation by the federal government itself. This would not give [CUAS companies] broader authority to market the same technology to state or local governments or individuals,” he says.

The new grants also imply a strictly federal approach to CUAS for the time being. Airports themselves differ on assuming drone-detection and mitigation responsibility, Oswald reports. Smaller operators tend to see local enforcement authorities (with proper resources) as better equipped to undertake CUAS. Larger airports, which have already taken on anti-terror responsibility, may see CUAS as a logical extension of their own capabilities.

“They’ve had to be prepared to address those situations,” Oswald affirms. “I think there’s also a reality check on what level of federal resources there would be to respond in a tactical sense [to drone incursions].”

There has been no official confirmation of actual detection of UAVs at Gatwick, or Heathrow or at Newark or elsewhere in the U.S. Drone incursions have not drawn attention at other U.S. civilian facilities, and success on the battlefield is difficult for even the military to assess.

Vendors thus face the prospect of selling detection and mitigation systems without real-world examples of their efficacy. It is a thorny problem for CUAS manufacturers and potential customers, says Oleg Vornik, the CEO of DroneShield, a U.S.- and Australia-based company providing multisensor fixed/mobile drone detection and jamming, which it says it operates in 50 countries.

Vornik describes a global sales model in which airports run controlled trials of prospective CUAS systems, installing them for a few weeks at a time, operating them and assessing performance. The idea is contingent upon drones entering the relevant airspace, something airport operators would have to arrange themselves unless the CUAS provider offers to fly drones in. The latter is like having a car salesman test-drive the car for you, however.

“This is a nascent technology, and there’s no perfect answer,” says Vornik. “We don’t love having a mandated set of requirements [against which competing systems are measured] and then airports or others choose from those [companies] that are certified. That doesn’t exist, but doing something is better than doing nothing.”

He estimates there are only about six CUAS providers capable of fielding potentially effective systems. “If you do a Google search, sure, you get a couple hundred firms that pop up, pretending they’re in the counter-drone space. But customers tend to be quite savvy, especially in the airport sector; and can tell the difference between two guys with an idea and an established company,” he says.

Among mitigation approaches, “smart” jamming seems to hold the most potential, says Grant Jordan, CEO of SkySafe, a San Diego-based company that has tested ATTV-mounted detection/jamming systems with the U.S. Naval Special Warfare Command. “From our perspective, [radio-frequency] solutions get you 90% of the way there. They’re the best, most scalable solutions in the greatest number of real-world situations. But there will always be situations in which a kinetic system is required,” he says.

Anecdotal reporting from the battlefield suggests that kinetics (i.e., shooting down drones) is the only truly effective countermeasure. The Pentagon declines to confirm this, citing classification concerns and limited real-world metrics. Kinetic mitigation obviously creates significant safety and liability concerns in a civilian environment. Other approaches such as geofencing are less than optimal as well.

Actually taking control of rogue drones comes with a high degree of difficulty, he says. “We don’t love taking control of the drone because it’s so dependent on exploring vulnerabilities of the underlying protocol. You’re basically hacking into an encrypted connection. You’re fighting against the tide,” Vornik says. It is a perpetual cybercat-and-mouse game, which he says leads to a 50-50 chance of defeating a drone. And if a CUAS system assumes flight control of a UAV, it also potentially assumes liability for the aircraft.

“No system is a silver bullet,” ACI-NA’s Oswald agrees. Layered detection/mitigation solutions may be the only guarantor of sufficient success, an expensive proposition.

So what is an airport to do? Plan. “Beefing up and enhancing UAS contingency planning is ongoing, especially since Gatwick,” says Oswald. “Even small airports are looking at drone contingency plans and tabletop exercises.”

Airport operators hope the FAA CUAS test sites can help produce both chickens and eggs, so that a true commercial CUAS market can emerge. 

UNMANNED AVIATION

Developed for the military, the Anti-UAV Defense System has been deployed at UK airports to detect drones.
U.S. Program Works Toward Integrating Small Drones

PRIOR WORK UNDERPINS PROGRESS
REGULATORY CLARITY STILL NEEDED

Bill Carey Blacksburg, Virginia

The program U.S. Transportation Secretary Elaine Chao leads to introduce small commercial drones regularly into the airspace system already has some notable achievements.

Since Chao named 10 industry-government-university collaborations to participate in the Unmanned Aircraft Systems Integration Pilot Program (UAS IPP) in May 2018, at least three of the partnerships have announced major developments. The Trump administration initiative aims to accelerate both entry into the airspace and commercialization of drones at the state and local levels, providing a push to the slow-moving FAA regulatory process.

On March 26, UPS and drone-delivery system developer Matternet launched a new service using Matternet’s M2 quadcopter to deliver blood and other medical samples weighing up to 5 lb. from the main hospital of WakeMed Health and Hospitals campus in Raleigh, North Carolina, to a nearby medical office park. The first operational flight marked “the beginning of numerous planned daily revenue flights,” said the IPP partners: UPS, Matternet, WakeMed, the FAA and the North Carolina Department of Transportation.

Earlier, on March 8, delivery system developer Flirtey said it received FAA approval to conduct drone flights beyond visual line of sight (BVLOS) of the operator, which the FAA allows only by waiver, through an IPP project with the city of Reno, Nevada. Flirtey plans to use multirotor drones to deliver automated external defibrillators to cardiac arrest victims, as well as packages.

In January, insurance provider State Farm said it obtained a long-term FAA waiver to operate drones BVLOS and over people, also restricted by the FAA, for damage-assessment flights nationwide after natural disasters.

State Farm achieved the milestone through an IPP partnership led by the Virginia Innovation and Entrepreneurship Investment Authority and the Center for Innovative Technology (CIT), an economic development corporation that supports technology startups in the state. But the company had been working with the Mid-At-
Atlantic Virginia Partnership (MAAP) at Virginia Tech for nearly two years before receiving the FAA waiver.

The MAAP manages day-to-day operations of the IPP program in Virginia for the CIT. The test site operation dates to December 2013, when the FAA selected six lead organizations to manage UAS test sites nationwide. (New Mexico State University at Las Cruces had operated an FAA-recognized UAS test site since 2008.) Two other FAA-designated test sites from that class, led by the University of Alaska-Fairbanks and the North Dakota Department of Commerce, are also participating in IPP partnerships.

Neither the test site nor any IPP programs are supported by federal funding, although Congress recently appropriated $6 million to support company research at the test sites, money that does not go directly to the facilities, says MAAP Director Mark Blanks.

Created by Congress in the FAA Modernization and Reform Act of 2012, the test site program originally was scheduled to expire in 2017 but was later extended for two years. The FAA reauthorization legislation that President Donald Trump signed into law last October continues the program through September 2023. Plans call for the IPP effort to end in October 2020.

Based at Virginia Tech, a land-grant research university in Blacksburg, the MAAP is pursuing three projects under the IPP. It is working with State Farm on damage-assessment operations, with Wing, a subsidiary of Google parent company Alphabet, on commercial package delivery and with Richmond, Virginia-based Dominion Energy to apply drones for “linear infrastructure inspection” of transmission lines and towers.

Progress made with those companies as an FAA test site underpins the organization’s work for the IPP, says Blanks. State Farm is one example. The safety case the MAAP prepared for the company helped it obtain short-term waivers to operate the 1.52-lb. SenseFly eBee Classic flying wing BVLOS and over people after Hurricane Florence in the Carolinas and Hurricane Michael in Florida in 2018. The FAA approved the submission that led to the long-term, nationwide waiver announced in January in a day’s time, says Blanks.

Wing and the MAAP ferried Chipotle burritos by drone along the Virginia Tech Transportation Institute’s Smart Road, a transportation research facility, in September 2016 and delivered popsicles and ice cream to neighbors of the university-owned Kentland Farms test site in August 2018 under the IPP. Among the customers were Blanks’ three children. “They came to expect this, that every afternoon a drone was going to show up and deliver a popsicle and ice cream,” he muses.

A large photo of an earlier version of Wing’s Hummingbird 7000 hybrid drone overlooks the MAAP’s offices. The 15-lb. vehicle has 12 electric lift motors spaced on two rails for vertical flight and two propulsion motors on its 5-ft. wingspan to fly horizontally. It hovers at 21 ft. and lowers small packages by tether to the ground, where a latch mechanism releases them.

“Our test site jump-started the IPP because all of the projects that we’re doing under IPP we were already doing as a test site,” says Blanks. “But the IPP brings prioritization on the FAA side, so they’re accelerated. IPP takes it to a whole other level,” he adds.

After previously serving as UAS program manager at Kansas State University’s Applied Aviation Research Center, Blanks was named as Virginia associate director of the MAAP in August 2015. He became director in July 2016 when it became solely a Virginia entity.

