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Airbus, Boeing and L3Harris

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MISSILE DEFENSE

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INTERVIEWS

ON THE COVER

Aviation Week's Flight Paths Forward series continues with deep dives into the futures of Boeing, Airbus, Embraer, Mitsubishi, the aerospace supply chain and, in defense, the F-35 program. The articles and accompanying CEO interviews run throughout this issue, beginning on page 26. Aircraft photo by Adrian Dennis/AFP/Getty Images; background photo by Patrick Cooper/Getty Images.

Aviation Week publishes a digital edition every week. Read it at **AviationWeek.com/AWST**

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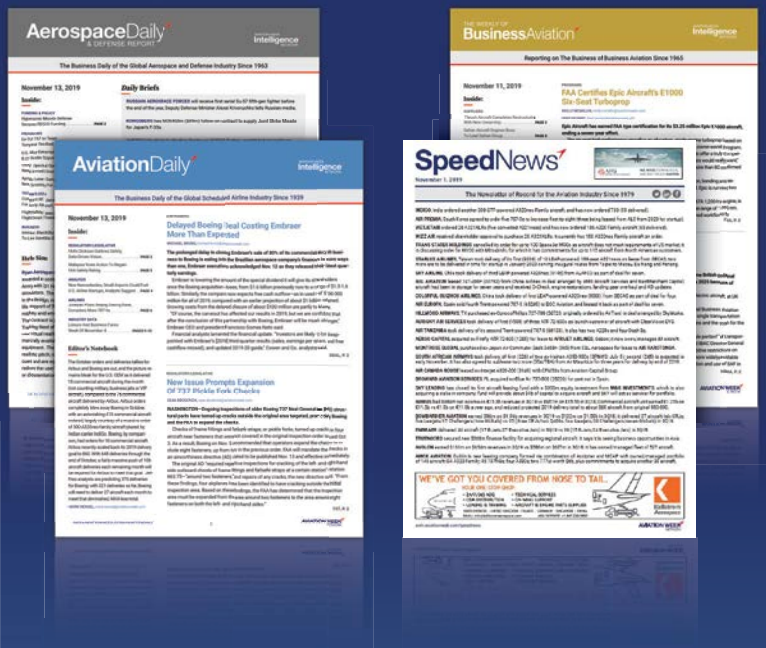
BEHIND THE SCENES

Marooned at home and deprived of air shows—including July's canceled Farnborough and EAA AirVenture Oshkosh events—John Morris, the longtime editor of Aviation Week's *ShowNews*, had extra time to complete a special project he had been working on for 15 years. In July, Morris took to the skies for the first time in his homebuilt biplane at Goodspeed Airport (42B) on the banks of the Connecticut River. The Staaken Flitzer Z-21, a 1924-technology wood-and-fabric biplane, was constructed using 33 pages of plans and a pile of wood and is powered by a German 80-hp AeroVee VW engine. "It was an immense thrill to fly the Flitzer after all those years of building it," proclaimed "Baron" Morris, who closed out the month as the recipient of the Aerospace Media Awards Lifetime Achievement honor (page 8).

MAUREEN SPUHLER PHOTOS



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FEEDBACK

THE HYDROGEN ECONOMY

In the early 1970s, faced with the ending of the Apollo program, we at Rocketdyne (now Aerojet-Rocketdyne) considered other markets for our technology, such as application of hydrogen turbines as used on the J-2 rocket engine. In response to oil embargoes and eventual oil-field depletion, we proposed moving to what we called "The Hydrogen Economy." We faced most of the problems of infrastructure, storage, safe handling, cost, supply and wide-scale distribution noted in your articles "Into the Hydrogen Future" and "Europe Focuses on Aircraft Powered by Hydrogen" *(June 29-July 12, pp. 16 and 19, respectively)*.

We received funding from the Department of Transportation to study hydrogen-powered trains, ships, buses and trucks, all of which had relatively centralized fueling and limited exposure to the general public. With oil supplies increasing and exhaust pollution somewhat alleviated by better mileage and catalytic converters, the drivers for change became less urgent and the project was abandoned.

At the time, the advantage of having no carbon dioxide emissions was not recognized widely, even though one of our selling points was that you could safely drink the exhaust product (water) once cooled. With advances in technology like more efficient fuel cells and a more urgent need, perhaps after 50 years the future of the hydrogen economy has arrived.

Stephen A. Evans, Foothill Ranch, California

The articles on hydrogen-powered aircraft were interesting for showing the scope of the research projects. The question of the ultimate benefit derived from that fuel is its eventual source. Right now, 95% of hydrogen produced in the U.S. is from steam-reforming of natural gas. That is an endothermic process, so the net energy derived is not 1:1 from the natural gas input. Beyond that, both carbon monoxide and carbon dioxide (to a much lesser extent) are produced and have to be captured.

In the U.S., we are blessed with an abundance of natural gas (methane) and oil; countries like Germany either have to use the natural gas imported

H2FLY

from Russia (already a security risk) or go the coal-gasification route, which will produce even more CO/CO_2 as the carbon-to-hydrogen ratio is much higher in coal. Bituminous coals have a carbon-to-hydrogen ratio between 14 and 17, and most anthracites have a ratio between 24 and 29, whereas methane is 0.25.

Granted that the goal is to have solar or other renewable (or nuclear) energies produce hydrogen from water via electrolysis, but near-term sources of renewable energy are focused on removing coal and oil from the electricity production system. The ability to use them for hydrogen production at a scale and cost factor to provide a competitive fuel is probably well off in the future.

Raymond F. Maddalone, Fishers, Indiana

FOR FLIP-FLOPPING

In "Boeing's Bank Is Back" *(June 29-July 12, p. 13)*, Michael Bruno praises President Donald Trump's flip-flopping and states that "Trump is right on the money."

Bruno refers to likely objections by "bank haters" and "antibank academics" but argues that the U.S. Export-Import Bank's new insurance coverage that would support jobs at Boeing, General Electric and their suppliers is "the right thing to do."

I wonder what Bruno thinks of the Glass-Steagall Act, 2017 tax cuts or Black Lives Matter. (I have faint hope that the Black Lives Matter protests might do something about racial and income inequality in our country.)

Thank you for praising Trump's flip-flopping, which in turn might encourage him to flip-flop on the COVID-19 pandemic. He might actually flop over to recommending masks, contact tracing and social distancing to lead us out of this mess.

A.T. Jensen, Auburn, Washington

'NOW WE HAVE TO THINK'

"The Next Bomber?" *(June 15-28, p. 12)* examined arsenal plane tradeoffs, suggesting C-130s or C-17s as candidates. But these aircraft would be highly tasked, especially in wartime. "Megafortress" *(June 29-July 12, p. 6)* touted the venerable B-52 as a de facto candidate for the mission. However, a better choice would be the surplus Boeing 747-400 airliner fleet currently being retired from passenger service.

The 747-400s could be easily modified to carry very heavy loads of conventional cruise missiles, hypersonic and ballistic missiles as well as kinetic weapons for self-protection. Airborne lasers might also be installed in the future. These aircraft, with their standoff capabilities, could address major problems posed by long-range air defense missiles and increasingly anti-stealth capabilities that threaten current and future manned penetrating platforms, including the very expensive B-21.

Arsenal aircraft would need to be modified to be air-refuelable and might also carry equipment to refuel escorting fighters. Off-the-shelf equipment like the E-7 Wedgetail AEW&C radars and weapons bays similar to those on P-8 ASW 737s could be installed.

Such aircraft should be ideal for the Pentagon's "Pacific Pivot," including needed top cover for the Navy's carrier battle groups. Because of their long range/endurance, they would have more persistence than F-18s, F-35s or F-22s.

Used 747s have been readily adopted for other missions (e.g., water bombers, satellite launchers, etc.), because they are inexpensive, capable and reliable. These platforms would offer a lot of "bang for the buck." Pentagon and congressional planners should remember Winston Churchill's adage: "Gentlemen, we have run out of money; now we have to think."

Alan E. Diehl, Albuquerque, New Mexico

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WHO'S WHERE

Daniele Misani has been promoted to CEO of *TXT*, where he has held senior management positions, principally in the Aerospace and Aviation division. He succeeds Enrico Magni, who will stay on as board chairman. TXT produces specialized software for aerospace and defense and other critical industries.

Virgin Galactic has hired **Michael Colglazier** as CEO of commercial service. Colglazier had worked at Walt Disney Co. He succeeds **George Whitesides**, who has been promoted to chief space officer, overseeing orbital spaceflight programs.

Air BP has promoted **Martin Thomsen** to CEO. He succeeds Jon Platt, who will retire. Martin has held several positions with BP including fuels general manager.

Carl Novello has been hired as *Nxtcomm* chief technology officer, overseeing engineering, design and development of electronically steered antennas. He was vice president at Kymeta and before that was with Intellian Technologies, Panasonic, Harris Corp. and Comsat.

New unmanned air mobility company *AcceleratUM* has named **Brett Feddersen** president. He was FAA leader of national security, incident response and unmanned aircraft system (UAS) security systems. AcceleratUM was co-founded by Lessing Stern, chairman; Michael Huerta, former FAA administrator; Jim Williams, former FAA director of UAS integration; and Ben Rifkin, CEO of Ten Eighty Capital.

The Aerospace Corp. has hired **David Radzanowski** as chief financial officer. He succeeds Ellen Beatty, who has left. He was Equator Corp. leader of strategic business functions for Australia's future submarine program and before that NASA chief financial officer and chief of staff for then-Administrator Charles Bolden.

Becky Yoder has joined *Astroscale U.S.* as senior vice president of finance and business operations. Yoder was director of operations for the Orbital Technologies group at General Atomics Electromagnetic Systems.

Charles Clancy has been promoted to senior vice president, chief futurist and general manager of *MITRE Labs*, established by MITRE Corp. in restructuring its research and development capabilities. Clancy was MITRE Corp. intelligence programs vice president. In addition, **John Wilson** has been promoted to MITRE Labs vice president and chief information and security officer from MITRE Corp. vice president of technical centers, and **Christina Orfanos** has been promoted to MITRE Labs vice president of talent experience and total rewards from MITRE Corp. talent strategy and integration director.

LinQuest Corp., a provider of space systems technology for the U.S. defense and intelligence communities, has hired **Ronald Gembarosky** as senior vice president and chief security officer. He was chief security officer at Science Applications International.

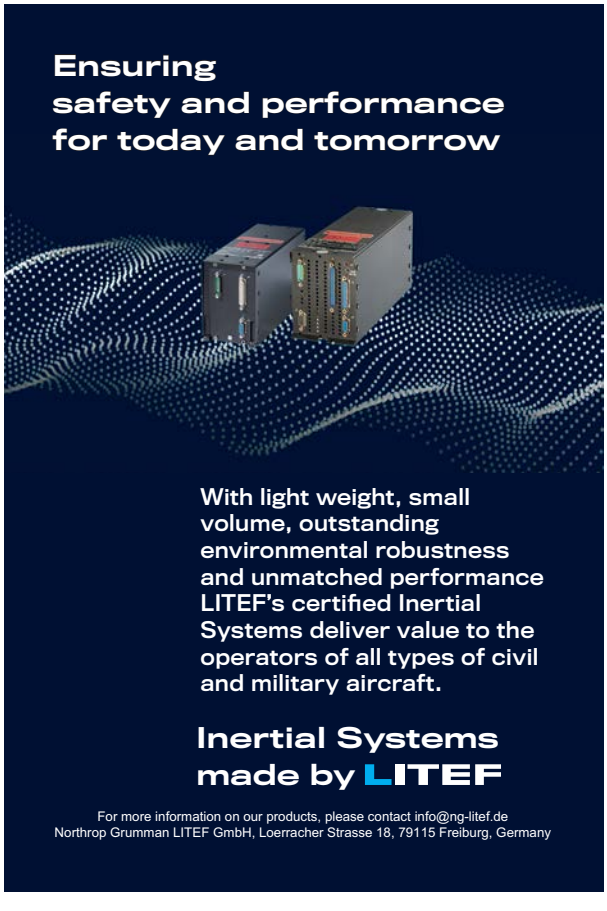
Triman Industries, an AE Industrial Partners subsidiary, has hired **Dan Edwards** as president and **Eugene Mamajek** as vice president of business development and strategy. Edwards was vice president of operations at MAG Aerospace, and Mamajek was executive director of avionics systems at Esterline Technologies Corp.

Karen Feaster has been appointed director of *Daytona Beach International Airport*. Feaster was deputy airport director for the past five years of her 28-year Daytona tenure, which began as a volunteer internship.

Vertical Aerospace has appointed **Eric Samson** as head of engineering of the electric flight organization. He was vice president of engineering and head of design at Jet Aviation.

Caerdav has hired **Richard Pitts-Robinson** as business development manager and **Gary Munro** as commercial executive. Pitts-Robinson was head of commercial sales at Flybe Aviation Services; Munro was a sales executive at Porsche.

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



FIRST TAKE

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LEONARDO

DEFENSE

A Leonardo prototype M346 Light Fighter Family of Aircraft, which is equipped with a mechanically scanning, multimode Grifo radar, made its first flight on July 13.

Europe's new Multinational Multi-Role Tanker Transport Unit will fly its first aerial refueling training missions in August to support NATO combat aircraft.

Eight Lockheed Martin F-35As ordered by Turkey will instead be modified and delivered to the U.S. Air Force under an $862 million contract (page 52).

Rolls-Royce will supply the engines and infrared suppression system for the Bell V-280 tiltrotor proposal to the U.S. Army for the Future Long-Range Assault Aircraft program.

Germany plans to purchase three Bombardier Global 6000 business jets for its signals-intelligence mission, after canceling efforts to purchase the Eurohawk derivative of the Northrop Grumman Global Hawk UAV.

COMMERCIAL AVIATION

U.S. airline passenger traffic has plateaued at 20-25% of 2019's level, signaling that a new surge in U.S. COVID-19 cases is choking off a recovery. American Airlines, International Airlines Group, Lufthansa and United Airlines urged the EU and U.S. governments to introduce a common coronavirus test program that would allow airlines to accelerate the restoration of transatlantic flights.

Boeing's 737 MAX backlog could decline another 10% due to soft demand and the fragile health of airlines, according to a new Canaccord Genuity forecast (page 32).

JOEPRIESAVIATION.NET

British Airways will retire its remaining 31 Boeing 747s after operating the aircraft type for almost 50 years.

American Airlines warned that it will have to furlough 25,000 workers—20% of its staff—unless U.S. government payroll support is extended beyond Sept. 30, following United Airlines, which is projecting 36,000 layoffs.

SPACE

The launch of the James Webb Space Telescope, a successor to the Hubble observatory, is being postponed at least seven months, largely due to pandemic-related workplace shutdowns.

20 YEARS AGO IN AVIATION WEEK

Airbus and Boeing announced $30 billion worth of orders at the 2000 Farnborough Airshow, but the event was overshadowed by tragedy when an Air France supersonic Concorde burst into flames and crashed as it took off from Paris Charles de Gaulle International Airport on July 25, killing all 109 passengers and crew and four people on the ground. Pierre Sparaco, who led Aviation Week's commercial aviation coverage in Europe, rushed back to his hotel in London to cover the accident and was not seen again at the show. He led Aviation Week's initial five-page report on the accident, which was coauthored by Transport Editor Frances Fiorino and Senior Engineering Editor Michael A. Dornheim.

WORLD NEWS & ANALYSIS

Concorde Troubles Began On Takeoff Roll

PIERRE SPARACO, FRANCES FIORINO and MICHAEL A. DORNHEIM

Investigators focus on dual engine loss tied to tire failure and large fire during takeoff

CONCORDE SUPERSONIC TRANSPORT SPECIFICATIONS

The reporting was particularly painful for Sparaco, a veteran Paris-based aviation journalist who had covered the program from its very beginnings in the early 1960s through development, flight testing and service entry. French accident investigators ultimately blamed the fire and crash on runway debris struck by the aircraft as it took off, as well as the vulnerability of its design. Sparaco died in 2015. The last of his many books was a biography of Andre Turcat, who had piloted Concorde's first flight.

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

F-35 Deliveries: The Decade Ahead

	Actual	Projected										
	2011-July 16 2020	July 17-Dec. 31 2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Country Totals
Australia	26	7	15	15	9								**72**
Belgium					4	4	4	4	4	4	5	5	**34**
Denmark			4	6	7	4	3	3					**27**
Greece											4	8	**12**
Israel	24	6	6	6	6	5	9		8	8			**78**
Italy	15	3	4	7	13	14	9	11	10	4			**90**
Japan	18	4	6	9	15	12	15	16	16	12	12	12	**147**
Netherlands	12	6	8	8	2	4	6	7	7	7			**67**
Norway	25	3	6	6	6	6							**52**
Poland						4	6	6		4	6	6	**32**
Singapore								4	4	4			**12**
South Korea	24	4	12								10	10	**60**
Turkey*	6												**6**
UK	18	3	6	8	7	6	6	6	12	12	12	12	**108**
U.S.	379	55	99	102	104	109	107	106	107	110	110	110	**1,498**
Totals	**547**	**91**	**166**	**167**	**173**	**168**	**165**	**163**	**168**	**165**	**159**	**163**	**2,295**

* Six F-35s to be delivered to Turkey through 2019 were withheld as a result of Ankara's acquisition of the S-400 and will instead be delivered to the U.S. Air Force.

Source: Aviation Week Military Fleet Discovery Database. Prepared by Michael Tint

Aviation Week's Military Fleet Data team assessed the number of Lockheed Martin F-35s likely to be delivered, based on statements by nations that have declared they will buy the aircraft. It does not include ongoing competitions. For more information about the F-35 program, see page 52.

To learn about our fleet data products and services, go to: **AviationWeek.com/products/fleet-discovery-military**

The United Arab Emirates' first interplanetary spacecraft began a seven-month journey to Mars on July 20 following a successful launch aboard a Mitsubishi Heavy Industries H-IIA rocket from the Tanegashima Space Center in Japan.

The British government has signed a long-awaited contract with Airbus for the next-generation Skynet 6A communications satellite, scheduled to launch in 2025.

A Long March 5 rocket launched the first all-Chinese mission to Mars on July 23, placing the 5-metric-ton Tianwen 1 spacecraft into an Earth-Mars transfer orbit. Tianwen 1 is due to arrive at Mars in seven months, with a lander carrying a rover scheduled to descend to the surface 2-3 months later.

GENERAL AVIATION

Business aviation moved toward normal in late June, with small jet and turboprop utilization back to pre-COVID-19 levels and medium jet activity nearing normal rates, according to Aviation Week's Intelligence and Data Services. But large cabin jet activity continues to lag.

AVIATION WEEK WINS AEROSPACE MEDIA AWARDS

The Aviation Week Network has won five 2020 Aerospace Media Awards. Senior Air Transport and Safety Editor **Sean Broderick** was named Aerospace Reporter of the Year for his coverage of the Boeing 737 MAX crisis in *Aviation Week & Space Technology* and *Aviation Daily*. France Bureau Chief **Thierry Dubois** won Best Propulsion Submission for an *Aviation Week & Space Technology* article on how propeller manufacturers are aiming for technology improvements. **Victoria Moores**, *Air Transport World*'s European bureau chief, won Best MRO Submission for an article on how to plan for the unpredictability of lease returns that was published in *Inside MRO*. Freelance photographer **Mark Wagner** won Best Aviation Image for a photo of the Chinese J-10 fighter team (right) that appeared in *ShowNews*. And **John Morris**, the editor-in-chief of *ShowNews* since 1994, was honored with a Lifetime Achievement Award for his 50 years as a journalist. This year's award winners were announced virtually in an online presentation from London on July 21.


MARK WAGNER/SHOWNEWS

UP FRONT
KEVIN MICHAELS

WHAT A DIFFERENCE A YEAR MAKES. In March 2019, Boeing was on top of the world, boasting an eight-year order backlog and a market capitalization of $240 billion. Today, it is at a structural disadvantage versus Airbus, with its share price diminished as it grapples with the worst crisis of the jetliner era. Some observers are beginning to doubt that it can hold up its end of the airliner production duopoly.

CEO Dave Calhoun is just 21 months from his mandated retirement age, and his honeymoon as a new leader is running out. Will he be a transitional leader, or take risks to reposition the company for long-term success? I believe he can be a transformational leader by pursuing a bold five-part strategy.

Rebooting Boeing

A **five-part strategy** for CEO Dave Calhoun

❶ Launch a moonshot. Boeing's product positioning issues are well-known and need to be addressed sooner rather than later despite the COVID-19 crisis. The company's top priority is, of course, recertification of the 737 MAX. Shortly thereafter, it must launch a white-sheet program to address its competitiveness issue versus the Airbus A321neo. This will boost the morale of Boeing stakeholders—employees, customers, and suppliers—and signal that it wants to move past the 737 MAX disaster, regain industry leadership and invest in promising new digital design and production technologies.

❷ Recalibrate the vertical integration strategy. Boeing went too far in outsourcing on the 787, and now it looks like it is taking on too much insourcing. Some vertical integration initiatives do make sense, including interiors, composite wings and avionics, but several others are marginal. Can Boeing, for example, really create lasting customer value in auxiliary power units through its joint venture with Safran? The timing of this move is ironic given the fact that this could be the last generation of jetliners using APUs. It is on a path to convert variable costs into fixed costs, which does not bode well in a prolonged industry downturn.

Airbus acknowledged this reality by recently abandoning its vertical integration initiative on nacelles for the A320neo and awarding the package to Collins Aerospace. Funds used for misguided vertical integration moves would be better deployed pursuing the next commercial moonshot or, on the military side, a sixth-generation fighter.

❸ Kill the Partnering for Success (PFS) program, one of the company's biggest mistakes of the last decade. PFS is not only a silly name, it puts its suppliers—responsible for 65-70% of its cost structure—in the untenable position of earning inadequate profit margins, which reduces their ability to invest in the future. This does not mean that Boeing abandons its pressure on suppliers to improve productivity, delivery and quality; nor does it mean that it should not seek to grow aftermarket royalties.

By ending PFS, Boeing could change its supplier payment terms from 90 days to 60 days to inject needed working capital and improve supplier viability in the COVID-19 crisis. It could also revise its draconian termination for convenience clauses and intellectual property ownership demands. Nothing would do more to restore supplier confidence than Boeing burying PFS. The timing is perfect.

BOEING

❹ Jettison the unrealistic goal of $50 billion in services revenue. It is an arbitrary target, and there is not enough maintenance, repair and overhaul white space for the goal to be tenable, given Boeing's current services revenue of $18.4 billion. It contributes to supplier mistrust and distracts from the core mission of developing, producing and supporting great aircraft.

Boeing should still pursue services growth, but in a measured manner and in areas where it creates genuine customer value—including parts distribution, training, digital services, military sustainment and modifications. Otherwise, it is destined to make major mistakes—including bad acquisitions or launching unprofitable services—in the pursuit of a quixotic goal.

❺ Continue to restructure the board of directors. Most of the current board members approved decisions that led to Boeing's decline and pursuit of financial engineering in lieu of long-term competitiveness. The 737 MAX crisis demonstrates that the board was heavy on political influence and light on technical expertise.

Boeing has begun to address some of these shortcomings with the appointment of three new directors since 2019. It would do well to continue the housecleaning to create a credible counterbalance to the CEO and the wisdom to guide it back to jetliner parity.

This five-part strategy will likely receive blowback from Wall Street. But that is precisely the point. For far too long, Boeing took its eye off the ball to chase share-price inflation. Dave Calhoun has a golden opportunity to reboot and revitalize Boeing in his remaining 21 months and create a legacy as one of its most consequential leaders.

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

GOING CONCERNS
MICHAEL BRUNO

ANYONE LOOKING FOR A JOB IN the aerospace and defense sector should check out TheLayoff.com. While anonymous tipsters on the site can be crude, vitriolic and frequently motivated by agendas, the chat board as a whole provides incomparable insight into a company's workforce reputation, especially as many aerospace and defense (A&D) companies cut employees due to the downturn from COVID-19.

Unfortunately, there is a lot of fodder to peruse these days. Tens of thousands of layoffs—not furloughs, but permanent reductions—have come since spring. From GE Aviation and TransDigm Group cutting 25% of their workforces to Airbus and Boeing letting go of 10% to Bombardier and Triumph Group axing thousands, the manufacturing side is fighting to save capital, and targeting head count is common.

Separately, airlines may be in even worse shape; their employees are dreading the end of September, when federal aid stipulations are set to expire. United Airlines in July started notifying 36,000 front-line employees about potential involuntary cuts, setting the stage for a downsizing of as much as 45% of its workforce this fall.

It is easy to predict that more than 100,000 positions will disappear from the A&D industry over the next two years. Whether it is to conserve cash in the face of exigent liquidity concerns or because of marketplace changes in the wake of COVID-19, several realities are driving workforce cuts. What makes their sting more painful is that they come on the heels of pronounced efforts to hire more workers in the last half of the past decade when all sides of A&D envisioned growth.

According to the Aerospace Industries Association, the A&D industry supported roughly 2.5 million jobs in 2018, the last full year of data. That included 881,000 direct jobs and another 1.6 million in the supply chain, which often serves multiple industries.

But 2018 could serve as the high-water mark. Long before the COVID-19 pandemic and even before the Boeing 737 MAX was grounded and production halted this year, industry was consolidating at a rapid pace. In April, Raytheon and United Technologies Corp. consummated their merger, following L3 Technologies and Harris Corp. a year ago. The supply chain has experienced similar combinations, from large takeovers such as TransDigm Group buying Esterline Technologies to countless private equity-funded rollups.

Industry Downsizing

Yet again, but **it can change** its reputation

GE AVIATION

"Likely the most discussed trend, evidenced by both the quantity and deal value of mergers announced in 2019, is the race for scale throughout the supply chain," mergers and acquisitions advisor Mesirow Financial said in March. "And 2019 more than doubled 2018's announced deal value."

Each deal brings further workforce reductions. Managers look to take out costs, starting with back-office functions and then deciding which business segments to cleave off as leaders focus on their core business portfolios. Deal-making is expected to pick up with a vengeance in the second half of this year as more distressed assets come onto the market, according to several consultants.

Meanwhile, industry is likely to adopt digitalization aggressively after COVID-19, meaning more robotics, automation and artificial intelligence. "The new normal is going to be different, and I think automation is going to be a big factor," says Hawk Carlisle, CEO and president of the National Defense Industrial Association.

Not every corner of A&D will see redundancies. Niches such as aircraft maintenance, data science, digital-design engineering and classified work requiring security clearances still could struggle to fill openings. But as a whole, A&D may be home to fewer workers for years.

With plenty of living memory of past downturns after the Cold War ended, 9/11 and 2013 federal budget sequestration cuts when A&D companies went out of business or let go droves of workers, the current wave will do no favors for the sector. Perhaps that is unavoidable. But beyond treating laid-off workers fairly as they exit, A&D companies can do something else to salvage their reputations for future candidates.

"For core functions, companies will need to launch targeted and intentional upskilling programs—not as one-time initiatives but as part of a sustained culture change that adopts new ways of learning to keep pace with technological change," argues PwC Global A&D Leader Glenn Brady. "Now is also a prime opportunity to improve noncore employees' digital fitness—for example, upskilling in digital technologies that introduce data modeling, design thinking and automation."

A&D may not be able to combat its repeated history of shedding workers, but it would do itself a lot of good if it embraced retraining of those it keeps and enhancing their skills. Just imagine this post on TheLayoff.com: "Yes, they let me go, but I'd go back."

INSIDE BUSINESS AVIATION
WILLIAM GARVEY

HE CLAIMS TO BE THE FIRST Canadian iPhone owner and the first to put a Tesla 6 on Vancouver roads. "I really like new, innovative technology," says Greg McDougall (at left below). "I'm an early adopter."

Meanwhile, Dan Wolf's (at right below) concerns about emissions damaging his coastal habitat led him to install enough solar panels on his outfit's roofs to more than satisfy its electrical needs. And he has signed a memorandum of understanding (MOU) to buy wind-generated electricity for future consumption.

The two forward-leaners have shared histories, interests and vision. Both are pilots with thousands of flight hours logged. Each founded and leads a successful regional airline—McDougall's Vancouver-based Harbour Air Seaplanes and Wolf's Cape Air in Massachusetts and beyond—and, notably, they so believe aviation's future will cruise cleanly and profitably on kilowatts, they are committing to electric flight.

McDougall was intrigued with the numerous projects underway globally to bring electric propulsion to aviation. Although many efforts were in early development, he became convinced the technology's promise of dramatically lower maintenance and energy costs combined with zero emissions is what commercial aviation needs.

So sure was he that upon his induction into Canada's Aviation Hall of Fame last year, he told the gala audience the honor was premature since his company's singular achievement would be its adoption of electric propulsion. He recalls the diners reacting with "disbelief, ridicule, all kinds of things."

Undeterred, he became a vocal advocate of electrification, and his word traveled. Presently, he got a call from Roei Ganzarski, CEO of MagniX, a young company developing electric aircraft motors that recently established headquarters in Seattle. Days later, the two met for coffee and before a refill had agreed to collaborate.

McDougall envisioned refitting Harbour Air's 22 workhorse de Havilland Canada DHC-3 Otter floatplanes with electric power. Years earlier, he had pioneered replacing the de Havillands' radials with Pratt & Whitney PT-6s. Now, those turboprops would give way to MagniX's 750-hp (560-kW) Magni500 motors.

Similarly, Wolf was evaluating which electric-aviation projects had the best chance of commercial success. He finally settled upon Eviation, a MagniX sibling developing "Alice"—an all-composite, nine-passenger aircraft that is propelled by three tail- and wing-tip-mounted pusher props, all turned by three 375-shp (280-kW) Magni250 systems. He believes designing an aircraft around electric power from the outset results in a more efficient and better performing platform than applying such a system to an airframe initially fitted with an internal-combustion engine.

Moreover, Wolf is no stranger to developing aircraft. Knowing that Cape Air's fleet of pampered Cessna 402Cs was nearing retirement, and unable to entice any U.S. manufacturer to build a replacement for them, the carrier worked with Italy's eager Tecnam in the design, systems selection and outfitting of the P2012 Traveller, which the FAA certified last year. Cape Air already has 11 of the unpressurized, 9-10-passenger piston twins in service, expects 20 to be delivered this year and has options on an additional 92. Wolf sees Alice and Traveller as complementary and thinks an electric version of the latter could eventuate.

eFly Fellows

A 15-min. **change of course** for aviation?

HARBOUR AIR

CAPE AIR

On Dec. 10, 2019, McDougall was first to put the shared vision to flight when he ascended from Harbour Air's Fraser River terminal in a company de Havilland DHC-2 Beaver fitted with a Magni500, making good on his Hall of Fame prediction. "Today, we made history," he said, calling the flight of the commercial, six-passenger "ePlane" an "incredible world-class milestone."

That first flight lasted just 15 min. as a result of the low-density batteries used. However, McDougall believes that thanks to the ongoing improvements in battery technology, once his eOtters are operating in about two years, they should have performance and payloads similar to today's and enough duration to satisfy Harbour Air's network. The majority of the carrier's flights average about 28 min. The battery will be recharged at each destination with 1 min. of charge equal to 1 min. of flight time.

Harbour Air plans to obtain and own the supplemental type certificate for the installation.

As for Alice, its first flight was scrubbed this past January when a fire during ground-testing in Arizona damaged the prototype beyond repair. A replacement is in the works. Unconcerned, Wolf stands by his MOU to put the first 15 trimotors into service. He describes Alice as "an amazing piece of technology," which he expects to have in Cape Air livery in three or four years.

Meanwhile, early adopter McDougall says he is thrilled to be "pioneering something dramatically new in aviation."