Former AAI Textron executive Rose Mooney led the MAAP in its early days, when the state-supported test sites struggled for relevance with uncertain missions. “When I first started, I asked all the test site directors at a panel presentation in a public forum to give me a 30-min. spiel on what their value proposition was,” Blanks recalls. “The first test site director said, ‘I’m not sure what that is. We haven’t figured that out yet.’ That was the first week I started here.”

The FAA’s Part 107 regulation governing the commercial operation of small UAS weighing less than 55 lb., which became effective in late August 2016 after a decade of preparation within the agency, helped the test sites, Blanks says.

“Our value proposition was based on demand—people were coming to us wanting to do everything else they couldn’t do [with drones],” he says. “When Part 107 was released, it accelerated the industry and, for us, was a huge benefit. With that, we are able to focus on harder problems: flying high-er, beyond line of sight, over people, with multiple aircraft—that’s what people are coming to us for now.”

Test site directors now hold monthly calls with participation by John Reinhardt, the FAA’s external partnerships program lead. The sites have a standard certificate of authorization (COA) from the agency that allows them to fly small UAS to 1,200 ft. in Class G uncontrolled airspace; specific operations from airports require separate COAs.

The MAAP has a COA that covers airspace up to 7,000 ft. in central Virginia and includes several airports. The permission allows it to test larger unmanned aircraft such as Textron Systems’ 75-lb., catapult-launched Aerosonde Mk. 4.7, which it has flown from Blackstone Army Airfield.

After testing by the MAAP, State Farm in January announced a long-term FAA waiver to operate the SenseFly eBee Classic, which comes fitted with an RGB camera and modem, for damage-assessment flights.
Situated within the university’s Institute for Critical Technology and Applied Science, the MAAP has been self-sustaining for the past couple of years, says Blanks, who declined to disclose its budget. It had 12 full-time employees during Aviation Week’s visit in March and planned to hire eight more people.

Among its major funders is NASA, which is supporting work the MAAP, Gyrophon Sensors and other partners are conducting using ground-based radar to help drones detect and avoid other air traffic, a capability they must have to fly BVLOS. Researchers are testing airborne detect-and-avoid capability for NASA using a thin, hand-size Echodyne EchoFlight metamaterial electronically scanned array radar fitted to a Titan X8 multicopter drone.

The test site develops safety cases for companies seeking waivers and approvals from the FAA to fly drones to higher altitudes than normally allowed, BVLOS, over people, using multiple aircraft or for air carrier operations. The process starts by defining a concept of operations, assessing risk and identifying mitigations. The site then collects data by testing—only about a quarter of the work it does, Blanks says.

Using the FAA’s Order 8040.4B Safety Risk Management Policy as guidance, the site completes safety cases when all risk mitigations are verified with data. The presentation made to the FAA includes the concept of operations, testing data, end-to-end system analysis and level or risk summary.

“This is our core value to industry. The Boeings of the world can do a lot of the engineering and development, and they can build those safety cases themselves. But you take a nontraditional aviation company, they don’t have that expertise, the facilities, all those pieces of the puzzle,” Blanks says.

“Our customer set now is not so much the traditional [aviation] primes; it’s the enterprise companies that are trying to use this technology,” he says.

The MAAP’s main flight-test facility is Kentland Farms, an 1,800-acre property with a small, 300-ft. runway for vertical-takeoff-and-landing operations, located 9 mi. from the university. Other facilities include Gryphon’s multisensor Skylight system for detecting and tracking drones and a trailer-based mobile operations center. It manages a football-field-size, netted drone park that Virginia Tech officially opened in April 2018, an enclosure that allows students and faculty to fly drones without the need for FAA authorization.

The test site collaborates with the Center for Injury Biomechanics at the university on researching injury risk to humans from low-flying drones. At an impact lab on the campus, small drones are propelled by pneumatic energy down a rail at up to 80 mph, then stopped short of the rail end to sail by free-flight into an instrumented crash dummy.

As of early April, the FAA had issued 2,547 waivers to Part 107 requirements dating to the effective date of the regulation in August 2016. An Association for Unmanned Vehicle Systems International analysis of the 1,960 waivers issued two years after the rule’s release found that 92% authorized drone operations at night. Five percent of waivers were for operations and certain airspace; 2% were for the simultaneous operation of multiple drones.

Despite the waiver process, most operators actually are flying “extended” visual line of sight rather than BVLOS flights, according to Blanks. “They can fly beyond line of sight, but only to a certain range, only as far as they can see the airspace visually, which is what all the BVLOS approvals are right now,” he says.

“What we’re using is visual detection for beyond line of sight. Our range is limited still, but it’s much farther than Part 107 will get you. That is the case for 99% of all the BVLOS approvals right now,” says Blanks.

Exceptions include BNSF Railway, which obtained the first waiver to fly drones BVLOS for track inspections the day Part 107 took effect. A year earlier, the FAA had selected the freight rail carrier to participate in a “Pathfinder” drone research effort.

During testing along a 200-mi. section of track in BNSF’s Clovis, New Mexico, subdivision, the rail company controlled aircraft using the Collins Aerospace CNPC-1000 data link, which operates within the L-band aviation spectrum. Harris Corp. supplied portable automatic dependent surveillance-broadcast “Xtend” receivers to track drones at low altitudes.

Last October, Avitas Systems, a GE Ventures company based in Boston, announced FAA approval to fly a Vapor 55 conventional helicopter drone weighing more than 55 lb. for extended-range BVLOS operations without a visual observer, using ground-based radar supplied by DeTect Intelligent Sensors for an equivalent level of safety. Avitas says it worked closely on the use case with Shell Oil Co., which wants to use drones for aerial inspection of oil and gas infrastructure in west Texas in the Permian Basin, one of the world’s top-producing oil fields.

In April 2018, Xcel Energy of Minneapolis obtained an FAA waiver to operate the 35-lb. Altus ORC2 unmanned helicopter BVLOS to inspect transmission lines within a designated area 20 mi. north of Denver International Airport.

The ability to conduct flights over people, as well as BVLOS, will help facilitate the types of commercial operations the MAAP and other IPP participants are developing, but regular flights over people await regulatory guidance.
In February, the FAA published a notice of proposed rulemaking (NPRM) to amend Part 107 to allow operations of small unmanned aircraft over people under certain conditions and at night without requiring a waiver. For night flights, the agency proposes that remote pilots complete knowledge testing, which includes new subject matter related to night operations, and fit their aircraft with an anti-collision light visible for at least 3 mi.

The agency recommends three categories of operations over people based on the risk of injury presented. Category 1 applies to drones weighing less than 0.55 lb. Because they pose a low risk of injury, remote pilots would be able to fly them over people, subject to Part 107 requirements, but without additional restrictions.

Cat. 2 applies to drones weighing more than 0.55 lb., with added performance-based requirements. The aircraft must be designed so that if it strikes a person, it will not cause an injury as severe as being struck by a rigid object moving at 25 ft.-lb. of kinetic energy. It cannot have exposed rotating parts or operate over people with safety defects.

Operational limitations would prohibit flights over any open-air assembly of people and keep the aircraft within a closed or restricted-access site. If the operation is not within a closed site, the drone may transit, but not hover, over people.

Simultaneously with the flights-over-people NPRM, the FAA published an advance notice seeking public comment on “safe and secure operations” of drones, a response to concerns by the Defense, Energy, Homeland Security and Justice departments over the threat of malicious use of drones over large public gatherings or critical infrastructure.

Under a NASA project, the MAAP is testing the Echodyne EchoFlight MESA radar, the small white panel fitted to the front of this Titan X8 multirotor drone, for airborne detect-and-avoid capability.

Working with Shell Oil, Avitas Systems received FAA approval to fly the Vapor 55 BVLOS using a ground-based radar in place of a visual observer.
The aircraft will not cause an injury if it strikes a person. The risk of injury through operation over people is low for Category 1, which applies to drones weighing less than 0.55 lb. Because they pose a less than 0.55 lb. Because they pose a low risk of injury, remote pilots would be able to fly them over people, subject to certain conditions. The FAA identifies safety defects such as exposed wires, hot surfaces, sharp edges, faulty construction or corrupted software as being disqualified from operations.

An FAA-identified safety defect such as the use of drones over large public gatherings is not part of the FAA's prohibition against operating unmanned aircraft systems over people and operations at night. The FAA recommends three categories of operations over people: Category 1, 2 and 3. Category 1 applies to drones weighing less than 0.55 lb. With added personal protection, Category 2 applies to drones weighing more than 0.55 lb., with added personal protection. The FAA would permit operations of small UAS without requiring a waiver for night flying under certain conditions. The agency also proposes that restricting flights over any open-air assembly, with safety defects, operational limitations would permit operations of small UAS under certain conditions and at night until it completes a separate rulemaking process.