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

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Steve Trimble Washington

In piecing together a delicate plan to field two advanced rotorcraft simultaneously within a decade, the U.S. Army chose its priorities carefully.

The Army could load the first Future Long-Range Assault Aircraft (FLRAA) and Future Attack Reconnaissance Aircraft (FARA) with advanced new systems and weapons needed for operations in the 2030s or keep to existing or highly mature technologies and field both aircraft years earlier.

Ultimately, the Army selected an acquisition strategy based on the latter. Increment 1 versions of the FLRAA and FARA are now scheduled to enter service together in the third quarter of fiscal 2030. More advanced Increment 2 versions of both should enter service in 2034 and 2035, respectively.

But the key to fielding both increments for each new type on time may depend less on rotor systems and drivetrains than on software architecture and resolving industry concerns about government demands for data rights.

In a series of briefings to defense contractors the week of July 13, Army leaders laid out a vision for using the FLRAA and FARA contracts to change the aviation branch's relationship with suppliers. The Army is seeking to make the aircraft and mission systems installed on both as common as possible, with a modular open-systems architecture (MOSA) allowing the service to rapidly upgrade payloads, subsystems and design rights, thereby enabling a perpetual cycle of competitive bidding.

"If it's not affordable, they're walking away from it."

Although the Army's commitment to the new industrial model was clear, the service's acquisition leaders acknowledged that such a strategy will force companies at all levels of the supply chain to adopt a new, unproven business model.

"Most of you are thinking, 'OK, a modular systems approach is a nice buzz term, but how do I sell that to a board of directors; how do I sell it to the [company] leadership?' Because I can potentially give up all of the future revenue streams," says Pat Mason, the program executive officer for Army aviation. "So we owe you greater answers on that, because it's the question that you're asking, and we have to understand your perspective. From that, we then have to develop a clear business case that allows you to move forward."

In purely aircraft performance terms, the FLRAA and FARA requirements do not compromise on performance. Any of the four candidates selected by the Army in March to compete for both contracts—Bell's V-280 and Boeing/Sikorsky's SB-1 for the FLRAA; Bell's 360 Invictus and Sikorsky's Raider X for the FARA—would enter service in 2030 exceeding the 170-kt. speed limit for most conventional helicopters.

Mission systems and aircraft systems will be isolated from each other in the Future Attack Reconnaissance Aircraft, with bidders narrowed to the Bell 360 (top) and Sikorsky Raider X.

But despite appearances, speed is not everything in the Future Vertical Lift (FVL) program that spawned the FLRAA and FARA contract competitions.

The FVL initiative is seeking to introduce a revolutionary leap in how the Army acquires the evolving array of software, electronics, sensors and weapons that come with an aircraft and represent an increasingly important share of its overall capability.

With schedule and cost driving the acquisition strategy, the Army will seek to deliver the FARA and FLRAA with as many common electronic systems and payloads as possible, along with a MOSA for software. To minimize schedule and cost risk, FARA and FLRAA aircraft entering service in 2030 will be designed with electronics and systems already available or due to reach a high level of maturity by 2024.

More advanced systems capabilities still at the laboratory stage mid-decade will be considered for Increment 2 versions of both types. The Increment 2 version of the FLRAA is scheduled for delivery in fiscal 2034. A year later, the FARA program plans to field an Increment 2 version. Limiting development activity during Increment 1 to the airframe is the Army's goal.

"One of the key things we're trying to do with Increment 1 is get the 'truck' right—the vehicle," says Jason Lucas, the Army's FLRAA technical division chief. "We need to get us an air vehicle platform that can take us into the future. The other thing that we absolutely have to get right is our architecture, and our modular open-system approach to enable us to integrate advanced technologies [and] keep up with the pace of threats.

Eurofighter needs faster planning **p. 51** Japan's accelerates F-X timeline **p. 57**

IONS

> U.S. ARMY FVL VISION: COMPETITION, OPEN SYSTEMS AND INCREMENTAL UPGRADES

> EMPTY WEIGHT AND COSTS EMERGE AS EARLY CONCERNS

An Increment 2 version of the Future Long-Range Assault Aircraft should arrive about four years after either the Sikorsky/Boeing SB-1 (top) or Bell V-280 enters service in 2030.

FARA/FLRAA Potential Common Systems

Communications	Navigation	Aircraft Survivability Equipment	Sensors	Other
Radios	GPS	Infrared and radio-frequency countermeasures	Degraded visual environment	Launcher
Link 16	Digital map	Missile warning	Pilotage/ targeting	Air-launched effects
Advanced networking	Obstacle awareness	Radar warning	Radar	Mission computers
Advanced teaming	Assured precision, navigation and timing	Laser warning	Helmet-mounted display	Digital backbone
Identification	Autonomy	Expendables	Health monitoring	Operating environment

Source: U.S. Army

"One of the things you didn't hear me say is that we need to develop a lot of advanced mission system equipment, a lot of new development" in Increment 1, Lucas adds. "We are going to take existing mission equipment."

The Army's risk-averse approach comes after decades of frustration over new aircraft development. Three failed attempts to field a scout helicopter to perform a mission similar to FARA's weigh on current program leaders. Col. Gregory Fortier, FARA project manager, notes that as a younger officer he had been told to expect an assignment in a Sikorsky/Boeing RAH-66 squadron, a Bell ARH-70 squadron and an Armed Aerial Scout test squadron.

"As we know, those three did not come to fruition," Fortier says, adding that avoiding a fourth program failure requires having "critical and difficult conversations" with industry up front.

Such discussions came up during the industry day event. As a possible consequence of relying on existing maturing systems and payloads for the Increment 1 versions of the FARA and FLRAA, Army program managers are growing concerned about aircraft weight estimates.

"I'm still seeing very heavy empty weights across our air vehicles, which I don't enjoy," says Brig. Gen. Walter Rugen, director of the Army's FVL cross-functional team.

FLRAA and FARA technology "should be lighter and lower-cost," he says. "You all may say I'm asking for the impossible, but I think it's nuanced. At the end of the day, we're in a hypercompetitive environment with budgets, and if we don't bring things in that are leap-ahead and fully capture the deflationary nature of the technology and get lighter and cheaper, I think we may find ourselves on the outside looking in."

Another difficult conversation inside the programs concerns the Army's plan to demand ownership of more of the intellectual property and data rights for technologies installed in the aircraft. As each of the armed services seeks a greater share of the ownership rights on future weapon systems, the defense industry is being forced to adapt to a new paradigm in the government-industry relationship.

"We realize this runs contrary to some of the legacy business models, such as, 'Here's a box. We want to integrate it and then we want to sustain it for 30 years,'" says Michael "Ski" Horrocks, integration project manager for FLRAA and FARA mission systems. "So we do have teams working right now brainstorming how to create new collaborative and sustainable business models."

The in-service date for the FLRAA and FARA may be a decade away, but the Army is already facing critical decision points by year-end. The most important is creation of the FVL Architecture Framework (FAF) to define the interfaces and standards for the common mission systems architecture of both. Last year, the Army stood up a body composed of military, industry and academic experts called the Architecture Control Working Group to deliver the FAF by November 2020 for scheduled approval the following month.

"We see Increment 2 as an opportunity to provide advanced mission system solutions to help tackle some of the most significant threats and integrate some innovation," Lucas says.

The Army's schedule calls for selecting the FLRAA developer in fiscal 2023 and the FARA prime contractor in fiscal 2024, with limited user tests of production aircraft beginning for each program four years later. But a lesson from the Army's painful experience with new aircraft development suggests little tolerance for costly technology, even if the contractors can deliver better performance.

"We can develop and design and deliver this tremendous capability at the end of this fiscal 2028 timeframe," Fortier says. "But if it's not affordable, they're walking away from it."

Is There Another Contender for Drone Industry Dominance?

> SKYDIO WINS PENTAGON INFRASTRUCTURE INVESTMENT

> AFTER DJI MODELS, LOCAL AGENCIES FAVOR SKYDIO 2

Bill Carey Washington

An initially consumer-oriented drone manufacturer has emerged as a potential counterweight in the U.S. to China's DJI, which dominates the world market for sophisticated hobby and commercial drones.

Former Google Project Wing engineers who met as Massachusetts Institute of Technology graduate students founded Skydio in 2014. Within four years, the company released the Skydio R1, a $2,500 quadcopter fitted with 12 navigation cameras, depth and motion sensors, and an embedded "autonomy engine" flight computer running artificial intelligence (AI) software, all enabling it to accurately sense its position and avoid obstacles.

Valued as a "self-flying" hobby aircraft with "follow-me" functionality, and capable of shooting 4K-resolution video, the R1 was considered a breakthrough model in autonomous consumer drones. Skydio built it as a limited edition, and it is no longer in production.

In October 2019, the company unveiled the Skydio 2, which is smaller (1.7 lb.) and cheaper ($999) than the R1, but with orders of magnitude more visual-sensing acuity. A quadcopter with offset front (below airframe) and back (above airframe) rotors, the Skydio 2 is fitted with six 4K navigation cameras in top-and-bottom, trinocular configuration, producing 45 megapixels of resolution compared to about 3 megapixels available from the R1, the company says.

The Skydio 2 flight computer runs Skydio's software on an Nvidia Tegra TX2 processor. Its front-facing, gimbaled main camera, a Sony IMX577 image sensor with Qualcomm RedDragon processor, shoots 4K, 60 frames/sec., high-dynamic-range video.

On July 13, Skydio announced a $100 million Series C venture capital infusion—increasing the funding it has raised to $170 million—and the launch of a third-generation, X2 family of ruggedized quadcopters with folding rotor arms for the commercial and government markets.

Scheduled for release in the fourth quarter, the X2 series adds a dual-sensor payload with color and FLIR Systems' Boson long-wave infrared cameras, increases flight duration to 35 min. from 23 min. for the Skydio 2, and comes with new mission-optimized software releases. The X2D model is built to U.S. Army Short-Range Reconnaissance (SRR) program specifications.

Skydio's new X2D model is built to U.S. Army Short-Range Reconnaissance program specifications.

SKYDIO

Notably, X2 drones will be assembled at Skydio's Redwood City, California, facility using primarily U.S.-sourced components. That will be a key consideration as suspicion that Chinese-made drones present a data security risk gels into policy at the federal level, and the Pentagon seeks to reinvigorate a domestic manufacturing base for small drones.

That road is paved with broken ambitions. 3D Robotics of Berkeley, California, introduced the Solo quadcopter in 2015 but halted production after burning through a reported $100 million in venture capital; the company reverted to selling enterprise software for drones, including DJI models. Action camera manufacturer GoPro unveiled the Karma quadcopter in 2016 but recalled 2,500 units within weeks of its launch and discontinued production in 2018.

In April 2019, the Army and the Pentagon's Defense Innovation Unit selected Skydio and five other companies—Vantage Robotics, Altavian, Teal Drones, Lumenier and France's Parrot—to develop "rucksack-portable" vertical-takeoff-and-landing prototype models for evaluation under the SRR program.

This spring, the Army chose two of the companies—Skydio and Parrot—to participate in a user evaluation July 13-31 at Fort Benning, Georgia. Plans call for awarding a production contract to one vendor in the first quarter of fiscal 2021, which begins in October. Parrot has an agreement with contract manufacturer NEOTech, of Chatsworth, California, to build its drones in the U.S.

The Defense Department and Texas A&M University cosponsored a Drone Venture Day in November 2019 at which 39 manufacturers of unmanned aircraft systems (UAS) and counter-UAS systems met with investors.

Explaining the initiative at a later briefing with reporters, Ellen Lord, undersecretary of defense for acquisition and sustainment, said: "I think you know that DJI flooded the market

PARROT

with low-cost quadcopters particularly, which eroded our industrial base and really altered the landscape for the U.S. government and for the small drone industry. What we want to do is reinvigorate that [base]."

The fiscal 2020 National Defense Authorization Act (NDAA) signed into law in December 2019 prohibits the U.S. military from buying Chinese-made UAS including flight controllers, radios, data transmission devices, cameras, gimbals and software.

The American Security Drone Act, bipartisan legislation spearheaded by Sen. Rick Scott (R-Fla.) would prohibit U.S. federal agencies from procuring drones from countries identified as national security threats, namely China. The Senate Homeland Security and Governmental Affairs Committee approved the legislation in March.

Earlier this year, Interior Secretary David Bernhardt formally ordered his department to stop flying UAS manufactured in China or made with Chinese components, effectively grounding its fleet of 810 small drones.

"The X2 product is fully compliant with both the NDAA and the American Security Drone Act, which are designed to mitigate the potential security risks associated with Chinese components," says Adam Bry, Skydio co-founder and CEO.

"In particular, we write all of our software ourselves in-house in Redwood City," he adds. "All the processors are sourced from other U.S. companies—Nvidia, Qualcomm—that's the silicon that we're lying on. We do everything we can to minimize our dependence on Chinese components, but we do have commodity [items] like injection-molded plastics, metals, things of that nature [that] are still coming from China."

On June 30, Parrot unveiled the commercial Anafi USA, which is based on its development of a quadcopter for the U.S. Army.

Policies aimed at suppressing the market for Chinese-made drones mainly target Shenzhen, China-based DJI, which is reputed to own 70% of the global market share for small hobby and commercial models. Affordable and technologically sophisticated, DJI drones are particularly popular with U.S. state and local police and public-safety agencies.

A spring 2020 survey of local agencies by the Airborne International Response Team (AIRT), a nonprofit research organization based in Miami, revealed just how popular DJI drones are with first responders. Of 257 agencies that answered the question of which drone brands they operate, 90.6% said DJI.

Following in second place, surprisingly, was Skydio at 10.89%, then Autel Robotics of Bothell, Washington, at 8.95%, Parrot at 7.39% and China's Yuneec at 7%.

"One of the things that really popped out for us is Skydio basically capturing 11% of the fleet makeup, only nine months after the Skydio 2 came out. Skydio basically leapfrogged all of those players in less than nine months, according to this data," said AIRT Executive Director Christopher Todd, who announced the survey results on July 13.

"We've had some internal debate as we've peer-reviewed this," added Todd. "Did Skydio catapult because of their revolutionary sense-and-avoid autonomy technology? Was it because they are a U.S. manufacturer and there is a movement away from foreign into U.S.-made products? We weren't able to decipher that, but we sense that it's probably a combination of those factors."

The obstacle-avoidance capability of the Skydio 2 is credited with helping the Chula Vista, California, police department obtain a new close-proximity, low-altitude waiver from the FAA. That waiver allows it to fly the drone beyond the visual line of sight of an operator, as long as the aircraft ascends no higher than 50 ft. off the ground and stays within 1,500 ft. laterally of the pilot.

In July, the Pentagon named Skydio as one of five recipients of $13.4 million in industrial base investments for small UAS systems, paid from the Coronavirus Aid, Relief and Economic Security Act. The company received $4 million to improve its radio control data link so that it can be used across government agencies.

Among other recent government awards, the Drug Enforcement Administration signed a $37,470 purchase order with Skydio in May.

"The U.S. government and the [Defense Department] have astutely recognized that these small consumer drones are incredibly useful tools for a wide range of use cases," says Bry. "There's a need and a desire to have U.S. companies competing in this space. We're proud and excited to be a part of that, but we also think our products can and should stand on their own.

"Our focus from the very beginning in 2014 has been on delivering full autonomy in our drones. We think that's a core pillar of making them useful for a lot of different customers. The losing strategy, for sure, is to try to copy what DJI is doing and to [produce] a more expensive and worse version of their product. That's not what we're going after."

CHECKLIST CHALLENGES

> MAX TRAINING UPDATES PROMPT MEMORY-ITEM DISCUSSION

Sean Broderick Washington

Industry's scrutiny of the 737 MAX as part of Boeing's effort to get the grounded model back into service may lead to a broader review of how pilots are trained to handle problems that require immediate responses.

Proposed training changes being reviewed by operators and the FAA include modifications to seven non-normal checklists (NNC). Some were necessary to align procedures with modifications Boeing has made to the MAX flight control computer software that regulators demanded—part of the ramifications of two fatal accidents in five months that led to the model's March 2019 grounding. But changes to five of the checklists stem from human factors-related reviews that determined pilots need more and better information to handle time-sensitive, high-risk scenarios properly (*AW&ST* July 13-26, p. 18).

Large MAX customer American Airlines is taking its review a step further, looking at how it handles the most critical NNC elements—immediate-action or "memory" items.

American is among a handful of carriers at the forefront of an emerging trend that sees operators limiting, or in American's case, completely eliminating, memory items from its procedures. Instead of requiring pilots to memorize a few key steps on a dozen or so critical checklists, the carriers created a quick reference card (QRC) with just the memory items that pilots can access when needed.

American's QRC is a two-sided placard when printed, while an interactive digital version on a pilot's tablet features hyperlinks to relevant, more detailed troubleshooting instructions. Its pilots have largely welcomed the late 2018 shift to QRCs. But in reviewing the proposed MAX training, a consensus is building around modifying American's pilot protocol by having pilots recommit at least two procedures to memory: airspeed unreliable and runaway stabilizer.

Both procedures figured prominently in the two fatal MAX accident sequences, Lion Air Flight 610 (JT610) in October 2018 and Ethiopian Airlines Flight 302 (ET302) in March 2019, that led to the model's March 2019 grounding and changes by Boeing, including the modified training. Boeing's proposed updates include new wording for both checklists based solely on human-factors lessons gleaned from the accidents and subsequent reviews. But the risks that either scenario presents, especially if the aircraft is close to the ground when trouble strikes, mean pilots have little time to spare before taking initial action.

"All of the [non-normal] checklists are important. But looking at those two, something bad can happen if you're close to the ground," says Dennis Tajer, an American 737 pilot and spokesman for the Allied Pilots Association that represents the carrier's pilots. "You don't have a lot of time to pull out a card."

While carriers must have all flight manuals, including checklists, ap-

Scrutiny of the 737 MAX checklists could lead to a broader discussion on how pilots prepare for emergencies.

JASON REDMOND/AFP/GETTY IMAGES

> BOEING IS CHANGING 737 MAX PILOT CHECKLISTS

> ISSUE SPOTLIGHTS LACK OF RESEARCH ON BEST PRACTICES

proved by regulators on an individual basis, American's move could have wider ramifications. Both of the other U.S.-based 737 MAX operators, Southwest Airlines and United Airlines, also use QRCs.

The bigger picture is that the scrutiny of how pilots are expected to react in the most critical situations could see higher-level changes and perhaps even more common ground among manufacturers and regulators.

Emergency checklists are a crucial part of every pilot's training, yet there is no consensus around how to best design memory-item checklists or even whether to use them. A 2013 European Union Aviation Safety Agency review of the issue found plenty of studies on memory during high-stress situations but laments "comparatively little research" on emergency checklists specifically.

The lack of reliable research has led to notably diverse approaches. A 2006 UK Civil Aviation Authority guidance tool recommends keeping memory-item steps "to a minimum (preferably fewer than four and certainly no more than six) for multi-crew operations." FAA guidance issued more than a decade ago says memory items "should be avoided whenever possible." When necessary, memorized checklists should include no more than two items and no decision steps, the agency adds.

A multiyear NASA study on flight deck procedure design, released in 2016 and partially funded by the FAA, suggests that the U.S. MAX operators are on the right track. "Avoid memory items whenever possible," the study says in a set of recommendations to organizations designing procedures. "If the procedure must include memory items, they should be clearly identified."

While operators are responsible for developing their own procedures, they lean heavily on manufacturers' boilerplate flight training and pilot manuals as templates. As is the case with regulators, there is little consensus among aircraft designers.

Airbus and Boeing both include memory items in their manuals. Even the newest designs such as the Airbus A350 have more than half a dozen. Gulfstream, on the other hand, does not identify any abnormal or emergency procedures as memory items, "yet . . . expects pilots to perform some of the initial and critical steps without reference to any documentation," an FAA document on G650 pilot training explains.

Eliminating all memory items is unavoidable. Even at carriers that have embraced QRCs or similar approaches, pilots must be prepared to react in certain situations by relying only on their recall. American prohibits QRC use until an aircraft's landing gear is retracted, its flight path is under control, and the aircraft is at least 400 ft. above ground level, for instance. Nearly all operators have similar de facto requirements linked to engine-related emergency procedures. Taking such an approach supports shifting most memory items to QRCs by requiring pilots to remember only the most critical steps in a minimum number of scenarios.

"Sometimes it is a good idea not to act too quickly and risk mixing something up," says one veteran Airbus A320 captain. "Is your aircraft still flying, and is there enough air below you? If both can be answered with 'yes,' you actually do not need memory items. It's better to make sure you understand the problem."

A lack of understanding played key roles in both of the aforementioned MAX accident sequences. Boeing wrongly believed that any malfunction triggering the aircraft's Maneuvering Characteristics Augmentation System (MCAS) flight control law that provides automatic nose-down horizontal stabilizer input would be diagnosed quickly as runaway stabilizer. Pilots would execute the memory-item checklist, including Item 5—toggling two switches and depowering the stabilizer motor.

Neither crew did that, however, though the ET302 pilots referenced the checklist during their efforts to keep the MCAS, responding to erroneous angle-of-attack data from a malfunctioning sensor, from pushing their 737-8's nose down.

The design of the MCAS and how pilots perceived its inadvertent activation proved to be a larger issue than the checklists themselves, but Boeing's changes to the MAX are covering both bases. The JT610 pilots' checklist struggles began before the MCAS activated, when they received an airspeed unreliable warning just after takeoff but before retracting the flaps, which is one condition for activation of the MCAS. The captain, acting as pilot flying, asked for the airspeed unreliable checklist. The first officer (FO) did not respond initially, then told the captain that he could not find it and it did not exist. More than 3 min. after the initial request, and following what the National Transportation Safety Committee final report on the accident describes as "sound similar to paper pages being turned" captured by the cockpit voice recorder, the FO began reading the checklist.

"The inability for the FO to perform memory items and locate the checklist in the [quick reference handbook] in a timely manner indicated that the FO was not familiar with the NNC," the report says. "This condition was reappearance of misidentifying NNC, which showed on the FO's training records."

While the report took the FO's specific situation into account, it also faulted Boeing's "assumption of relying on trained crew procedures, to implement [runaway stabilizer] memory items" as "inappropriate."

Such criticism helped drive Boeing to propose modifying seven of the MAX checklists.

"Pilots often criticize how engineers design in a '1g environment,' meaning in an air-conditioned, quiet cubicle without accounting for the dirty, sweaty, noisy, tired, distracting world of operations," says one senior executive with OEM safety program development experience. "This shortcoming has certainly come out in the 737 MAX crisis but was known well before those accidents as a problem in engineering psychology."

While memory-item approaches will continue to vary, the first step to safety improvement is recognizing the shared responsibility. Operators must weigh how and when to implement memory items, while aircraft manufacturers "must strive to balance clarity and simplicity with comprehensiveness," the senior executive says. "That is no small feat, particularly when designing procedures for non-native English speakers who may also be inexperienced and fatigued."

Regional Turboprops Spearhead Air Traffic Recovery

> TURBOPROPS MAY HELP MAINTAIN NETWORKS

> ATR OFFERS AN ENHANCED VISION SYSTEM AS WELL AS FREIGHTER AND SHORT-TAKEOFF-AND-LANDING VERSIONS

Thierry Dubois Lyon

Regional turboprop manufacturers ATR and de Havilland Aircraft of Canada have been suffering from the ongoing COVID-19 pandemic but may see light at the end of the tunnel earlier than other commercial aviation segments.

Regardless of its predicament, market leader ATR is proceeding with the development of new variants in a bid to keep relevant an airframe that is 30+ years old. It is considering proceeding with new propulsion configurations, as Europe may see smaller aircraft as the right stepping stones to switch to hydrogen or hybrid-electric power.

ATR

ATR's ClearVision enhanced vision system is designed to make landing in bad weather possible more often.

On the other hand, ATR plans to cut 204 employees—including 186 in France—from its 1,400-member workforce. When they made the announcement, company executives said they accepted that recovery from the pandemic, although faster in the regional air traffic segment than elsewhere in commercial aviation, would be slow.

"This crisis means 2-3 years of lower volumes than over the past five years. . . . ATR has to resize its workforce, creating conditions for ATR to be stable, solid and independent. It was a difficult choice . . . but it is the right decision because our future is at stake," CEO Stefano Bortoli tells Aviation Week.

ATR's management team has estimated workload requirements so as to retain skills and ramp up quickly when demand rebounds, Bortoli says.

Production was stopped for only 10 days but is not yet back to precrisis levels. Bortoli would not share the current production rate, only saying it has undergone "a sizable decrease." Last year, the company delivered a total of 68 ATR 42s and ATR 72s (in the 40- and 70-seat classes, respectively). The backlog of firm orders stands at 242 aircraft, according to Aviation Week's Fleet Discovery data.

In Canada, competitor de Havilland is in a comparable situation since it paused production in March and announced a restart in early May. "We have not resumed full-scale production yet, but we have started a phased return to work of employees and a measured resumption of activities," a spokesperson says. "In the first phase announced on May 4, employees returned to work to focus on resuming preflight activities and delivery of [80-seat-class] Dash 8-400 aircraft. Additional employees returned on May 27, and more recently, we brought back our supply chain and procurement team members. These are incremental steps toward restarting full production."

In March, 800 employees, or 65% of de Havilland Canada's workforce, were on paid leave. Since then, about 140 employees who were formerly on paid leave have returned to work.

A major proportion of regional turboprops is in parked/reserved status (defined as having flown either one or two of the previous seven days), or in parked or storage status. ATR has 576 aircraft in service as well as 106 in parked/reserved status, according to Aviation Week data.

This situation may evolve favorably for operators and manufacturers. "Regional aircraft play a crucial role when the aviation industry works to reestablish markets," says the de Havilland spokesperson. In July, Dash 8s are scheduled to serve 853 routes around the globe, according to the airframer's statistics. Of these, 5% are routes previously operated by jets, 10% are new routes, and 85% are routes on which Dash 8 service has resumed or will resume.

Bortoli echoes that view. Traffic will restart with domestic flights and in areas at lower risk of contagion such as the EU and the Australia-New Zealand travel zones, he says. Since carriers have to "test water temperature," as Bortoli puts it, ATR aircraft are seen as well-placed thanks to their limited capacity and range.

Teal Group analyst Richard Aboulafia agrees. Networks need to be kept intact at lower passenger counts, and regional aircraft can be part of the solution, he points out. However, ATR salespersons may lose some of their major marketing points. ATR's lower fuel consumption (less than that of the Dash 8-400 and an asserted 40% better than a same-size jet) is less pertinent when the fuel price is low, Aboulafia says.

ATR also is offering its new 72-600F freighter, which the company has been developing since FedEx signed a firm order for 30 in 2017. Deliveries will start this year as planned, according to Bortoli. The first one will operate

in Europe and the second in the U.S.

Two factors make the new variant appear particularly relevant: the growth of e-commerce and the accompanying need for parcel deliveries; and the decrease in belly cargo capacity on passenger aircraft as the number of flights has declined.

Another aspect of regional airliners is ClearVision, the first enhanced-vision system in commercial aviation with a wearable display, which was to enter service by this summer. But launch customer Aurigny Air Services of Guernsey in the Channel Islands had to delay the pilot training process due to the pandemic. The system is designed to allow more frequent landings in bad weather, thus making flight schedules more dependable.

ATR also is developing a short-takeoff-and-landing (STOL) variant of the ATR 42. Reduced-scale wind-tunnel testing is complete, and the first flight is scheduled for 2022. Aboulafia thinks well of the STOL idea, saying ATR could sell a few dozen, especially in Asia.

In China, the airframer is zeroing in on ATR 42-600 certification. In July, representatives of the Civil Aviation Administration of China participated in a certification flight in Toulouse, alongside their European Union Aviation Safety Agency counterparts. The process is ongoing with review of the paperwork issued at the end of the flight. "There should not be a major obstacle, but China is China," Bortoli says, referring to seemingly endless red tape in the country.

China is a virtually untapped market for regional turboprops, and ATR sees great potential there. In 2017, two letters of intent were signed with small operators, but contracts have yet to materialize.

Longer term, the French bailout package for the aerospace industry requires meeting binding environmental goals. A new regional aircraft, either hybrid-electric or hydrogen-powered (which would involve a fuel cell), should enter service in 2030. Funding of a private-public partnership for aviation research in the EU is expected to support that target.

"After discussions at the shareholder level, we will have something to say about ATR's involvement in the project by year-end," Bortoli says.

Airbus and Leonardo each own 50% of Toulouse-based ATR.

ULTRAFAN PLAN

> COMPOSITE FAN AND CASE FOR DEMONSTRATOR IN FINAL ASSEMBLY

> ITP COMPLETES FIRST INTERMEDIATE-PRESSURE TURBINE CASE

ROLLS-ROYCE

Guy Norris Los Angeles

Six and a half years after Rolls-Royce revealed radical plans to develop a next-generation geared engine called the UltraFan, the company is starting to build up modules for the first demonstrator.

Rated at 84,000-lb. thrust and with a 140-in.-dia. composite fan, the engine's new core and geared drive mark a departure from the three-shaft architecture that has formed the basis of the company's big-fan family since the 1970s. The engine is scheduled to begin ground tests in 2021, with follow-on units joining the test effort in 2022 and paving the way for initial production versions later in the decade.

The engine size for those initial applications remains unknown but lies within the 25,000-100,000-lb.-thrust range covered by the scalable UltraFan architecture. Having seen the first potential application, the New Midmarket Airplane, disappear with Boeing's product-strategy rethink, Rolls remains agnostic on initial candidate applications.

The collapse in global air transport triggered by the COVID-19 pandemic may give Rolls more time to refine its initial offering as Airbus and Boeing pause their product-development planning. "We are keen to get through the technology de-risking stage . . . so having a little more time to reflect on that might be beneficial," says Andy Geer, chief engineer and UltraFan program head.

Overall fan diameter of the UltraFan demonstrator will be 140 in., producing a bypass ratio of around 15:1.

"But the world doesn't stand still. Depending on the rate at which the business recovers and to what extent the fuel price goes back to where it was—or starts to attract carbon taxation—all of those factors could affect the dynamics of the market quite quickly. We just have to be in a position to be ready for when that long-term market recovery comes along," Geer says. "It is still the purpose of the demonstrator to be ready for whenever the customer airlines and airframers converge their strategic needs."

Rolls believes nothing has changed to fundamentally alter either the goal of the UltraFan demonstrator or the long-term prospects for the engine. "It's scalable, and then you have choices," Geer says. "Once you have demonstrated the capability, you have choice. And beyond that, you have credibility

ROLLS-ROYCE PHOTOS

The UltraFan fan set will comprise 18 blades, one of which is seen in assembly at the company's Composite Technology Facility in Bristol, England.

when you offer those choices. The goal is to get these technologies ready to use. The exact way we use them—the mix—we can adapt that once you have credibility of the technology set."

To get to the demonstrator, Rolls has focused on two main tracks: improving thermal efficiency by building the hotter, smaller core of the Advance3 test engine; and enhancing propulsive efficiency by developing new low-pressure (LP) system components to increase bypass ratio with a bigger, slower fan.

While the Advance3 core could form the heart of a future direct-drive turbofan, it also paves the way for the geared UltraFan. The new core reduces the workload on the intermediate-pressure (IP) compressor while increasing the workload on the high-pressure (HP) compressor.

The UltraFan's new LP architecture builds on this by introducing a bigger IP turbine that is used to drive the IP compressor and fan via a gearbox. By linking the fan to the high-speed IP turbine instead of driving it directly with the LP turbine, as in Rolls' current Trent engines, the UltraFan eliminates this large latter turbine section, making underwing installation easier.