The FAA published an advance notice seeking public comment on "safe and secure operations" of drones, a response to concerns by the Defense, Energy, Homeland Security and Justice departments over the threat of malicious drone activities. The FAA has organized an "unmanned system security plan," which includes new subject matter and is still ongoing. The FAA states in the NPRM that it may propose--prior to finalizing its policy concerning remote identification and tracking that would permit operations of small UAS to fly over people and at night until it completes a separate rulemaking process, the FAA suggests that it may propose--prior to finalizing its policy concerning remote identification and tracking that would permit operations of small UAS to fly over people and at night until it completes a separate rulemaking process.
The objective was to create a fast and flexible multimission, midsize tanker and transport aircraft using advanced but proven technology. When I first saw the KC-390 about a year ago, in a hangar at Embraer’s Gaviao Peixoto facility in Brazil, I was struck by its appearance, most notably its turbofan engines mounted far forward on an anhedral wing. Flying the aircraft only reinforces the impression of strength.

Aviation Week was welcomed back to Brazil in late March by Walter Pinto, Jr., KC-390 program director, to evaluate the aircraft in the simulator as well as in flight as the tanker-transport moves into production. It is heading toward military certification by year-end followed by service entry with the Brazilian Air Force.

After an introduction to the KC-390’s flight controls in the engineering simulator at Embraer’s headquarters in Sao Jose dos Campos, we moved to Gaviao Peixoto to fly aircraft No. 3, registered PT-ZNG, which had originally been earmarked as the first for delivery to the air force but has been redirected to complete certification.

Before the flight, I was guided through the handling of the aircraft in the simulator by Embraer test pilot William Souza. Embraer has made steady progress with its fly-by-wire (FBW) systems, beginning with the Legacy 450/500 business jets, followed by the E2 regional jets and now this first military application.

The FBW has two flight-control laws: normal, and direct as a fallback option. In normal law, the sidestick commands pitch rate until the landing gear is selected up, after which gamma-dot and pitch-rate command is applied. Gamma-dot is the rate of change of the flightpath angle. In backup mode, it is a direct stick-to-surface command.

Embraer has defined a complex flight envelope to meet the various requirements using FBW, changing laws for specific missions and allowing varying G-loads, depending on the task and factors such as aircraft weight. Military certification will allow load factors up to 3g. To use the basic changes in capability, there is a master mode switch on the overhead panel with the positions Main, Max Effort, Tactical Nav, Airdrop, SAR (search and rescue) and AFF (aerial firefighting).

Control of the FBW system is via interconnected and active sidesticks that provide force feedback to both pilots, significantly improving their
Embraer KC-390 by the Numbers

<table>
<thead>
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<th>Dimensions (ft.)</th>
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<tbody>
<tr>
<td>Wingspan</td>
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<tr>
<td>Length</td>
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<td>Height</td>
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<table>
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<tr>
<th>Cargo Compartment (ft.)</th>
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<tr>
<td>Height (10.5 over aft compartment and ramp)</td>
<td>9.8</td>
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<tr>
<td>Width</td>
<td>11.3</td>
</tr>
</tbody>
</table>

| Engines | 2 x IAE V2500-E5 @31,330 lb. thrust each |
| Load Capacity | 80 troops/66 paratroopers/74 stretchers/seven 463L pallets |

| Air-to-Air Refueling | 3 x 8,820-lb. auxiliary fuel tanks |

<table>
<thead>
<tr>
<th>Weights (lb.)</th>
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<tbody>
<tr>
<td>Max. takeoff (military)</td>
<td>191,800</td>
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<tr>
<td>Max. takeoff (civil)</td>
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<td>Max. fuel</td>
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<th>Performance</th>
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<tbody>
<tr>
<td>Cruise speed (kt.)</td>
<td>470 (Mach 0.8)</td>
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<tr>
<td>Ceiling (ft.)</td>
<td>36,000</td>
</tr>
<tr>
<td>Range (nm)</td>
<td>1,520 with 50,700-lb. payload, 3,310 ferry range</td>
</tr>
</tbody>
</table>

A variety of leading-edge slat and trailing-edge flap combinations give the KC-390 stable handling qualities over a wide speed range.

As we prepared for a simulated cargo drop, Souza familiarized me with the variable-flap system, which enables use of slats only, flaps only or every combination of flap extension, from 1-40 deg. This is done by moving the flap lever to 1, for example, which drives the flaps to 10 deg. Then selecting a number between 1-9 on the scale next to the handle and hitting the execute button. Using 3 on the flap-unit scale, the flaps are driven to 13 deg.

By calculating the cargo loads that should be dropped, the desired aircraft speed of 130-140 kt. and the weight of the aircraft, a flap position is derived to achieve an aircraft pitch angle of 5-7 deg. Beyond the 40-deg. position is a notch designated “Full.” This drives the flaps to the maximum 40 deg., but also sends the aircraft systems a signal that a landing is now the objective.

Air Drop mode additionally enables the horizontal stabilizer to be mistrimmed to put the aircraft into a nose-down attitude, so when the cargo leaves the ramp and the aircraft experiences a swift change in weight it is in trim and allows full elevator authority.

On our next simulated takeoff, Souza reduced thrust on the right engine to idle just after liftoff and asked me not to step into the rudder. The beta (sidelip) target turned blue in the upper part of the primary flight display (PFD), showing an asymmetry had been detected, and the FBW envelope protection system added some rudder.

I lowered the aircraft’s nose a little to maintain speed as we climbed, and the aircraft slowly turned until I added some pressure on the left rudder to minimize drag. Embraer’s philosophy is to support the flying pilot by using active protection while keeping them in the loop, in this case by forcing them to add rudder for the necessary climb performance.

After restoring thrust on both engines, we moved to the simulation of air-to-air refueling. The KC-390 can refuel in flight through the probe just above the left side of the cockpit. Souza showed me another use of the aircraft’s electronic capabilities: The control laws for the sidestick can be changed fundamentally for aerial refueling. While it was difficult in normal law to get the aircraft into a stable position behind the tanker to approach the drogue, it felt significantly more stable after the law change, as the sidestick was now strongly damped to make small, precise changes easier.

As a tanker, the KC-390 can refuel helicopters at speeds as low as 120 kt. and jets up to 300 kt. at 2,000-3,200 ft. using two wing-mounted Cobham hose-and-drogue pods. These deliver up to 400 gal./min. and the KC-390 can offload a maximum of 12,000 kg (26,500 lb.) from three tanks that can be loaded on pallets into the cargo hold to feed their fuel via the aircraft’s center tank. The center tank alone can carry 10,000 kg of the aircraft’s 23,000-kg internal fuel capacity. Using palleted tanks can extend that range.

With us for the flight from Gaviao Peixoto were Souza, Embraco safety pilot Clovis Travassos and flight-test engineers Jose Pinto and Patricia Boer. On our walkaround, what struck me first were the two wide balloon tires on the nose gear. The main gear has similar tires, four each on bogies.
on either side. All are low-pressure, nose tires at 85 psi and mains at 105 psi, to operate from soft, unpaved ground or damaged runways. The aircraft can take off and land five times without any required maintenance action, and tire changes can be done on the ramp. The gear is produced by an Embraer subsidiary.

The sponsons are comparatively large and a result of what Pinto calls “design from the inside out.” Embraer first determined the necessary size of the cargo hold, then built the aircraft around it. The hold has a width of 3.45 m (11.3 ft.) over its entire length and a minimum height of 2.95 m over a length of 18.5 m, including the ramp that stores two of the seven standard pallets. Its floor sits 1.24 m above the ground to allow easy roll-on/roll-off loading via the lowered ramp. Behind the main gear are two extendable hydraulic support struts to stabilize the aircraft on soft ground or in gusty conditions.

The aircraft can carry a maximum 26,000 kg, allowing it to transport two fully tracked M113 armored personnel carriers, one Boxer or Brazilian Guarani wheeled armored vehicle, or a Sikorsky H-60 helicopter. One of the design goals was maximum flexibility, and the KC-390 can be reconfigured between roles in 30 min. to 3 hr. For disaster relief or medical evacuation, 74 litters can be installed with room for staff and life-support equipment.

In our aircraft, seats were folded along both sides of the hold. The KC-390 can carry up to 80 soldiers or 66 paratroopers with full gear. Two doors are located behind the wings. To provide a more stable jump position for paratroopers, deflectors next to the doors unfold into the airflow. Doors can be exchanged in flight, for example when reaching the target area on a SAR mission to install doors with large bubble transparencies for better visibility.