The first large components for the demonstrator engine are coming together. Initial composite fan blades are in assembly following ground and flight tests under the Advanced Low Pressure System program. Developed in partnership with industry, the European Clean Sky and UK government Innovate programs, the blade set and composite fan case will save around 1,500 lb. per shipset on a twin-engine aircraft compared to a metallic design.

"Having a low-speed fan is essential when you move to such a high bypass ratio, so for this it involves both low-speed aerodynamics and carbon-titanium construction," Geer says. Building on ground and flight testing at Trent 1000 scale, plus component tests at UltraFan scale, the company has completed the first fan case. Further tests at UltraFan scale are planned in a trailing-blade impact rig in 2021.

Testing of the power gearbox in Dahlewitz, Germany, has been underway since the end of 2019 with the eighth build-standard of engine-representative hardware. The system consists of a ring gear enclosing five planetary gears that rotate around a central sun gear. The fan drives off a centrally mounted planet carrier.

The baseline gearbox design has been tested in a special attitude rig since 2016 and in a power rig since 2017. "We have a number of other units in build which will continue testing through 2021 to take it to maturity. Basic characterization is now complete, and we are happy with that," Geer says.

Advance3 demonstrator tests have meanwhile passed the 100-hr. mark, including full-power runs. The advanced core is integrated with a Trent 1000 LP turbine and Trent XWB-84

A Rolls-Pratt Partnership?

Joe Anselmo and **Michael Bruno** Washington

THE COVID-19 DOWNTURN HAS PROVIDED BREATHING room for Rolls-Royce to define the UltraFan, its next-generation geared engine. It is a rare bright spot for the beleaguered engine-maker, which has seen earlier losses tied to expensive Trent 1000 fixes compounded by the aviation market's 2020 meltdown.

But a huge question remains: Where will Rolls find the money with which to see the ambitious project through? That has led to speculation about a partnership with Pratt & Whitney, whose parent company, Raytheon Technologies, has deep pockets and a major defense business that is buffering it from the commercial downturn.

Raytheon Technologies CEO Greg Hayes told Aviation Week in a recent interview that he is open to a joint venture with Rolls "at some point." The two engine-makers' businesses are largely complementary—Pratt focuses on the narrowbody market and Rolls on widebodies—and they share a common competitor: GE Aviation and its CFM International partnership with Safran. Those synergies mean there could be a strong business case for cooperation.

Rolls and Pratt have partnered before on International Aero Engines, a multinational aircraft engine consortium; Pratt bought out Rolls' stake in that company in 2012. But while Hayes does not rule out another partnership, he throws cold water on the idea of buying one of the UK's technology leaders. "We're not going to buy Rolls-Royce," he says. "That just doesn't make sense."

fan system to demonstrate new features including a low-emissions lean-burn combustor and additively manufactured components.

The rebuilt engine will return to test this year for a second phase that is scheduled to continue through 2021. The first phase characterized the core's basic behavior under relatively controlled operating conditions. "Now we get to push it into more extreme circumstances it would see in operation," Geer says.

In parallel with testing under Advance3, the lean-burn design is being evaluated under the Advanced Low Emissions Combustor System program. Reducing emissions by combusting fuel more efficiently through a series of concentric burners, the design has completed ground tests in a modified Trent 1000. A further phase of ground and flight tests is to start shortly, according to Geer.

A better combustion system also is expected to maximize turbine capability and help improve cycle efficiency in the UltraFan. The exit conditions of the combustor play a significant role in the efficiency of the HP turbine. "If you can design your combustor to provide the best possible temperature profile entry conditions to the turbine, that helps the engine system," he says.

Another area of testing is focused on the aerodynamics and mechanics of the UltraFan's lightweight four-stage IP turbine. Developed with Rolls' Spanish subsidiary ITP Aero, the nickel alloy turbine section has completed aerodynamic evaluation on a rig at the CTA Aerospace Test Laboratory near Barcelona. ITP has manufactured the first IP turbine case for the demonstrator.

"We are moving quickly through the design release and manufacturing of components across the whole of the UltraFan demonstrator engine," reports Geer. "It's a busy time, and it's not ideal that we happen to be doing this on the back of the COVID-19 pandemic. Inevitably, it's a bit of hard work at the moment, with the world supply chain being disrupted."

Despite this, the demonstrator remains on track to start tests in 2021. "We've had hits as a result of COVID and are seeing a range of challenges," he says. "If we only need a single part in a module, but it has been impacted by a supply-chain disruption, then it causes us to wait to launch that module. It's been a little bit hand-to-mouth in how that works out in today's world."

Production of the barrel of the first composite fan case, seen underway earlier this year, is now complete.

Check 6 *Aviation Week editors talk with chief engineer Andy Geer about why UltraFan will be an engine for all seasons:* **AviationWeek.com/podcast**

Boeing Teams With Etihad for 2020 ecoDemonstrator

- THE 787-10 IS SEVENTH TYPE TO BE USED AS AN ECODEMONSTRATOR
- THIS YEAR'S FLIGHT CAMPAIGN TESTS WILL FOCUS ON NOISE, AIR TRAFFIC EFFICIENCY AND SUSTAINABLE FUEL

Guy Norris Los Angeles

ONE IN A SERIES

With the drive for efficient flight operations accelerating as airlines seek to recover from the COVID-19 pandemic, Boeing is planning another round of its ecoDemonstrator technology program.

The 2020 flight campaign will use a yet-to-be-delivered 787-10 from Etihad Airways, which signed a strategic sustainability partnership with Boeing in late 2019. Tests will focus on aircraft noise, four-dimensional route optimization and synthetic fuel.

"This will really have an emphasis on sustainability," says Rae Lutters, the ecoDemonstrator chief engineer. The previous six flight campaigns collectively flew 165 technologies since the program began in 2012, but only four will be tested this time.

This contrasts with 53 technologies tested on a 777-200 in the 2019 campaign. "It's smaller than in the past due to the current COVID-19 situation," says Lutters. In addition, some of the technologies due to be evaluated on the 787-10 were brought forward to the 777. "It's a very short program," she explains.

The decision to proceed in difficult times for Boeing "sends a pretty strong message in the current environment that we're still investing in programs like ecoDemonstrator to evaluate advanced technologies and drive sustainability into our systems," says Doug Christensen, the program technical lead.

The predictable tempo of the campaigns has accelerated participation from government agencies, researchers and industry, says Christensen. As a result, Boeing is "fielding requests, probably on a weekly basis, from suppliers coming in and wanting to fly," he notes.

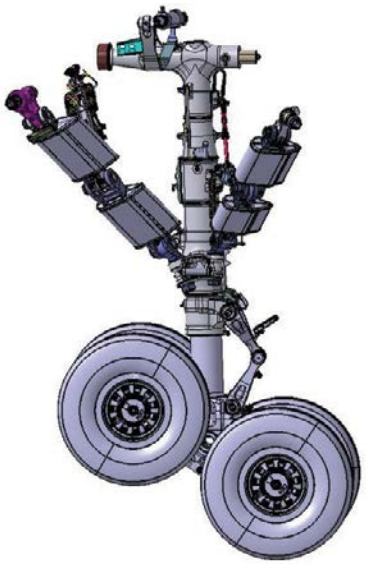
In the upcoming flight campaign, acoustic measurements will be undertaken in partnership with NASA to validate tools to predict community noise impacts. Together with Safran Landing Systems, Boeing expects to test flow deflectors, or fairings, to assess the potential for reducing landing-gear noise on the 787 and future aircraft.

The 787-10 is nearing completion at Boeing's South Carolina facility, from which it will be ferried to Glasgow, Montana, for equipment installation in mid-August. Flight tests are scheduled to last less than three weeks, from August to early September. The aircraft then will be returned to South Carolina for refurbishing and final outfitting before delivery to Etihad.

The initial days of testing will be focused on producing a detailed noise signature map for the 787-10. "We'll be putting about 1,000 microphones on the ground and a significant number of Kulites [pressure transducers] on the aircraft," says Al Creek, the ecoDemonstrator aircraft platform manager. Kulites measure acoustic pressures where conventional microphones cannot operate due to high dynamic or static pressure or high temperature. Flights will be made over the microphone array with different power and flap settings, flight conditions and procedures to produce the noise map.

"This will allow NASA to get data to validate its noise-prediction tools and see if they can be improved for the design of future aircraft," says Creek. Boeing will get a close look at the noise the 787-10 generates. This could lead to reduced noise-indexed landing fees for operators at noise-sensitive airports such as London Heathrow.

Following completion of the NASA noise tests, Boeing plans to modify the landing gear temporarily with an experimental set of passive noise-reduction fairings developed by Safran. "The 787 is such a quiet airplane now that we're noticing airframe noise, and we've identified that landing gear noise



is one of the prime contributors during approach and landing," Creek says.

Safran research indicates landing gear are responsible for 20-40% of perceived noise on approach, largely due to turbulent flow around the leg strut and support braces. In a bid to reduce some of this turbulent interaction, airfoil-shaped fairings will be attached to the main-gear drag and side braces.

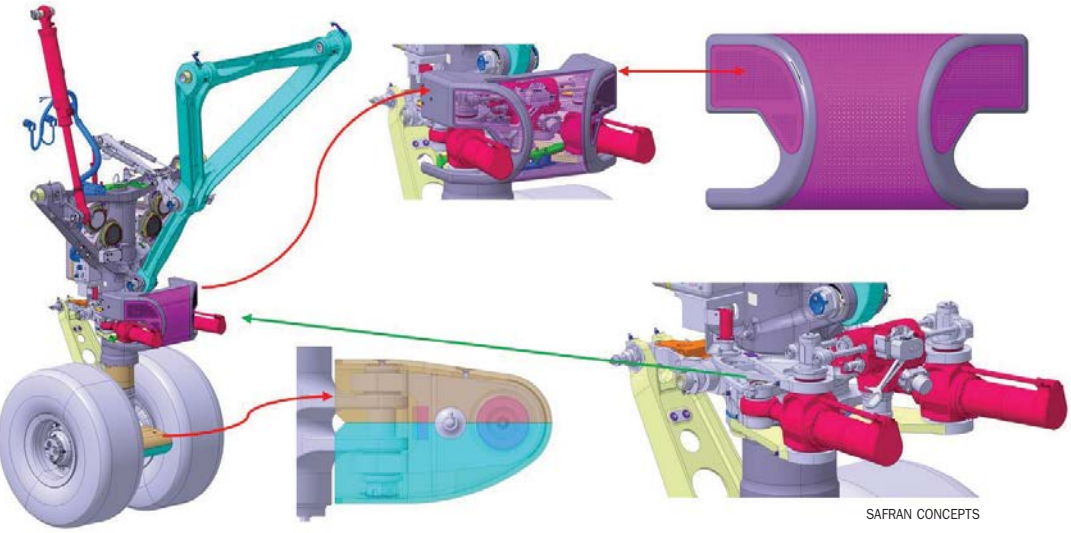
Perforated and solid flow-deflectors also will be attached to the steering mechanism and tow fitting at the front of the nose landing gear. The 787-10 will fly through this test phase with its landing gear extended, the phased array of ground microphones measuring aircraft sound in various flight conditions.

Live demonstrations of 4D trajectory-based flight operations integrated with FAA air traffic control (ATC) will be conducted during the cross-country ferry flights to and from Glasgow. The outbound flight will be used to verify system operability and the return flight will include a full demonstration for FAA leadership.

Intended to reduce fuel burn, noise and approach emissions by making more efficient use of airspace, the 4D demo will build on data-connectivity technologies tested in the 2019 ecoDemonstrator. In that campaign, Boeing worked with Honeywell, Inmarsat and SITA to demonstrate an internet protocol next-generation data link for air navigation services and airline operations control.

The goal this time is to demonstrate better use of time, the fourth dimension, using the FAA's growing Data Comm ground network. The agency gradually is deploying controller-pilot data-link communications throughout

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



SAFRAN CONCEPTS

Low-noise fairings (far left) will be attached to the drag and side braces of the main landing gear.

Passive low-noise flow deflectors will be added to the nose leg steering mechanism (top right) and tow fitting (lower left).

U.S. en route airspace. The system allows controllers to data-link clearances and instructions to pilots, including direct uploading of reroutes to the aircraft's flight management system (FMS).

The demonstration will include a digital departure clearance and cruise-climb, inter-center digital coordination, and use of an ATC data link for a continuous-descent approach and GPS-guided landing using increased-glideslope required navigation performance. The aim is to verify performance-based navigation and FMS autoload functions.

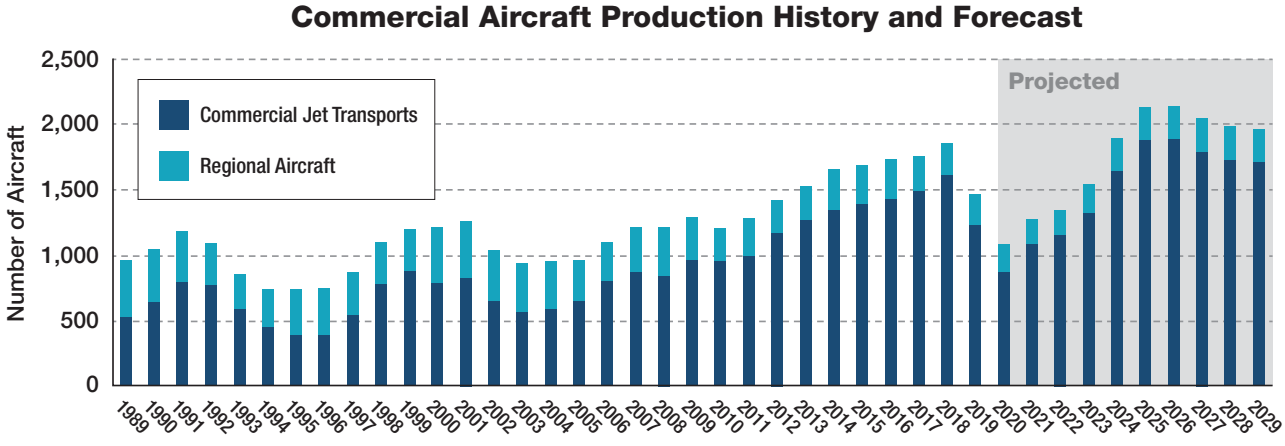
Finally, all of the 787-10 flights will use up to a 50% blend of sustainable aviation fuel produced from agricultural waste by World Energy.

Beyond the 787-10, planning is underway for the next ecoDemonstrator campaign, including resurrecting the Boeing-owned 777-200 used in 2019 and now in storage. "We are planning on a much larger program next year," says Christensen. "We've identified our technologies and an airline partner. We're also working on 2022 and have a list of technologies and a platform."

The Days After

> THE SUPPLIER BASE ENTERED COVID-19 OUTBREAK SUFFERING HICCUPS BUT EXPECTING HISTORIC GROWTH

> PANDEMIC STARTS TWO YEARS OF DECLINING INDUSTRIAL CAPACITY



Source: Naveo

Michael Bruno Washington

Suppliers across the Western aerospace and defense industrial base faced an existential crisis entering the second half of 2020.

Commercial air travel, the lifeblood of industry, took a body blow in the first half of the year with the one-two punch of the Boeing 737 MAX crisis and then the outbreak of COVID-19. Passenger air traffic could end 2020 at about 55% of 2019's total level, according to financial analysts; in 2021, the question will be whether a significant uptick can occur without a vaccine against the novel coronavirus.

In turn, manufacturers do not expect 2019 production levels to return until 2023-25, with thousands of once-planned large commercial aircraft now effectively erased from bankable plans for much of this decade. Experts see 30-50% excess capacity across aerospace and defense (A&D) manufacturing and a threat that around 20% of lower-tier suppliers could exit the industry in coming years. Recall that before the COVID-19 pandemic, monthly narrowbody production rates at the two leading OEMs were headed for the 60s, widebody rates were only softening against a predicted upswing in a few years, and defense budgets were expected to remain flat with only inflationary improvements.

"COVID-19 is that asteroid hit that takes out the Sun," says Warbird Capital CEO and Chief Investment Officer Nicholas Pastushan. "It looks like a potential mass-extinction event as it comes to businesses in aviation."

Pastushan's career includes six years at GE Capital Aviation Services, where he was director of industry research, followed by more than a decade as chief investment officer for the erstwhile CIT transportation portfolio. "We used to describe events like this as being, well, you know, a nuclear war, end-of-the-world kind of thing: 'I guess we're all dead anyway, so who cares?' Well, we're not dead, and this traffic disruption event has happened," he says.

Both Pastushan and Bank of America analyst Ronald Epstein say they expect demand for new-build aircraft to plummet. "If 2023 really is the year we'd get back to 2019 levels, that means for the next couple of years, no aircraft are needed for growth," Epstein said during an Aviation Week webinar in June. "With 60% of new aircraft deliveries traditionally going to meet industry growth, now all that is needed is the roughly 40% for replacement."

"We're looking at a couple of years' worth of needing zero production," Pastushan said.

According to Naveo Managing Director Richard Brown in a July 8 report, 2020 new-aircraft production—likely around 1,090 airliners—will represent a return to 2006 levels. In production value, it will equate to roughly $71 billion worth of work: about $50 billion off pre-MAX 2018 levels.

Timothy Kuder, senior commercial aerospace industry analyst at advisor Frost & Sullivan, says the lost work through 2025 represents $475 billion in commercial aviation manufacturing, "which is just aircraft production we thought was going to be there but we're never going to see again."

Both Epstein and Pastushan said production is not expected to halt completely because that would be a death knell for the supply chain and

industry altogether. But that will be little comfort to a wide swath of industry that faces the need to make structural changes as aircraft OEMs seek the lowest sustainable production rates of their products.

"There is going to be tremendous pain throughout the supply chain," echoes Jay Carmel, who leads the civil aerospace practice at advisor Avascent.

The Western A&D manufacturing sector, like many others, resembles a pyramid structure. The top counts 8-10 OEMs and flagship national defense prime contractors, and roughly a dozen major Tier 1 suppliers—with some of the latter increasingly rivaling their OEM customers in business activity. Then come a few score of major Tier 2 providers and "big-small" defense contractors—a shrinking layer over the recent decade—and 15,000 or more Tier-3-plus suppliers, many of which feed into multiple industries but also include mom-and-pop shops. Commercial aviation business activity accounts for roughly three-quarters of the whole sector, and defense composes the rest.

Fears of fallout increase proportionately as observers look further down the pyramid. "A lot of those small-part or spare-part manufacturers are smaller companies," says Mike Blades, Frost vice president of A&D and security for the Americas. "They are going to be hit much harder by this than a larger company that has a diversified portfolio [and] can weather the storm by selling more of what they have on hand that is not aerospace-related or insulated from the decrease in demand. We are going to see issues in the supply chain and possibly companies going out of business. The supply chain was not in the best shape to begin with."

Indeed, several experts note lower-tier providers already were strained going into the pandemic. "A decade of OEMs pressuring subtier manufacturers to make investments and tool up for production rate increases—coupled with relentless cost cutting through Boeing's Partnering for Success and Airbus' internal efficiency SCOPe/SCOPe+ programs—has left the aerospace supply chain capital-starved," Alton advisors said in a June report.

CEOs atop the industry continued to sound the alarm in the second quarter, particularly about their supply chain. "The real concern, if I think about everybody here, [is that] while the airline customers are going to have a tough time, it is the small business suppliers that I'm most worried about," says Raytheon Technologies CEO Gregory Hayes.

"We see the airlines are badly hit, and we are badly hit," says Airbus CEO Guillaume Faury. "And the next wave is going to be the supply chain."

Who is more at risk? Many list aerostructures first, because the segment was fragmented and suffered higher fixed costs and lower pretax profit margins before the crisis. Interiors are another oft-cited sector at risk. Maintenance, repair and overhaul and parts suppliers also are listed, especially for widebodies and older airliners now likely to be headed for earlier retirement. Boeing and its suppliers are seen as more vulnerable than Airbus and its ecosystem, both because MAX production is practically null and because there are about 800 inventoried 737s to be delivered, in addition to customers' own parked aircraft.

"Under our baseline assumption of recovery, aftermarket sales will be 65-75% of 2019 in 2022, and OEM sales will be back to 2018 levels into 2024," UBS analysts said in a June 18 report.

Still, not every vendor is suffering the same, and defense suppliers in general are relatively safer. The Pentagon has injected more than $3 billion in accelerated payments into primes and their suppliers to bolster their financial positions since COVID-19 hit the U.S. in force.

Moreover, the defense-industrial base already had consolidated substantially—to a degree that government officials were worried before the pandemic. The commercial supply base, by contrast, remains far more fragmented due to decades of OEMs outsourcing about two-thirds of their aircraft program spending to suppliers. Above all, the commercial segment faced rising prospects from a then-historic backlog of aircraft orders, driving more interest from new players and investors.

"Consolidation within the lower tier of defense contractors over the past decade has contributed to the sector's resilience," Moody's Investors Service said in June. "The average U.S. defense contractor that we rate is simply a larger, better operated and more dynamic company than it was 10 years ago."

According to Moody's, "most" of the defense contractors are led by management teams that experienced and navigated the "challenging" seven-year period following the Budget Control Act of 2011, the law that brought sequestration spending caps after a so-called supercommittee of lawmakers failed to find agreement on federal cuts. Subsequent years saw turbulent business conditions for government contractors, including government shutdowns and hard-fought, last-minute bipartisan budget deals, as well as government buyers seeking low-price, technically acceptable deals.

"Aerospace and defense companies' production levels, billable service hours, new business development and collections have been only minimally disrupted by the COVID-19 outbreak,"

OPTIMISTIC

- Consolidation focuses on distressed assets that existed before pandemic.
- Production rates across shipsets remain above the lowest sustainable levels with higher end-market demand.
- Demand returns to prepandemic levels by 2022.

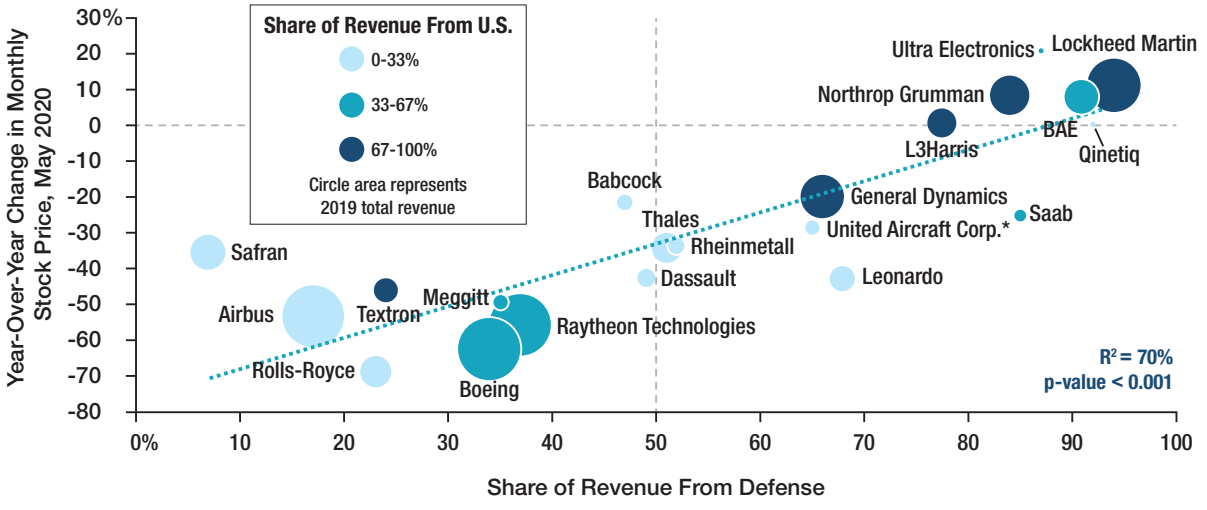
NEUTRAL

- Consolidation includes distressed assets as well as roll-up mergers yielding more resilient suppliers.
- Production rates across shipsets are stabilized at lowest sustainable rate for all providers.
- Prepandemic demand levels are achieved in 2023-25.

PESSIMISTIC

- Consolidation and market-exiting lead to up to 20% of suppliers in lower tiers leaving A&D.
- Production rate planning is abandoned and the supply chain faces fluctuating purchase orders.
- End-market demand resets to a new normal below prepandemic levels with no recovery.

Defense Company Stocks Faring Better Under COVID-19



*Share of revenue from defense estimated using 2017 aircraft delivery data and aircraft unit cost estimates

Source: Roland Berger

said Bruce Herskovics, a Moody's senior analyst. "Government efforts to keep facilities open and projects active have contributed to this stability, which also reflects the sector's maturation."

Numerous consultants suggest the A&D supplier base is nearing the end of the first phase of a three-step transition, and the initial deep crisis is beginning to wane. In the first phase, survival was likely as measured by liquidity, the cash and equivalents available to keep operating. "The biggest concern right now is how to ensure a smooth landing," says Manfred Hader, who co-heads Roland Berger's global A&D practice.

As the supply base shifts into the second phase—the pandemic overhang—companies have to prepare for up to 24 more months of aftershocks to the industrial base and have multiple "what-if" plans ready. "They should consist of no-regret moves (e.g., capacity rationalization), more aggressive actions triggered as specific scenarios unfold and big strategic moves (e.g., spin-offs) that need to be planned in advance so the company can move fast once it has a green light," the Alton report said. Companies are advised to set up special internal teams dedicated to this side-planning, while other managers focus on daily operations.

In this second phase, suppliers will be pressed to take aggressive action to reshape their businesses, according to presentations by KPMG consultants in May, as lessons from prior aviation shocks such as 9/11 or the 2008 financial crisis proved companies should not just try to ride it out. "Companies that took swift and decisive action outperformed those that 'hunkered down' by 3-4 times," they said.

Complicating the challenge, however, is parallel advice against drawing sweeping conclusions. While widebody aircraft are having issues, for instance, it does not mean every twin-aisle type is suffering equally; the Boeing 787 is expected to fare better. In narrowbodies, the larger, longer-range A320 family is expected to perform better than MAXs for at least a few years.

"This is a much more surgical approach in this downturn," Robinson and Cole partner Jeff White says. "Not everyone will be impacted equally and hugely."

At the same time, several outside advisors to industry managers are certain A&D has entered an inflection point akin to transformations after the oil crisis of the 1970s, the end of the Cold War in the 1990s or after 9/11. A leading determination is that total business activity is expected to fall roughly 50% from peak to trough before a rebound takes root. This final phase will begin concurrently with the second phase of pandemic overhang and likely pick up momentum into 2021.

"Cause does not matter, but our premise is that industries tend to evolve at economic inflection points, both upturns and downturns," KPMG consultants say.

In this third and final phase, several trends will play out to redefine the industrial base: supplier consolidation, regionalization of supply chains, redomiciling and/or government investment in critical technology capacity, digitization of business practices and services across A&D, OEM insourcing and others. Resiliency, regionalization and cost reduction will be leading motivations.

Thus, more mergers and acquisitions are expected as well as divestments of so-called noncore business assets, and private equity investors are expected to play as much of a role in the future as they have to date. At the same time, governments are seen playing a larger role in legacy industry affairs, too, from being direct stakeholders due to bailouts to having a larger say in setting priorities. These range from requiring "greener" airliners to deciding who can buy what vis-a-vis "trusted capital" and antitrust authorities.

Furthermore, issues will emerge from actions that already have occurred. "Maintaining a healthy supply is one thing, but reforming the whole thing after turning it off is another challenge entirely," UBS analysts note. "Moreover, not only has the supply chain been turned off, in some parts it has been turned off, turned on and then turned back [off] again. In some other areas, suppliers were never turned off, which means years of underproduction versus a new lower demand profile await them in 2021 to 2025."

BOEING

MR. FIX-IT

When he was appointed CEO of Boeing last December, **David Calhoun** already had his hands full with the Boeing 737 MAX grounding. Then the coronavirus crisis hit, decimating demand for air travel and new airplanes. Wearing a mask and properly socially distanced, Calhoun met at the company's offices in Arlington, Virginia, with *AW&ST* Editor-in-Chief **Joe Anselmo** and Senior Air Transport and Safety Editor **Sean Broderick**. Senior Propulsion Editor **Guy Norris** joined the conversation by phone.

AW&ST: **A year ago, Boeing said it would be rejiggering safety oversight and engineering because of the MAX situation. Now that you're six months into the job, how far along are you in fixing those issues?** I think we're making tremendous progress. Those MAX moments [and the loss of lives] were devastating. It was like an earthquake. I don't want anybody at Boeing or in the world to forget that. We have more work to do so those kinds of things never happen again. There is more board engagement around safety and implementation of a more comprehensive safety management system within the company to gather not just discrete failures on airplanes but also squawks in the service industry to highlight things we should be looking at in the company and processing in real time.

We're also muscling up the engineering arm of the company. It's really [allowing] engineers to be independent of program leaders and have a direct line to the board on safety reporting. We've announced all the reorganizations, and we're not getting any pushback. Our program managers welcome it.

What makes you confident you've identified all the issues with the MAX and won't see a similar situation on the 777X or anything else that comes down the road? The alignment of our company around the engineering function. That single function, with its eye on safety, will have the authority and the charter to get ahead of the issues as opposed to catching up to them. Our 737 customers have zero concerns on confidence. A bunch of them have been flying it for a long time with no trouble, and a whole bunch of pilots love the aircraft. Now we've got to make sure that consumers understand this fleet of airplanes has a long history with a good safety record and just went through a deep examination with respect to certification.

Are there lessons learned from the MAX situation that you're able to apply? That pilot-control interface is real, and it should be studied every day. It should be studied based on the complete variation of skills that are available to the aviation market. We can never short that again. Every time we drop a spec for a flight control system in an airplane, we've got to understand this man-machine interface. And we have to understand it well, and it has to be contemporary. I don't think we'll ever miss that one again.

So much focus has been on "fixing" the MAX, but there are bigger-picture issues with human factors and understanding pilot populations and different training. We know the pilot population has changed. We know where we're selling airplanes and how young the compliance systems

are in some of those markets. One of Boeing's initiatives is addressing some of that, though we haven't had much of a chance to talk about it because of all the questions about MAX and COVID.

The COVID-19 crisis reminds us of when you took the helm at GE Aviation shortly before the Sept. 11, 2001, terrorist attacks. You steered that company through the recession that followed. This one is more severe and is going to take longer to recover from. Having gone through 9/11 gives me faith and confidence. I don't think anybody put forward as much capital as [GE] did at the time, and it paid off. When we're through the COVID waves, when vaccines are widely distributed around the world and people have begun to recover from the fear of the virus, we'll be right back to where we were. Global trade will not stop, global economic interdependence will not end, and the growing middle class in the world will want to travel. When you have faith in that, you can plan for the transition period. In Boeing's case it might be three years, or it might be five. I believe we have the resources and can sustain the research programs. We've got a portfolio of products to get us back and not just survive but win.

Is it fair to say the new midmarket airplane (NMA) is dead? Our team was out talking to plenty of people about it, but since we don't have a point design for our next airplane, I have to suggest that any particular vision anyone has for it right now does not exist. The design tools and production tools were always the most important part of the next point design, because we need to build that airplane for less money, more efficiently and to a higher level of quality than we've done in our lifetime. We'll get whatever [efficiencies] we can garner out of the propulsion community, but those kind of increments are not like they used to be. And so our differentiation at the airframe level has to be significant. I just think we got a little bit ahead of ourselves with the point design discussion. This is not about competing with the Airbus A321. This is portfolio versus portfolio, and we're going to find the spot where we think our customers want to fly in the most efficient way they conceivably can. We'll hunt for the biggest market, and that does not necessarily pit it against the A321.

You've got extra time now to develop your next commercial airplane. Does that open the door to technology previously thought to be a bit ahead of its time, such as the transonic truss-based wing? I think an airplane will be introduced before we get to that, or hydrogen and electric—all those things. That's the second generation, at least for this company, and I believe for the industry. But I do think there are a number of technologies that ultimately will get deployed. Again, it may have more to do with the way they're designed and built as opposed to the design itself.