The large cockpit has an optional third crewmember station behind the pilot seats, equipped with a display and tailored functions for missions such as aerial refueling and SAR. In the rear of the cockpit are two bunks. I sat in the left pilot seat, the huge windows allowing a great view. All six windows are protected against ammunition up to 7.62 mm and 0.5 in. For operations in hostile environments, removable Kevlar mats can be added to the lower cockpit area.

Four Rockwell Collins Pro Line Fusion 15.1-in. displays face the pilots. A fifth sits just below, angled on the center pedestal. Aft of it are keyboard, scratchpad and cursor control devices. Avionics are commercial, with numerous additional functions for military tasks. The cockpit is organized as on commercial aircraft: Lights illuminate only if the system condition is “in transit” or “non-normal.” The head-up display is supported by an enhanced vision system using four cameras installed in front of the windshield wipers.

Souza loaded the flight management system, and I easily followed the way through the menu as we prepared to start the IAE V2500-E5 engines with auxiliary-power-unit (APU) bleed air. Takeoff weight was planned to be 67,000 kg, with a zero-fuel weight of 52,800 kg and 14,300 kg of fuel, including 100 kg for taxiing. The digitally controlled engines took 75 sec. to stabilize at idle. After moving the flaps to the takeoff setting of 4, used for a short-field takeoff, we performed the flight-control check and completed the after-start checklist.

With a slight increase in thrust, we started to roll. The aircraft could comfortably be steered with the tiller from either seat. This steers the nosewheel up to 67 deg. left or right, so the aircraft can turn through 180 deg. within a radius of only 23 m.

With the temperature at 23C (73F), scattered clouds at 2,000 ft., a QNH (altitude above mean sea level) of 1014 and a 7-kt. wind from 160 deg., we were ready for departure. Calculated speeds for takeoff were V1 117, VR 121 and V2 124 kt., with a final-segment speed for flap retraction of 180 kt. indicated airspeed (KIAS). On Runway 20, I advanced the throttles. The engines stabilized at 80% N1 before I moved the throttles to the takeoff/go-around notch below the maximum position.

We accelerated quickly, and liftoff came at a pitch angle of 8 deg., with the target for initial climb of 11 deg. An electronic tailstrike avoidance system markedly increases stick force on reaching 13 deg. pitch, before the physical limit of 15 deg. We banking
right, toward airspace reserved for Embraer test flights, and climbed to 20,000 ft. I flew the aircraft manually, performing some turns to get a feeling for its behavior.

Moving the relatively massive sidestick a few degrees revealed the aircraft’s enormous agility, quickly putting it into a turn. With that perception, I used every chance during our flight to use the maximum rate of up to 20 deg./sec. This increases to 30 deg./sec above Mach 0.7, as the higher dynamic pressure translates into a higher rate, and the aircraft is not limited by loads during maneuvers. These flight characteristics made me forget the size and weight of the KC-390.

The spoilers are oversized and support its agility and capability for a quick and steep tactical descent. When the master mode switch is moved to the “Max Effort” position and the aircraft is slowed to 290 KIAS to extend slats only, it will descend with idle thrust and flight spoilers extended to 40 deg. at a rate of 11,000 ft./min. while accelerating to the maximum operating speed, of 300 KIAS. At maximum speed it will still descend at about 9,000 ft./min.

We then flew a shallow descent and watched the FBW protection system smoothly pull up the nose to bring the aircraft back to its maximum speed as we accelerated through 304 KIAS. This protection does not use the auto-thrust or speedbrakes, but tries to keep pilots in the loop by handing back the aircraft once it is within the envelope.

To demonstrate maximum-G protection, we slowed to 200 KIAS, extended the flaps to 2 and started a 45-50-deg. banked turn while I quickly pulled the stick fully aft. Because G-load is permanently shown in the left upper corner of the PFD, we could watch how the FBW’s programmed envelope protection constantly kept the aircraft at not more than 2g. The G indication increases situational awareness and lets pilots know when they could overload the aircraft in fallback “direct” mode without the protections.

While still at high altitude, we slowed down and configured the aircraft for a simulated approach to watch the low-speed protection. With flaps full at 40 deg. and landing gear down in manual flight and with manual thrust, I slowed the KC-390 to 109 KIAS, about 1.05 times stall speed, before the auto-thrust “woke up” and accelerated us to 125 KIAS, where it returned to passive mode and handed the function back to the pilots. During our next slowdown, I maneuvered the aircraft through some turns and saw it was still fully maneuverable and easy to control.

Souza and I prepared for a manually flown approach to Runway 2/20. But then the unexpected happened: We were losing fluid from the left-hand hydraulic system. We lost pressure after a few minutes and decided to make a full-stop landing and return to the ramp.

The aircraft has two hydraulic systems and electrohydrosstatic actuators on the control surfaces for higher redundancy in hostile environments. This capability helped us now, as all flight controls were still in the normal mode, but the landing gear had to be lowered by the backup free-fall method.
FLYING THE KC-390

Thanks to this unexpected event, I had the opportunity to watch the abnormal procedure, handling of the Quick Reference Handbook and alternate lowering of the gear by the large red handle located below the right seat. Later, it was discovered that a hydraulic line on the left engine was loose.

Because the aircraft was still flying as well as it had before the incident, Souza allowed me to continue at the controls. At 1,800 ft. above the field, we were out of the clouds, and I could continue to fly visually toward the long runway. We planned to land with flaps at their full 40 deg.; the approach speed was calculated at 134 KIAS with a reference speed of 127 KIAS.

At 50 ft., I slowly reduced thrust to idle and broke the descent rate as the ground effect below the large anhedral wing helped with a smooth touchdown. The KC-390 uses a derotation law on touchdown to quickly lower the nose gear to the ground for shorter landing distances, and Souza explained it is advisable not to provide any backpressure on the sidestick, as that would work against the control law, and the FBW would increase downward pressure in response.

Thrust reversers can be armed for...
landing, set to open automatically as the aircraft enters ground mode and the engines reach idle RPM. The aircraft has an enormous braking capability for operation on short and unpaved runways, with its spoilers extending to 50 deg., huge brakes on all eight main wheels and reverse thrust.

On landing, we used manual braking due to the hydraulic loss, and Souza took control to turn the KC-390 onto the ramp with some asymmetric braking because we had lost the nose-wheel steering with the hydraulic failure. Reaching our parking spot on the ramp, we started the APU and shut down the engines before completing the few items on the parking checklist.

I had expected the aircraft to be vigorous. But our flight showed its agility and flying characteristics are even more impressive than anticipated, making it a delight to fly this medium-size tanker transport.

Most important, Embraer has developed a fly-by-wire system that is able to extract the maximum performance from the aircraft. The KC-390 makes full use of its flight envelope when needed for military missions and at the same time reduces the workload for pilots, freeing them to use more of their capacity for demanding tasks.

**KC-390 Poised for Prime Time**

> PARTS FOR THE 10TH KC-390 ARE IN THE PRODUCTION SUPPLY CHAIN
> FINAL SYSTEMS AND REFUELING FLIGHT TESTS ARE UNDERWAY
> SALES HOPES GROW WITH BIGGER BOEING INVOLVEMENT

**Guy Norris** Sao Jose dos Campos, Brazil

With military certification beckoning, production accelerating and a potential marketing jump start from the pending Boeing joint venture, Embraer is gearing up for the most crucial phase yet of its KC-390 tanker-transport program.

Ground zero for this effort is Embraer’s Gaviao Peixoto facility in central Brazil where flight testing and final assembly take place. “We are moving from the development and certification phase to the production phase, although we still have some flight tests to complete to show compliance with the military certification requirements,” says KC-390 Vice President Walter Pinto, Jr.

“Production is ramping up to meet the delivery schedule to the Brazilian Air Force (FAB),” says Pinto. Four aircraft are on the final assembly line; fuselage sections for the seventh production airframe and the wing set for the ninth KC-390 have entered the facility, while major components for the 10th are in the supply chain. The production system is designed for up to 18 aircraft a year, depending on sales.

“The first production aircraft, No. 3, is complete and was to be the first aircraft to be delivered to the FAB. But instead it joined the certification and flight-test campaigns in October,” says Pinto. The aircraft was diverted to the test effort after the first prototype was damaged in a runway overrun in May 2018. The first aircraft for the air force, No. 4 or FAB1, is in final assembly with its IAE V2500-E5 engines attached.

“We are getting ready to deliver this by the end of [June]. Production is going smoothly although, of course, as with any new production line, we have faced challenges and are learning—just as we have with flight tests,” says Pinto. “Minor corrections have been done to improve assembly and make it easier to put together, but nothing dramatic.”

Between the first production and two prototype KC-390s, the test fleet has logged more than 2,000 flight hours.
FLYING THE KC-390

hours since first flight on Feb. 3, 2015. Brazilian civil certification was received in October 2018. “We are now fully focused on military certification and are expecting to achieve this in about 600 more flight hours if all goes smoothly,” he says.

Recent tests include troop unloading and emergency evacuation trials at Brasilia AFB, in which the upper fuselage escape hatches were used along with forward and aft doors. Loading tests with various military vehicles and helicopters have also been undertaken, ranging from a pair of tracked M113 armored personnel carriers and an Avibras Astros rocket launcher to a UH-60 Black Hawk. Flight tests have proved the KC-390’s ability to air-deploy loads ranging from 16 48 X 48-in. containers to two 96 X 48-in. containers to multiple drop zones on a single mission. Other tests include night-vision compatibility trials with the Brazilian forces, high-altitude/low-opening parachute tests and lightweight air-drops.

Upcoming tests include low-velocity air-drops of loads up to 19,000 kg at Yuma Proving Ground, Arizona, using aircraft No. 3. Additional low-speed tests to prove the combat offload capability are also scheduled at Gaviao Peixoto, as are final flight tests of the self-protection system. Developed with AEL Sistemas, a Brazilian-based subsidiary of Elbit Systems in which Embraer has a 25% stake, this includes chaff and flare dispensers and a directional infrared countermeasures system.

Embraer is also gearing up for a series of tanker tests in which the KC-390 will act as both refueeler and receiver. “We have done dry contacts with another KC-390, but now we are going to transfer fuel from ‘KC to KC,’” says Marcio Eduardo Monteiro, KC-390 program senior manager of product development. “We did dry contacts with FAB F-5s, and now we are going to do wet contacts with those and also the AMX (ground-attack aircraft).

“We will also do dry and wet with the KC-390 to a KC-130 and with the KC-390 as a receiver,” Monteiro adds. Helicopter refueling tests are also planned for this year, using aircraft No. 2 and a FAB Helibras H36 Caracal (Super Puma). Embraer has conducted low-speed testing with the wing-mounted hose-and-drogue units deployed. “We have demonstrated good flight stability at low speeds,” says Pinto.

Airbus hit challenges refueling helicopters with the A400M airlifter. “There are questions and concerns from the market about how the KC-390 can do it, but we will demonstrate how the aircraft’s flight-control system and flight surfaces give it that extra capability,” he says. “It is completely different aerodynamically to what people have been used to with legacy and current aircraft like the C-130,” Pinto notes.

Although the only firm order in hand is the Brazilian Air Force’s requirement for 28 aircraft, Embraer is edging closer to converting letters of intent from a string of smaller nations. These include Argentina, Chile, Colombia and New Zealand, the latter having publicly discussed acquiring five KC-390s to replace its C-130s. Interest has been shown by the Czech Republic and Portugal as well as SkyTech, an Australian/Portuguese joint venture that plans to take up to six KC-390s to operate with air forces under leasing arrangements.

Despite comments made early in the year by the chief of Portugal’s air force, Gen. Manuel Teixeira Rolo, who noted that price might be an issue clouding the KC-390 deal, “things have improved dramatically,” Pinto says. “We have worked with them to better understand the gap they are focused on. We also understand their requirements and have been working on our end. And they have worked it at their end.”

In January, Rolo told Portugal’s national defense committee that Embraer was asking more for the planned five-strong fleet than the €830 million ($949 million) budgeted by Lisbon.

“We have discussed some changes to the package in order to meet their budget,” Pinto notes. “They have a limited budget, and the contract is not only about the aircraft, it is about the whole package, including support and training. We have looked into the configuration of the aircraft to see how we could still meet their requirements in a different way. They would reduce their requirements on their side, and we would on ours. But it is a fixed budget and it is public, and we have to work with that.”

Embraer is confident that sales prospects will brighten with entry into service and says there has already been an uptick in interest since it announced plans with Boeing to form a joint venture to market the airlifter. This builds on an earlier marketing and support agreement signed in 2016 and comes as Boeing closes in on acquiring 80% of Embraer’s commercial aircraft business.

“The main idea is to open up new markets and sell the aircraft in countries that would be more difficult for us [on our own]. The influence of the U.S. is completely different than Brazil’s,” says Pinto.

On the potential for setting up a U.S. assembly line, Pinto adds: “Everything we eventually move, such as production in the U.S., depends on the addressable market. We know that to sell to the U.S. government we have to respect the Buy American Act—so it all depends on the business case. We are evaluating everything.”
MBDA is developing a family of weapons from its novel Spear 3 network-enabled standoff missile.

The multinational European missile-maker sees potential in further derivatives, now that development of the weapon—designed so that four will fit in each of the Lockheed Martin F-35’s two internal weapons bays—is well-advanced. One derivative could act as an electronic-warfare (EW) jammer or decoy and the other as a less complex glide bomb. The latter would have a lower cost than the baseline weapon but would be more lethal, thanks to a larger warhead.

While both are being developed primarily using company money, the development of an EW capability has sparked interest from potential customers, some even providing initial funding. MBDA’s Spear 3 chief engineer Stephen Temple said at the Royal Aeronautical Society in London in April.

While both derivatives “leverage heavily from the main program,” he said, the current focus of the EW version’s development is around the propulsion and payload. The EW version will likely carry more fuel to give it a longer range and persistence. Temple sees the EW Spear 3 as providing a capability similar to Raytheon’s Miniature Air-Launched Decoy (MALD), in which the UK has shown interest.

The engineering team is currently working to understand the speed at which the EW Spear 3 will fly and the type of antenna it will need to deliver jamming waveforms.

Video produced by MBDA but not yet publicly released shows how an EW Spear 3 could be launched ahead of a salvo of standard weapons aimed at enemy air defenses.

Video produced by MBDA but not yet publicly released shows how an EW Spear 3 could be launched ahead of a salvo of standard weapons aimed at enemy air defenses.

Work on the glide version is running behind that of the EW derivative, but such a weapon would be significantly less expensive than the baseline weapon.

MBDA hopes the Spear 3, already carried by the Lockheed Martin F-35 (top right), will be integrated on the Eurofighter Typhoon and Saab Gripen as well.

The 80-kg (176-lb.) missile is equipped with a small turbojet, extending ranges well beyond that of existing small-diameter glide bombs.

Building on MBDA’s development of the Brimstone, the Spear 3 will use a millimeter-wave radar seeker and semiactive laser terminal seeker and GPS/INS guidance and is capable of receiving updates via data link. Programmed prior to takeoff or launch, crews will be able to tune the warhead’s characteristics as well as define attack angles and azimuths.

MBDA is working with a four-year £411 million ($536 million) UK Defense Ministry design and development contract issued in 2016.

In March, it was announced that MBDA would support BAE Systems and Lockheed Martin’s efforts to integrate the weapon onto the F-35. The Spear 3, along with the Meteor beyond-visual-range air-to-air missile, will be integrated as part of the F-35’s continuous capability development and delivery (C2D2) program.

MBDA carried out a test firing of a Spear 3 in 2016. This Airframe and Propulsion Demonstrator (APD) flew a series of preprogrammed maneuvers before flying into the sea off western Wales, helping to derisk the company’s software modeling and analysis tools. Meanwhile, the programming of the weapon’s seeker has been conducted using an airborne testbed, carrying the seeker, navigation system and data link. The testbed allows the company to gather data for the radio-frequency element of the seeker so that it can more easily find targets against background clutter.

The next steps for the weapon’s development and flight trials are not being disclosed, but Temple says the
company is building operationally representative equipment and beginning prequalification activities.

“We are really starting to learn about the product we are developing,” he says.

A key part of the work is developing two launchers for the weapon, a three-pack launcher for external pylons and the four-pack launcher for inside the weapons bay of the F-35 family of aircraft. The launchers pass much of the data from the aircraft to the weapons and eject the missile out of the weapons bay using a cold gas pneumatic system.

Carried upside down on the pylon, once dropped, the weapon turns rightside up and opens its wings and fin stabilizers, while the turbojet is spooled up by windmilling air through intakes on either side of the missile’s body.

Designing the weapon to fit inside the constrained volume of the F-35 weapons bay has been the key design driver for the Spear 3.

The Spear 3 is the densest missile produced by the company. Although it is roughly the same size as the Brimstone in terms of diameter and length, it is twice the weight, with “more complexity than the Storm Shadow cruise missile,” says Temple.

The company has also had to consider the challenges posed by both internal and external carriage. Outside, the weapon is exposed to extreme cold, but inside the F-35 weapons bay, the temperature is considerably warmer, thanks to the proximity of the engine. This heat causes the Spear 3’s fuel to expand. The expansion characteristics of the fuel “took us by surprise,” says Temple, and could have had an impact on the amount of fuel carried. Too much expansion could rupture the system, while too little and the weapon may not meet its anticipated range.