The French government has linked its support package for Airbus to the introduction of a hydrogen-powered, carbon-neutral airliner by 2035. Do you think that's real, and could it have an impact on Boeing's product development strategy? I don't think the time frame the government suggests is reasonable. It's something longer than that. On the other hand, I'm all in favor, and I think Boeing will be a player. I don't think we'll ever allow ourselves to play second fiddle on that, amongst other alternatives.

My big hope in this COVID moment is that there's going to be a serious [parking] of [older] airplanes that need to be taken out of the skies, and they will steadily be replaced with today's technology, which is 20-30% more fuel-efficient and environmentally friendly. With all the growth, nobody really set down large parts of their fleets, but I think that day is on us, and I don't think that will be lost to the political and environmental interests out there. I think they're going to put pressure on the industry to take that step change with today's technology.

There's talk of a need for a 30% gain in fuel burn in the next-generation of narrowbodies. What is the most likely way to get there? Is it hybrid-electric, hydrogen, the structural concepts? There is not any one—it's going to be some version of hybrid in my view. There's going to be some development with respect to the wing and weight. Our ecoDemonstrator tests small increments in environmental and efficiency gains, and each little one will add to the list. But getting to 30% from where we are today is a long way.

How do you feel about your current commercial airplane portfolio? I like it. I don't feel desperate for anything. The 737 is rock solid. The MAX is going to be as safe as any other 737, if not safer, because of all the things that have been incorporated into the certification process. And the center of the market is not the A321—it's still the 737-8 in our world. [In widebodies,] I love our position on the 787. The market's going to slow down for a while [because of the drop in international travel], but people love the performance of that airplane. I love the 777X. We've tried to incorporate everything we can from this new certification process into the 777X certification. We'll start slower, no question, but I think we're going to be in a pretty good place on that.

Boeing had a deal to acquire 80% of Embraer's commercial aircraft business, which would have added the E2 to the lower end of your portfolio. Why did you pull the plug on the deal at the last minute? I made the decision as CEO. It was more about the deal than anything. Deals that involve shares, governments and other things sometimes get so tightly negotiated that they require that certain things are going to be a certain way when you push the button. This deal fell apart because what we thought we bought didn't turn out to be exactly what we got. There were a number of closing conditions that Embraer did not meet by the deadlines. It doesn't change my view that strategically the two companies had complimentary forces that would have been good for the industry, but in this case the deal fell short.

Airbus has a broader narrowbody product line, starting with the A220 (formerly C Series) and going up to the A321neo. Boeing was offered a really good deal to acquire the C Series before Airbus and turned it down. Was that a mistake? Absolutely not. I don't think

"The center of the market is not the A321—it's still the 737-8 in our world."

MARIAN LOCKHART/BOEING

there was ever a good deal. I would question that premise.

Boeing in recent years made a big push into the aftermarket space. How does that balance whether you want to incentivize customers to park older airplanes? I want to do what's good for the airlines, and I believe it's good for them to park inefficient parts of their fleets. That will definitely have an impact on my services business. We will make adjustments to reduce that footprint to accommodate what we think is going to be a younger, fresher fleet. While I believe strongly in the opportunity in the services market, I will always favor the most efficient fleet over my desire to maintain older planes. That may sound like heresy, but it's not.

What does that mean for Boeing's goal to generate $50 billion annually in aftermarket revenues? Let's just say that we have a big adjustment to make. It's still a big opportunity on the government side, which is more than half of the services business for us.

Boeing has faced major challenges across the company—the MAX in commercial, the KC-46 tanker in defense and Commercial Crew in space. Are you detecting a systemic problem, or are these individual and coincidental problems? I think they're unique to themselves, with one exception. It is not a surprise to anybody that the supply chain, production ramp-up and growth of the industry over the last 5-6 years has brought all kinds of stresses. You've been writing about it for quite some time. All the production lines and pretty much everything else had been stressed to move faster than they would otherwise be able to. And I think that takes a toll. I'm not saying that's the identical situation for each of these programs you're calling out, but that's the environment we've had for quite some time. Otherwise, these are unique problems.

At the end of the day, we didn't get done what we said we would, and we suffer in reputation, brand and confidence. So my Job 1 is to get back onto a stable platform in each of these cases. They can be made whole, and we'll be proud of them. But we're going to do it at a very slow, disciplined pace, and our confidence will come back with that.

The MAX grounding and COVID-19 have forced you to make some pretty brutal production cuts. What steps are you taking to make sure your key suppliers survive? Are you easing up on Partnering for Success? Yes. I think Partnering for Success may have gotten misinterpreted over the course of the years. I'm going to pledge transparency and support to our supply chain. [When the COVID crisis hit] and the credit markets practically shut down, we lobbied the [Trump] administration as hard as we could for support to the industry. We asked for big numbers, and they responded beautifully with the CARES Act. I've been surprised at how few have actually reached out to use it.

With respect to the rates, we're pledging pure transparency. I want them to know everything I know every day. We have tried to keep our suppliers ahead of us with respect to rate to protect our stability when we do begin to recover. We have definitely built that buffer into our system.

Boeing recently raised $25 billion from the capital markets. Do you anticipate having to raise any more money or take government aid in the coming year, or are you set? I certainly hope not. Our intention was to get us to the other side, not just through a year. That was a three-year deal for us. In the meantime, I would argue that the more troublesome problem in our industry was supply constraints and the instability of the supply chain. Without a virus, I don't think that was going to get fixed anytime soon. With a virus, you have an opportunity to reengineer lines and reengineer the supply chain and get ahead of the curve. I think both players [Boeing and Airbus] are starting to use the word "stability" more often. You can't get to the next level unless you're jumping off a stable platform.

BRAVE THE NEW WORLD

> BOEING FACES MULTIFACETED DRAMA

> LIKELY 737 MAX COMEBACK COINCIDES WITH CRISIS PEAK

> NO NEW PROGRAM LAUNCH EXPECTED FOR FIVE YEARS OR MORE

Hundreds of MAX orders have been removed from Boeing's backlog during the model's grounding.

JOE WALKER

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

A year may seem like a long time in politics, but for Boeing, two years in aerospace must be an eternity as it begins the slow recovery from the unparalleled series of setbacks, accidents and downturns that have struck it since 2018.

At the Farnborough International Airshow two years ago, before its world was upended by the first of two fatal 737 MAX accidents in October 2018, Boeing's biggest challenges concerned how to meet surging demand for its new single-aisle derivative family. At the time, the company furiously was studying the new midmarket airplane (NMA) amid seemingly positive prospects for a 2019 launch.

The company simultaneously was gearing up for the start of 777X flight tests and planning for production increases on the 767 and 787. Ultimately, Boeing ended the 2018 air show with 673 orders and commitments—the bulk of them for 737s, along with a total of more than 100 787s, 777s and 747 freighters. The event also provided an occasion for Boeing and Embraer to detail their merger plans.

But now, in what would be another Farnborough Airshow month in a normal even-numbered year, how far away that old world is. Perhaps nothing symbolizes the company's fall from grace better than the fate of its 737-7 development aircraft, 1E001. Two years ago, it was one of the stars of the 2018 show, impressing crowds with its agile flying display and quiet fly-pasts. Fast-forward to July 2020, and the same aircraft is being used for recertification flights aimed at ultimately returning the MAX to service after an unprecedented 16-month grounding.

So what now? With Boeing's most popular product sidelined, production of widebodies slashed in response to the market collapse triggered by the COVID-19 pandemic, the Embraer deal dead and its product development strategy in disarray, the company is retrenching. While Boeing steadies the ship, it also is leaning more heavily than ever on its defense business, which contributes

OPTIMISTIC

> Air travel rallies quickly and evenly around the world (2019 levels by 2022), the Boeing 737 MAX returns to service in 2020, and Boeing begins to ramp up production across the board.

NEUTRAL

> Demand recovery takes several years, and sluggish new-aircraft sales hamper most, if not all, of Boeing's product line.

PESSIMISTIC

> Demand headwinds are coupled with program-specific challenges, such as lukewarm acceptance of the MAX, problems with Boeing 777X certification or a long-term widebody orderbook slump.

more than 30% of the organization's overall turnover.

In charge since only January 2020 following the ouster of Dennis Muilenburg, is President and CEO David Calhoun (see page 29). He is facing what must look like an impossible task. Dealing with the fallout of the pandemic has come on top of what already was Boeing's worst crisis, the MAX accidents and the model's subsequent global grounding. And the MAX drama is not only about returning the aircraft to service but about analyzing the root causes of the misery and what changes are needed to the company culture and processes to eliminate them. All of that and more has to happen at the same time.

The MAX was losing market share vis-a-vis the Airbus A320neo even before the grounding, an untenable situation at least in the longer run that has forced Calhoun and Boeing Commercial Aircraft President and CEO Stan Deal to take a close look at the group's future product strategy.

In terms of its finances, Boeing is entering uncharted territory and certainly is far from where stakeholders thought it would be at the start of 2020.

In March, Boeing stunned the financial world and Washington when it asked for more than $60 billion in federally backed assistance—mostly for itself but also for the roughly 17,000 direct and indirect suppliers that feed into the OEM and prime defense contractor's supply chain. By the end of March, its net debt was roughly $23 billion ($39 billion gross before $16 billion in cash on hand). At the end of April, Boeing secured $25 billion in new funds via one of the largest single corporate debt offerings on record. That fundraising came on top of a nearly $14 billion credit facility that Boeing drew down in mid-March as the COVID-19 outbreak spread around the world.

Many financial analysts see the company ending 2020 $45-50 billion in the red. By comparison, at the end of 2018, Boeing had $4 billion of net debt and nearly $14 billion of free cash flow, with expectations of sequential growth over the following several years.

Calhoun asserts the Chicago-based aerospace and defense (A&D) behemoth will make good on its debt pile, but he acknowledged it will take longer. "We have stress-tested the case that we're putting forward in many, many ways that are much more difficult than what we believe we're going to do," he said April 29. "And we [will] get through it. Now at what rate we pay it down is the real question. But when we get to some form of stability at these production rates, and I believe we will, we'll be in good shape to begin returning money to our lenders."

To maintain goodwill with investors, Boeing canceled its planned $4.2 billion purchase of 80% of Embraer's commercial business and is laying off at least 10% of its workforce—both embarrassing turnabouts. And Boeing likely will have to take further actions that could box it in for years.

For now, analysts widely see Boeing burning a lot of money this year to support operations before making some next year. Standard & Poor's predicts Boeing could bleed $19-20 billion this year and then retain $9-10 billion in 2021. UBS analysts forecast Boeing burning through $15 billion this year and then generating $2 billion in 2021 after costs of operations are paid. Jefferies analysts expect $14.4 billion to be burned this year but see $11.7 billion being generated in 2022.

But there are hard choices. "Boeing won't burn cash forever. A portion of the burn in cash flow today is within the control of Boeing to regulate," UBS analysts noted in their June report. "If they chose to pull way back on production, they would burn less cash. But that could sacrifice the company's future earnings potential and risk sacrificing wide swaths of market share over the long term and do hard-to-reverse damage to the supply chain over what is likely the near-term demand shock."

Not surprisingly, with Boeing's key position atop the U.S. A&D industrial base as well as its role as one of the largest defense prime contractors, the Trump administration has marked the company as too important to fail. In mid-June, the Treasury Department said it was holding off on distributing most of a $17 billion federal fund for defense contractors provided under this spring's Coronavirus Aid, Relief, and Economic Security (CARES) Act in case Boeing and General Electric need the money later. As of the May 1 deadline, only about 20 applications, from smaller companies, had been received for the national security pool.

There are other ways Washington can help, too, including through the Federal Reserve's Primary Market Corporate Credit Facility and Export-Import Bank credit guarantees. Boeing has not ruled out any of this assistance publicly. A company statement April 30 on the $25 billion debt placement said simply that the company did "not plan to seek additional funding through the capital markets or the U.S. government options at this time."

Still, doing so may spur new cause for concern. "The markets are not anticipating Boeing needing to come back [for money] in the next 12 months," Douglas Karson, a bond analyst at Bank of America, said in June during an Aviation Week webinar. "I think that would be unlikely and probably met with some fear, because if Boeing burns through the $25 billion that it just got, plus the bank lines [of

credit] that it has drawn, that would probably point to a deeper problem in the aviation market."

With an initial return to service for the MAX in September now looking increasingly realistic, the company's focus remains fixed on efforts to begin delivering the huge inventory of stored 737s while slowly restoring production of new aircraft at its Renton, Washington, facility. Despite signs of progress on these fronts, Boeing is bracing for more headwinds. Even if certification is approved within the next two months, the manufacturer knows it will be challenging for most airlines to accept the grounded MAXs in significant numbers. Deliveries are needed urgently to restore Boeing's cash flow.

Recertification means more than bringing the 737 back to life. The process will begin the company's painstaking task of rebuilding crucial regulatory relationships with the FAA, European Union Aviation Safety Agency and other such organizations around the world. The MAX accidents exposed fundamental issues with Boeing's safety culture and tarnished the company's engineering reputation, both areas that current restructuring efforts are designed to address.

"It's really [allowing] engineers to be independent of program leaders and have a direct line to the board for safety reporting," Boeing CEO David Calhoun tells Aviation Week. "We've announced all the reorganizations, and we're not getting any pushback. Our program managers are welcoming it."

The MAX has gained no orders in more than a year, thanks to two fatal accidents in five months that led to a global grounding in March 2019 and a delivery halt a month later. Boeing is making progress in obtaining return-to-service approvals of changes to the MAX triggered by the accidents and subsequent reviews by regulators, most of them focused on revamped flight-control system software. Despite a shrinking backlog and the program's dismal operational start—mid-July marked 16 months into the grounding, or only six fewer months than the aircraft's time in revenue service—Boeing insists MAX buyers still want the aircraft.

"Our 737 customers have zero concerns on confidence," Calhoun says. "Zero." Needless to day, the Boeing CEO also has none: "I do have faith in the technology of the 737." Calhoun also is bullish on the MAX's long-term outlook. What concerns customers is matching fleet sizes with demand, and the MAX's orderbook illustrates the ramifications. At the end of 2018, or three months before the grounding, Boeing boasted a 737 backlog of 4,700—most of them MAXs. From January 2019 through early July 2020, it delivered 132 aircraft: MAXs handed over before deliveries stopped, the last 737 Next Generation models and P-8s, Aviation Week Fleet Discovery data show. But the 737 backlog shrank by 470 from MAX cancellations.

"Every single customer is trying to jigger its [delivery] schedule," Calhoun says.

The changes likely have just begun. Jefferies analysts believe as many as 600 additional MAXs will be removed from airline and lessor backlogs in response to what is expected to be a multiyear demand-recovery period.

The pace of retirements will influence this. In the 737's case, the average age of the 6,500-aircraft NG fleet is a young 10.1 years, a Naveo analysis of Aviation Week Fleet Discovery data shows. But about 1,440 of these, or 22%, have been in service for at least 15 years, making them strong candidates for storage or retirement, especially by operators with more efficient MAXs on order.

In the near term, Boeing is respond-

Retooled Boeing Defense and Space Bets on Business Change

> THE T-7A AND MQ-25 TYPIFY NEW APPROACH

> THE KC-46 STRUGGLES OFFER WARNING SIGN

Steve Trimble Washington

As a fresh crop of franchise programs are set to enter production, Boeing Defense, Space and Security (BDS) seems to be a model of stability in a corporation beset by multiple extended crises roiling the commercial aircraft and services divisions.

The MQ-25 unmanned aircraft system (UAS), T-7A trainer and MH-139 helicopter will each enter service by the middle of the decade, joining the U.S. Air Force's revived F-15EX order pipeline for a decade or more potentially. As a partner to Sikorsky, Boeing hopes to add another franchise program to the backlog in 2022, when the Army selects the winner of the Future Long-Range Assault Aircraft (FLRAA) contract. Not surprisingly, the BDS backlog at the end of 2019 stood at $63.9 billion, a 4% improvement compared with the year before.