“Packaging this amount of capability into a weapon that is relatively small drives a lot of design risks,” says Temple. “We are testing this system beyond the requirements because we don’t want to carry risk into the qualification program or F-35 integration program.”

The introduction of the Spear 3 onto British F-35s is one of the components that will enable the UK to declare full operational capability with the aircraft around 2023.

U.S. Air Force Fleet Is Structured for the Wrong War, CSBA Warns

> THE F-35 AND B-2 WILL FACE NEW THREATS BY 2030

> A NEXT-GENERATION FLEET IS NEEDED EARLIER

Steve Trimble Washington

Not only too small, by one-third, to fight a near-simultaneous war with Russia and China in 2030, the U.S. Air Force’s four newest frontline combat aircraft—the B-2, F-35A, F-22 and KC-46—will be limited to a standoff role in highly contested airspace.

In 2030, a new crop of Russian and Chinese very-long-range air-to-air missiles will keep Boeing’s newly delivered KC-46 tankers at least 500-1,000 nm away from defended air-space, flanked by a protective shield of aging F-16s. Meanwhile, Lockheed Martin F-35As will still slip through an enemy’s long-range fighter screens but will now stay safely outside an enemy’s borders, lobbing Stand-In Attack Weapons (SIAW)—the Air Force’s future version of the Advanced Anti-Radiation Guided Missile-Extended Range (AARGM-ER)—at targets from hundreds of miles away.

The long-range penetration mission—a mainstay of U.S. offensive strategy since World War II—will now rely on a new family of frontline aircraft designed to avoid detection by low-frequency tracking radars. Led by Northrop Grumman B-21s, a still undefined next-generation fighter and a mysterious new penetrating intelligence, surveillance and reconnaissance (ISR) aircraft, this sixth-generation strike package penetrates deep inside enemy airspace from multiple directions and lingers there as long as possible.

As the successors of the Northrop Grumman B-2, and Lockheed Martin F-22 and F-35A, these aircraft find the most elusive or dangerous targets, then nullify them using electronic or kinetic effects, or by sending the target information to distant F-35s with SIAWs or Boeing B-52s loaded with long-range weapons, including hypersonic missiles.

That sobering scenario, presented in an April 11 report by the Center for Strategic and Budgetary Assessments (CSBA), describes not a distant vision of aerial warfare but a near-term wake-up call for the airpower community and Congress, according to the authors. The National Defense Strategy (NDS) released by the Pentagon in 2018 calls for the military to be prepared to win a war with China and Russia within a decade, but today’s Air Force is woefully short of the aircraft and capabilities needed for the task, the CSBA concluded in the congressionally mandated report.

“We have a force that is not well-suited to these kinds of conflicts because we haven’t invested in the force in the last 25 years the way we should have,” CSBA Senior Fellow and report co-author Mark Gunzinger told Aviation Week. “Now we’re playing catch-up. We really, really are.”

Indeed, the CSBA report echoes the eight-month-old, unclassified summary of the Air Force’s own analysis, “The Air Force We Need.” In late 2017, Congress commissioned the reports by the CSBA and the Air Force—along with another unreleased, classified analysis by Mitre Corp. The objective was to gather insight for shaping resource decisions in the absence of a Quadrennial Defense Review (QDR). The latter was replaced in 2018 by the Defense Department’s less detailed NDS.

Of the three assessments, the CSBA offers the only independent and unclassified analysis of a force structure for the Air Force and one that is un-
constrained by the Trump administration’s budget and policy agenda.

“What the QDRs gave [Congress] was, ‘Here is our strategy, and here is the force that we can afford to best support the strategy.’ But that is not what Congress wanted. They said, ‘We come up with what the nation can afford. We want to know what’s needed,’” says Gunzinger, one of the report’s five co-authors and a contributor to five QDRs.

According to both reports, the Air Force needs more and different aircraft. The service’s “Air Force We Need” analysis concluded that the requirements laid out by the NDS, which include fighting rogue states and lightly armed insurgents, call for a total of 386 squadrons, including units devoted to nonaviation missions such as cyberwarfare and space. The CSBA analyzed requirements only for aviation units and came up with similar overall results. Today, the Air Force operates a total of 169 squadrons flying bombers, fighters, tankers, command-and-control (C2) and ISR missions. Whereas the Air Force calls for adding 50 squadrons to raise that to 219, the CSBA analysis proposes raising the inventory by 54 squadrons.

The two reports agree roughly on the size of the force but disagree on the fleet mix. The CSBA report calls for 24 bomber squadrons in 2030, a 71% increase over the 14 squadrons recommended by the Air Force. But the Air Force report proposes 89 squadrons made up of ISR and C2 aircraft, versus 76 called for by the CSBA. The numbers of fighters and tankers are roughly equal between both reports, with the CSBA calling for three more fighter units and four more tanker units than the Air Force’s vision for 2030.

The classification of the Air Force’s report makes the mix of aircraft types within those top-line fleet numbers unknown. But that is also what makes the CSBA version of the report so interesting. Unconstrained by the obstacle of secrecy, the CSBA project was free to speculate on the specific types of aircraft the Air Force will need after 2030. Moreover, two of the report’s authors—Gunzinger and Carl Rehberg—performed such analyses within the Pentagon until retiring from government employment within the last decade.

As an aircraft that entered the development stage 3.5 years ago, the B-21 presents a special case. Though nearly all schedule and performance details are classified, the authors make intriguing projections about the bomber’s current and potential production capacity over the next decade. Based on limited information provided by the Defense Department’s selected acquisition reports, the CSBA report estimates that Northrop Grumman will deliver 38 B-21s by 2030. But even that pace is not fast enough. The CSBA authors recommend accelerating the production ramp-up to complete 55 B-21 deliveries by 2030, starting with the first in 2024.

The Air Force needs B-21s because they form the heart of the CSBA’s projected stand-in strike package. The next-generation fighter and existing F-35As and F-22s are useful, but alone they lack the range and payload for the task.

“What if your tanker has to stand off 500 mi.? What if close-in air bases are under threat?” Gunzinger asks. “You don’t want to do that with something that requires a lot of refueling and carrying that [smaller] payload.”

Although larger than a fighter, the B-21 is considered survivable against the next generation of airborne and ground-based threats, in CSBA’s analysis. The Air Force has not released the size of the B-21, but Rehberg—a former B-1B pilot—considers it smaller than a B-52 or B-2, which helps its stealth signature.

“It’s also the outer mold line, and it’s the material you use that’s determine,” Gunzinger says. “You design something with a couple tails that stick up, and your exhaust is hanging out in the breeze—OK, that’s going to be pretty easy to find.”

The same analysis also consigned the F-35A to a standoff role in the CSBA’s 2030 study. “I think you need a new outer mold line for [what is] a highly contested environment,” Gunzinger says. “You need something that’s all-aspect, broadband [and stealthy].”

But the F-35A still has much to offer for a next-generation fighter, which the CSBA identifies as a dual-mission Penetrating Counter Air/Penetrating Electronic Attack (PCA/P-EA) aircraft. The report calls on the Air Force to accelerate the first delivery to 2026, even though the Next-Generation Air Dominance acquisition program has not yet opened for bids. The faster time line would require the Air Force to leverage mature technology as much as possible, Gunzinger says. One possibility is to combine the F-35’s existing avionics and mission system with a new airframe optimized for broadband stealth. That suggests a tailless, supersonic aircraft.

“That would drive you to a different kind of [outer mold line] and a different kind of concept for operating that,” Gunzinger says. “You’ll not necessarily be pulling high-Gs and so forth. It’d be more of a [beyond-visual-range] type platform.”

The authors provide less detail on the projected requirement for a P-ISR aircraft, due to the sensitivity of the mission area and their backgrounds in recent government service.

“It could be manned or unmanned, and there’s probably nothing more I can say about it, and neither can Carl because we were in that world not too long ago,” Gunzinger says. “Everything that penetrates ought to be capable of contributing to operations in the [electromagnetic spectrum] to include communications, sensing, jamming and creating other effects.”
Recycling of Carbon Fiber Remains Elusive

> MAJOR PROJECT FOR COMPOSITE MATERIAL RECYCLING WENT NOWHERE

> OTHERS NEAR SUCCESS BUT AT LIMITED SCALE OR FOR LOW-VALUE APPLICATIONS

Thierry Dubois Paris

While composite materials, especially carbon-fiber-reinforced plastics (CFRP), have proven their worth for the construction of lighter aircraft, their life-cycle impact is questionable. At the end of their lives, they are recycled into a low-value product at best; in the worst case, their destination will be a landfill site. The industry's numerous research and development (R&D) efforts of the past decade to reuse the fiber—the most valuable component in the material—in high-value applications have yet to find a favorable outcome.

In other words, building a new aircraft with carbon fiber coming from recycled aircraft is still a pipe dream. For engineers focused on environmental impact, this is all the more frustrating as producing new composites consumes a lot of energy (see table), and composites comprise more than 50% of the materials in the latest clean-sheet commercial aircraft designs.

Meanwhile, specialists in aircraft dismantling continue to sell scrap metal for reuse in aerospace, and suppliers of aluminum alloy—the main competitor of CFRP in aircraft construction—have made strides in recycling offcuts.

A striking example of the disappointment that composites optimists may feel is the failure of the Parcca R&D project. Parcca, a French acronym for “advanced processes for carbon composites recycling,” was a €1.9 million ($2.1 million) endeavor to test industrial-scale reactors where the pyrolysis and solvolysis processes would have enabled the recovery of carbon fiber.

Parcca aimed to retrieve 50% of the fiber in cured material and eliminate 95% of the resin on it while retaining 95% of the mechanical performance. Partners included the IRT Jules Verne research and technology institute in Nantes, France; Airbus; waste management specialist Veolia; and Sacmo, a company with expertise in designing machine tools. The project ended in February 2018 after 3.5 years.

Progress was made in pyrolysis, a process that uses heat to separate fibers from resin, but it is energy-greedy and damages the fiber.

Solvolysis, meanwhile, was deemed more promising. It involves mixing pieces of composites with water brought to 400C (750F) and 200 bar. In these conditions, water is in a supercritical state—its properties are between those of liquid and gaseous water. After 1 hr., fibers can be separated from resin. Sacmo created two demonstrators, one 20-liter (5.3-gal.) and one 25-liter. Engineers conducted 900 trials with the first demonstrator using composite material samples Airbus supplied.

Airbus A350 production (pictured) creates an annual 75 metric tons of carbon-fiber-based material offcuts.

However, Parcca’s promoters could not obtain authorization from local authorities to build the large-scale reactor. “Airbus and Veolia did not play a particularly dynamic role at that stage,” says a participant. An Airbus spokesperson did not respond to Aviation Week’s request for comment.

In any case, it was unlikely the recycled fiber obtained with solvolysis could have been used in aerospace. With solvolysis and heat-based techniques, the length of a recycled carbon fiber is reduced to 6-9 cm (2.4-3.5 in.), which is not suitable for airframe applications, which require fiber length of several dozen centimeters. And for high mechanical performance, composite materials need fibers to be oriented consistently; this is why some of them are described as “unidirectional.” Orienting short fibers is impractical, says Aziz Bentaj, CEO of Xcrusher, a startup company specializing in carbon-fiber recycling.

The shortening is due to the need to cut the pieces of composite materials apart before they enter the chemical process. This ensures enough contact surface for the chemical reaction, Bentaj explains.

Xcrusher has been developing two technologies for uncured and cured composites, respectively. Using uncured offcuts of pre-impregnated fabric makes the most of an electrical property of carbon fiber.

Carbon fiber is a very good conductor, says Bentaj, and creating an electrical impulse on the order of about 1 gigawatt through the fiber sublimates resin. It leaves the fiber as good as new, with intact mechanical and chemical characteristics, he says. The duration of the electric pulse—approximately a nanosecond—makes it energy-efficient. The resulting 2.5-m-long (6-17-ft.) fibers can be put together to form an 8-km-long (5-mi.) reel, says Bentaj.

A prototype component built for the automotive industry produced “encouraging results,” he notes. Static tests were deemed satisfactory, and Xcrusher is now working on dynamic evaluations, which simulate aging.

So what about an application in aerospace? Bentaj sees no problem in performance. He hopes to eventually provide a major composite material supplier such as Hexcel or Toray with recycled fiber.

A pilot factory built with waste management special-
A pilot factory built with waste management specialist Suez is starting operations in Saint-Ouen, near Paris. Over the course of one year, the various phases of the process will be tested separately, and then the complete process will be tested for three consecutive months. Bentaj says the scale of the €6.5 million, four-year project, led by waste management specialist Suez, is compatible with the quantity of offcuts produced by the Airbus A350 program: 75 metric tons (165,000 lb.) per year.

The trials will give Xcrusher and Suez an indication of the recycled fiber’s cost. Bentaj is eagerly awaiting this demonstrated cost, which he hopes will be competitive. The automotive industry uses low-modulus fiber priced at around €15/kg (88 lb./). Aerospace needs high-modulus fiber costing €30-50/kg.

For cured composites, such as those coming from aircraft pulled apart at the end of their lives, Xcrusher has another solution: They can be turned into highly conductive micro-metric powder. “It can be used in paint chemistry, as it can help create a smart wall,” says Bentaj. A smart wall can be used as a touch screen.

Hexcel is working on recycling, too. The company’s pre-impregnated fabric manufacturing processes leave 10-20% of offcuts, notes Thierry Merlot, Hexcel’s president for Europe, Asia Pacific, the Middle East and Africa. The partnership with Lavosier Composites, a startup in Lyon, France, is paving the way for the use of such offcuts. Carbonium is a material sourced entirely from CFRP by-products generated by the French aerospace sector. Compared to equivalent products derived from virgin materials, Carbonium reduces the environmental impact by an estimated 40-50%.

A sales contract has been signed with Swiss luxury watchmaker Ulysse Nardin, which uses carbonium for two watch models. Merlot hopes higher-volume recycling applications will be found, for example, in the automotive sector. “The technology is ready,” he says. Carbonium has a greater added value than the current uses of offcuts, such as road construction.

Thermoplastics, often touted for their recyclability, have yet to demonstrate it at industrial scale. The difference between thermoplastics and thermosets—which aerospace mostly uses for primary structures—lies in the resin (the matrix) rather than the fibers (the reinforcement). When heated, a thermoplastic resin softens and melts; when cooled down, it can resolidify without losing any property. The solidification process involves no chemical curing.

A European research project has shown that thermoplastic parts from aircraft at the end of their service lives can be recycled into new components with similar mechanical performance. The Clean Sky program’s Reset project focused on recycling the carbon-fiber-reinforced polyether ether ketone (PEEK) and polyphenylene sulfide (PPS) thermoplastics most commonly used in aircraft.

One of the work packages involved the conditioning and characterization of the recycled material and development of a new family of recycled CFRP based on PPS and produced by an extrusion process.

Using this new material, two small parts (a bracket and a cleat) were created by thermoforming. Mechanical properties of the material were found to be comparable with a commercial composite. The research project ran from 2016-17, but the results emerged this year.

Meanwhile, engineers at the Cetim Grand Est research and technology center in Mulhouse, France, believe separating the fiber from the surrounding resin may not be worth the time and energy. Instead, they are promoting Thermosaic, a material made from thermoplastic composite shreds. The idea is to put together overlapping patches of material, thanks to an unspecified thermomechanical process. The resulting panels can be processed by cutting, folding, welding or stamping.

The optimum fiber length is 3-10 cm, says Clement Callens, who is in charge of future thermoplastic processes at Cetim Grand Est. Longer fiber shreds would produce thicker panels, due to the need for overlap.

Thermosaic’s mechanical performance stands at two-thirds that of the performance of continuous fiber, taking short fiber (1-2 mm) as the baseline, according to Callens.

Thermosaic’s technology readiness level is seen at six, meaning it is estimated to be mature for a full product launch. A pilot production line has been running since 2017, says Callens. Porcher Industries, a specialist in carbon-fiber weaving, tested the technology. Applications for Thermosaic are foreseen in niche markets like industrial equipment, transportation, building and energy and it may be considered for secondary structures in aerospace, says Callens.

Once an application has been found and a process set up at an industrial scale, long-term availability of the resource might be a challenge, Callens notes. In aerospace, optimizing a manufacturing process or replacing a material with another may starve the recycling factory of fabric offcuts. This concern may affect every recycling effort, in fact.

Another approach to improving composites’ environmental impact may be to use non-petroleum-based fibers. The IRT Jules Verne is studying the suitability of lignin and cellulose, both plant-based, for applications in the automotive and leisure gear sectors.

—With Graham Warwick in Washington
Six Cool Innovations—and a Puzzling One

Thierry Dubois Hamburg

Engineers designing the passenger cabin have more freedom than those responsible for the airframe. At the Aircraft Interiors Expo (AIX) show in Hamburg in early April, companies showed off creative ways of providing passengers more comfort in the sometimes not-so-friendly environment of air travel. Here are some of the coolest innovations displayed at AIX 2019—and a baffling one.

HELPING THE HEARING IMPAIRED

ATR aims to improve the passenger experience and safety for hard-of-hearing persons with a dedicated interface for hearing aids. A significant proportion of the hearing-impaired switch off their aids when boarding, since they can have excessive sensitivity in some audio frequencies. The problem occurs in different frequencies depending on the person, but an aircraft cabin’s aural environment amplified by hearing aids is painful for many, notes Irene Aliouat, president of the Audition & Vie French association of hard-of-hearing persons (at right in photo above).

The passenger misses a lot with a switched-off hearing aid. He or she can no longer hear public address announcements, including those that relate to safety, or the inflight entertainment (IFE) system. As a result, the passenger can feel isolated. To address this, ATR has created a simple hearing induction loop, as can be found in many public places. Switched to a dedicated mode, the hearing aid receives only the input from the loop. A magnetic device transmits public address announcements and IFE sound, noise-free.

ATR suggests using a removable headrest cover that includes the transmitting magnetic coil. It can be easily moved around the cabin, so a passenger can use any seat and need not be separated from travel companions.

IDENTIFYING OPEN BAGGAGE SPACE

Airbus, meanwhile, is looking at ways to help with carry-on baggage storage. The airframer proposes using sensors and colored LEDs to indicate the status of an overhead bin section: full, partly occupied or empty. The idea is to help passengers and cabin crew locate free space. Such equipment could help accelerate the boarding process, which is currently impeded by a clogging melee of passengers and roller suitcases.

DAY AND NIGHT FIRST CLASS

For the less busy first class, Airbus is pitching a new concept: Instead of one reclining seat, the passenger could have both a seat and a private sleeping area. In terms of space and weight, the Day and Night arrangement is said to be equivalent to or better than a conventional layout.

And for couples traveling, Day and Night, introduced last year, has evolved so that the “night” area now looks like a two-person bedroom. A sliding door creates an aperture about the length of a person’s upper body.

PANEL LOUDSPEAKER

Diehl Aviation is looking at replacing conventional loudspeakers in the passenger cabin using the lower panel of the overhead baggage compartment as a membrane. An exciter
transmits vibration to the panel. Diehl says sound quality is better than with conventional membrane speakers, especially for voice transmission. In addition to contributing to a more streamlined cabin design, the panel loudspeaker is lighter than its conventional counterpart, Diehl says.

**VOICE-CONTROLLED LAVATORY**

Diehl is offering sensors to enable touchless operation of the lavatory door, seat, lid, flush and faucet for improved hygiene. The company is also proposing voice-activated controls. Following the example of Apple’s Siri and Amazon’s Alexa, Diehl has named the assistant Flips. The passenger precedes each command with “Hey, Flips,” such as in “Hey Flips, open the seat.” Speaking to the toilets, however, is a perplexing experience.

As sensor-based and voice-controlled operations are relatively slow, they can be overridden manually in case of urgent need.

**VIDEO AT THE SPEED OF LIGHT**

Aerostructure and wiring specialist Latecoere is developing a “Li-Fi” system, based on light signal transmission via optical fiber and light-modulation infrared LEDs, to increase the bandwidth of IFE systems. Li-Fi can transmit multimedia content more quickly than can Wi-Fi. The current prototype offers 10 Mbps per passenger, and Latecoere plans to increase speed tenfold by June. Li-Fi is promised to enable 4K video on demand for an entire cabin.

A Li-Fi beam is very directional, so each Li-Fi ceiling lamp would transmit data for one passenger only, opening possibilities for personalization, which is why the concept is named Private Capsule. The cost of ownership would be compatible with economy class, according to Latecoere.

**JETLAG ADVISOR**

Despite designs to enhance comfort and whatever the class, a passenger on a long-haul flight often struggles with jetlag. Panasonic is introducing a “jetlag advisor” to help the passenger minimize the impact. The software program analyzes the time difference, distances and flight duration and makes recommendations about sleep, meals and light exposure. It takes the passenger’s profile into consideration, such as his or her age and normal wake-up time. Passengers may receive advice as early as two days before the flight.
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May 3—Military and Aviation Exhibition 2019. Israel Trade Fairs Center. Tel Aviv. See new-techevents.com/military-aviation
May 4-Aug. 17—AOPA Flight Instructor Refresher Course.Various locations. See aopa.org/forms/event-calendar/fire_onsite
May 9—RTCA SC-224 Standards for Airport Security Access Control Systems Plenary. Washington. See rtca.org/content/upcoming-committee-meetings
May 14—RTCA SC-231 Terrain Alert Warning System Plenary. Washington. See rtca.org/content/upcoming-committee-meetings
May 18—17th Annual Rocketry Challenge—Rockets on the Hill. Great Meadow Field, Virginia. See rocketcontest.org

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June 3-4—CAPA Airline CEOs in Seoul and Gala Dinner. Seoul.
June 4-6—ap&m Global Europe Summit & Expo. Frankfurt.
June 24-25—CAPA LCCs in North Asia Summit. Cebu, Philippines.
Sept. 11-12—Aero-Engines Europe. Istanbul.

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Waking Up to a New Green Reality

By Anthony L. Velocci, Jr.

The aerospace industry, particularly the commercial side of the business, has enjoyed an unprecedented period of prosperity during the last 50 years. With the introduction of the Boeing 747 in 1970, commercial air travel went from being the preserve of the economic elite to a truly mass transportation industry, changing the world immeasurably. In the U.S. alone, commercial aviation accounts for about 5% of gross domestic product.

Based on the demand for air travel, which has doubled about every 15 years, there is no reason to think this pattern of relentless expansion cannot be sustained—unless, that is, leaders become so overconfident in the industry’s success that they leave commercial aviation vulnerable to major societal and political shifts that could undermine its long-term future.

Industry observers, and particularly industry insiders, most likely will dismiss such a notion as nonsense. But how else to explain the industry’s lack of response to the introduction of the Green New Deal on Feb. 7 by Rep. Alexandria Ocasio-Cortez (D-N.Y.) and Sen. Ed Markey (D-Mass.)? Under their aspirational proposal—and as part of a broader strategy to tackle climate change—the nation would embark on a mobilization effort to cut greenhouse-gas emissions to net zero within 10 years and achieve 100% renewable energy in the U.S. by 2030 through various means, including replacing much of commercial air travel with railroads.

In case anyone failed to notice, the silence from the aviation community has been deafening. In a recent procedural matter, all Republicans and a handful of Democrats in the Senate voted against continuing debate on the bill. However, also worth noting is that every Democratic senator running for president co-sponsored the bill. However, also worth noting is that every Democratic senator running for president co-sponsored the Green New Deal.

The fact that Ocasio-Cortez and Markey presented such an unrealistic concept in the first place is beside the point—as is their apparent ignorance of why a healthy, growing commercial air transport industry is an essential enabler to economic expansion. More troubling is the decision by commercial aviation leaders to brush aside—that was widely ridiculed.

Such a seemingly smug reaction could be overlooked if it were not for the fact that the U.S. is experiencing some of the most profound shifts in political ideology since the end of World War II, and the potential for historic change is in the air. On one end of the political spectrum, something approaching democratic socialism is finding favor; not just among a growing number of congressional members but also a generation of young people and a surprising number of middle-aged voters. On the other end, conservatives are moving even further to the right.

As a practical matter, trade organizations representing the broader aviation community should consider the Green New Deal a disquieting wake-up call to be ignored at the industry’s peril. For those who think the proposal or some version—with aviation squarely in the crosshairs—is too outlandish to ever happen, think again. For better or worse, a change in administrations cannot be ruled out in 2020, and if that occurs it will be game on.

Moreover, it would not be the first time an aviation/aerospace sector allowed itself to be blindsided out of hubris or miscalculation. The most recent example is the sequester used in the Budget Control Act of 2011 to encourage Congress to reduce the annual deficit. Just the prospect seemed so potentially harmful to U.S. national security that few people—least of all aerospace leadership—thought the draconian concept would ever become policy.

Similarly, the U.S. space program was at its pinnacle in 1969 when NASA, partnered with the aerospace industry, landed humans on the Moon and safely returned them to Earth. The momentum seemed unstoppable—except that the pioneering initiative lost its luster for then-President Richard Nixon and many other Americans, and within five years of Neil Armstrong’s “one small step” the Apollo program was canceled.

Aviation—indeed, the broader aerospace industry—has been taking its success for granted for years and still is, with little or no regard for whether the nation as a whole is knowledgeable about the contribution of both segments to the country’s overall prosperity. For its part, industry leadership, such as it is, seems incapable of looking beyond the near term, content with token efforts to educate selective fickle audiences.

And so, for at least the third time in the last 50 years, there are unmistakable signs that aviation and aerospace yet again are approaching a potentially course-altering crossroads. As pressure grows for commercial aviation to play a bigger role in reducing carbon emissions, the industry needs to be less insular and more strategic. It must develop a bold, sustained messaging campaign suitable for the broadest possible audience on why it cannot be taken for granted. The stakes are too high to ignore.

Anthony L. Velocci, Jr., was editor-in-chief of Aviation Week & Space Technology from 2003 to 2012.
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