Boeing still cannot afford too many mistakes. The fate of several programs—including the partnership with Bell on the V-22, P-8A, F/A-18E/F and CH-47—hinge on either new foreign orders or congressional intervention to avoid a line shutdown within the next two years.

Some of Boeing's franchise victories also put it at risk for heavy losses. For example: The Air Force considered the KC-46 to be a low-risk development program based on mature technology, so it awarded Boeing a fixed-price development contract in 2011. Boeing has recorded more than $3.72 billion in reach-forward losses on the KC-46, and the company still must pay to redesign and install the Remote Vision System across the fleet over the next three years. Since 2011, Boeing has received additional fixed-price development contracts for NASA's Commercial Crew, the Air Force's T-7A and VC-25B, and the Navy's MQ-25 programs.

Boeing's role in the next wave of defense technology also is not clear. Although the company has been a global leader in hypersonic technology for decades, Boeing was overlooked by the Pentagon on a series of contracts awarded since 2018 to develop several

ing with a slow production-rate ramp-up. Top 737 supplier Spirit AeroSystems has been told to deliver 72 shipsets in 2020. Production officially restarted in June after several weeks of preparation, and new aircraft fuselages are rolling out.

Jefferies projects MAX production reaching just five per month by year-end, bumping up to 31 per month by 2022—aligning with Boeing's latest estimates. When the MAX was grounded, production was at 52 per month and headed to 57. The pandemic's ramifications mean the 737 program may never see such levels again.

Recertification also will clear the way for Boeing to resume full-scale development of the final MAX variant, the stretched 737-10, the first flight of which was delayed by the crisis. Launched in 2017, the 230-seat aircraft originally was expected to enter service in July but now likely will debut in late 2021, assuming flight tests go as planned. The test focus for the 143-ft.-long 737-10, stretched by 66 in. over the 737-9, will be on flight characteristics and performance of the completely new taller main landing gear design. Configured to raise the body by a further 9 in., the design combines a telescoping feature to shorten the gear legs and a semi-levered lower element to move the aircraft takeoff rotation point aft.

At the other end of the size scale, the test and certification of Boeing's first 777X derivative, the 777-9, also has slowed due to disruption caused by the pandemic plus a greater level of scrutiny from the FAA in the wake of the MAX recertification effort. Originally targeted at service entry this year when launched in 2013, the stretched 777's debut has now slipped to later in 2021 following successive development delays with the aircraft's Boeing-built composite wings and General Electric-developed GE9X engines.

The pace of flight-testing is, however, expected to increase substantially later this summer as two more aircraft join the program, which began with the first flight of the initial development aircraft last January. A second engineering, manufacturing and development 777-9, WH002, entered the test effort on April 30, while the third aircraft is expected to join shortly.

Despite the delays, though, the collapse of the global long-haul passenger market means none of the aircraft's leading customers such as Emirates or Lufthansa is in a hurry to accept the 777-9. For the mid-term, Boeing hopes the ramp-up of production in 2022-23 will coincide with the beginning of the long-range market recovery and that the aircraft's twin-engine economics will come into play as operators seek capacity in the wake of earlier Boeing 747-400 and 777-300ER and Airbus A380 retirements. "We'll start slower, no question, but I think we're going to be in a pretty good place on that,"

BOEING

Boeing 737 Program at a Glance

Backlog as of Dec. 31, 2018	4,708
Deliveries between Jan. 1, 2019, and June 30, 2020	136
Backlog as of May 31, 2020	4,221

Sources: Aviation Week Fleet Data Services and Boeing

new operational prototypes. Boeing has been the Air Force's primary supplier for intercontinental ballistic missiles for nearly 60 years, but it chose not to bid on the Ground-Based Strategic Deterrent contract to develop a successor to the LGM-30 Minuteman III.

Several peers, including L3Harris, Lockheed Martin and Northrop Grumman, have publicized their philosophy on a distributed command-and-control architecture. Boeing executives have said that the Phantom Works rapid prototyping division is working on a concept called Phantom Fusion, but they have not described the concept or any tests conducted so far.

Boeing's approach to Next-Generation Air Dominance (NGAD) has been more visible. The partnership with the Australian government on the unmanned Airpower Teaming System gives Boeing a prototype of a low-cost and attritable UAS, which could be offered as a candidate for emerging requirements for such an aircraft in the UK and U.S.

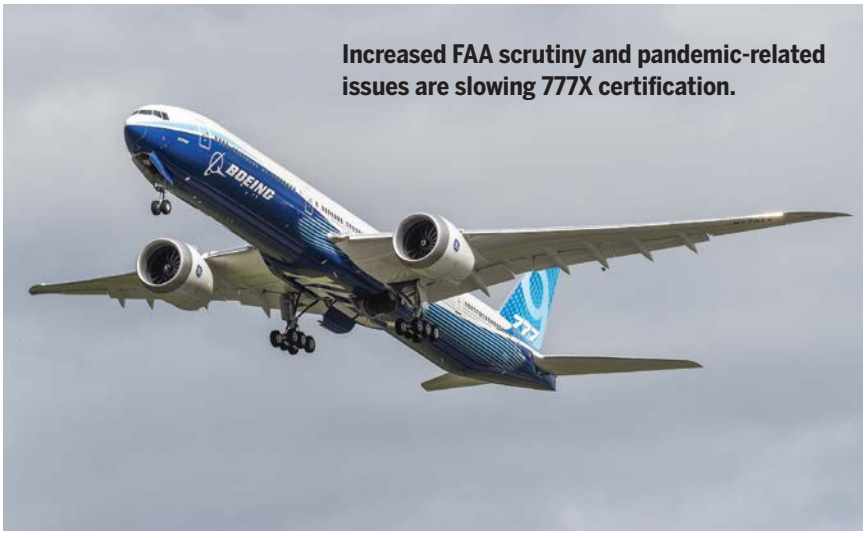
As BDS looks to future programs, the company's recent successes point to a new model: the T-7A and MQ-25 rolled out of Boeing's St. Louis factory as the first clean-sheet examples of a new Boeing design process. For decades, aerospace companies have used different sets of digital models of new aircraft to help predict aerodynamic performance and the manufacturing processes. For the T-7A and MQ-25, BDS expanded that approach by constructing a single model to simulate aerodynamics, manufacturing and sustainment at the level of a line replaceable unit.

"Rather than developing a certain product, we placed our bets on changing the way we did business," BDS CEO Leanne Caret told Aviation Week, adding, "And we have positioned ourselves nicely" (*AW&ST* July 13-26, p. 60).

Counting on the new process to generate significant savings compared to traditional methods, BDS leveraged that approach in 2018 to win the fixed-price contracts for the T-7A and MQ-25 by significantly underbidding competitors. Lockheed Martin said it submitted "aggressively" priced bids for both contracts, but Boeing's offers came in at about $5 billion less. Those victories came at a different time for Boeing, however, just 2-3 months before the first of two crashes that triggered the ongoing grounding of the 737 MAX 8. The awards also came 18 months before the global travel industry nearly ground to a halt due to the COVID-19 pandemic.

If BDS' future as a defense prime depends on leveraging the T-7A and MQ-25 models to win major new franchise contracts, such as NGAD and FLRAA, the company cannot afford another a KC-46-style, billion-dollar imbroglio on fixed-price contracts.

BOEING



Increased FAA scrutiny and pandemic-related issues are slowing 777X certification.

Calhoun says as he prepares the company for a long recovery phase.

"When we're through the COVID waves, vaccines are widely distributed around the world and people have begun to recover from the fear of the virus, we'll be right back to where we were," he says. "Global trade will not stop, global economic interdependence will not end, and the growing middle class in the world will still want to travel."

To get back to normal production rates, "in Boeing's case it might be three, it might be five years," Calhoun notes.

While pledging "transparency and support for the supply chain that supports Boeing," Calhoun also points out that COVID-19 presents an opportunity not to be missed to fix issues that have plagued the industry for years.

"I would argue that the more troublesome problem in our industry was the supply constraints and the instability of the supply chain," he says. "Without a virus, I don't know if that was going to get fixed anytime soon. With a virus, you have an opportunity to reengineer lines and reengineer the supply chain and get ahead of the curve."

Beyond the 737-10 and 777X and in spite of the MAX losing market share at an accelerated pace, Boeing has hit the pause button on its product-development studies. Company insiders tell Aviation Week it is likely to be five or six years before the company will commit to the launch of a next-generation single-aisle family, which is now the next logical focus for its efforts given the diminished long-term prospects of the MAX.

While in retrospect, the company's early-2020 decision not to proceed with the NMA was a blessing in disguise, the path forward remains uncertain, particularly in terms of timing and technology. For instance, although a Future Small Airplane (FSA) seems like the likeliest bet for the next big project, will the company pursue an evolved conventional design or perhaps take advantage of the COVID-19-caused delay to embrace more radical concepts?

If Boeing goes ahead with an all-new FSA around the mid-2020s, would the entry-into-service window of the early 2030s provide the company with sufficient time to consider even more advanced structures, systems and propulsion technology? Answers could come from ongoing work with NASA aimed at potentially flying an X-plane demonstrator of the company's transonic truss-braced wing (TTBW) concept later this decade.

Calhoun says, however, there will likely be a nearer-term, conventional product offering on the table before anything too exotic is considered. "I think an airplane will be introduced before we get to [things like TTBW] or hydrogen and electric, all those things," the CEO predicts. "That's the second generation, at least for this company and I believe for the industry."

While a raft of advances in aerodynamics, structures, systems and propulsion certainly will be considered for the next new product, the one guaranteed advance will be implementation of the model-based systems engineering and development (MBSE/MBD) design approach honed and developed for the NMA. MBSE/MBD centralizes all information about a system in a digital model that supports the entire life cycle of a program from design and build to maintenance and training.

By enabling Boeing and potential partners to perform virtual system integration and test, MBSE formed a key part of efforts to help crack the NMA business case. It was successfully tested on other Boeing efforts ranging from the T-7A military trainer to the folding wingtip of the 777X and is considered a vital technology in its own right. Calhoun says while "a number of technologies" may be deployed on the next new airplane, "the technologies may have more to do with the way they're designed and built as opposed to the design itself."

As for hydrogen power, and other longer-term sustainment strategies, Calhoun is "bullish," but believes the ambitious 2035 entry-into-service target set by the French government as part of its recent €1.5 billion ($1.7 billion) research and development support plan for a carbon-neutral commercial airliner may not be reasonable. "It's something longer than that," he says.

However, Boeing does not plan to be left behind as Airbus pivots to hydrogen fuel, particularly if French government support puts the European aircraft maker on course to develop a carbon-emissions advantage. "I think Boeing will be a player, and I don't think we'll ever allow ourselves to play second fiddle on that among other alternatives," Calhoun says.

Aside from nebulous reengining and rewinging studies for the 767—for an option to tackle the upper end of the former NMA market space—and potential longer-term reengining evaluations for the 787 later in the 2020s, Boeing's product strategy leaders therefore have much to ponder. The company knows it has effectively ceded the lower segment of the NMA market to the Airbus A321XLR and that once the MAX is back in the air, key decisions must be made to avoid potentially losing the future single-aisle sector to more sustainable options from its European competitor in the 2030s.

—With Jens Flottau in Frankfurt

Craic CR929 Development Extended as Partners Wrangle

> "SOME DIFFICULTIES IN COOPERATION" HAVE ARISEN

> SUPPLIER SELECTION WILL TAKE MORE THAN THREE YEARS

Maxim Pyadushkin Moscow and **Bradley Perrett** Beijing

The joint Russia-China Craic CR929 widebody airliner program has slipped by two years, and the Russians have fairly bluntly explained why: disputes between them and their Chinese partners over sharing technologies and markets. The first delivery is now due as late as 2029; the delay is linked to supplier selection.

Reporting on progress to Russian senators on July 8, Irkut CEO Ravil Khakimov said supplier selection would probably not be completed until next year—about halfway through the original development schedule.

Craic is a consortium of China's Comac and the United Aircraft Corp. (UAC), within which Irkut runs the Russian side of the program. Full-scale development began in May 2017 with a target of beginning deliveries no later than 2027.

The consortium began requesting proposals from suppliers in late 2017. Most prominent among the prospective supplier choices is the one for propulsion: Both General Electric and Rolls-Royce have offered engines.

Selecting suppliers has been delayed repeatedly, thus affecting the schedule for aircraft deliveries, the CEO said, adding the most recent objective had been to finish that task this year.

"We planned to complete [selection] with work in 2020 and move to contracting with all the subcontractors and suppliers," he told the senators. "Unfortunately, we have some difficulties in cooperation with the Chinese partners, so this stage is likely to move into 2021."

The current stage, called Gate 3, also includes final definition of the aircraft configuration. Khakimov did not say which difficulties had been met. Because of the delay in supplier selection, deliveries will not begin before 2028-29, the CEO said. Comac did not respond to a request for comment.

The program is supposed to be shared equally by the two countries, but the division of responsibilities has been the subject of protracted negotiations. A day before Khakimov spoke, Russian Industry and Trade Minister Denis Manturov told senators that although cooperation with Comac had not been without trouble, Russia was still financing the program.

"The Chinese entered the program with a main goal of getting technologies while keeping the local market for their own [widebody] aircraft," Manturov said, apparently meaning Comac wanted to sell CR929s that it would build. "We are in constant search for a compromise, as our goal is not to share the technologies but to get a foreign market," he said.

China has the most important market, but Russia has technology in composite wings and experience in widebody jets that the Chinese cannot hope to develop on their own this decade, said Sash Tusa of London analysis firm Agency Partners.

The CR929 schedule has shifted before. In 2018, Comac said the program goal was to begin building the first prototype in 2021, fly it in 2023 and make the first delivery in 2025—that is, after eight years of development. Since the Chinese company then was expecting to have the C919 ready for delivery after 13 years of work and had taken that long with the ARJ21, industry met this forecast with great skepticism.

Later in 2018, UAC President Yuri Slyusar told Aviation Week the 2025 target might be optimistic. In 2019, he said Craic would begin deliveries in 2025-27—diplomatically accommodating his partner's outlook while leaving open what he must have thought was a more realistic date and what was more likely his own.

Craic's headquarters are in Shanghai, the home of Comac. The parties have agreed to set up the main engineering center in Moscow, with a branch in Shanghai.

China and Russia agreed in 2014 to develop the aircraft because high-level officials of the two countries wanted a joint program—but Comac would have preferred to develop its own widebody.

Manturov said Russia has an alternative for the CR929, too, because UAC is in preliminary development of a two-engine derivative of the Ilyushin Il-96 widebody. This would be powered by the new Aviadvigatel PD-35 turbofan. The four-engine Il-96 uses that company's PS-90A.

The baseline CR929-600 is intended to carry 280 passengers in a three-class configuration and will have a range of 12,000 km (6,480 nm). Longer and shorter versions would have the same gross weight (see table).

Last year, UAC's Slyusar said the first flight would be in 2023-25. No update is available for that objective.

BRADLEY PERRETT/AW&ST

The first version of the Russian-Chinese aircraft is to be the CR929-600.

Craic CR929 Specifications

	CR929-500	CR929-600	CR929-700
Length (m/ft.)	58.675 / 192.5	63.755 / 209.2	68.835 / 225.8
Span (m/ft.)	63.86 / 209.5	63.86 / 209.5	63.86 / 209.5
Three-Class Seating	258	280	320
Maximum Takeoff Weight (metric tons)	245	245	245
Range (km/nm)	13,600 / 7,340	12,000 / 6,480	10,000 / 5,400

Source: UAC 2018

'We Have To Be Super-Humble'

Guillaume Faury became CEO of Airbus Group in April 2019 after just over a year as president of the company's commercial aircraft business. With only one year in the job behind him, the 52-year-old has to steer Airbus through the worst crisis commercial aviation has ever faced, cutting costs where possible while protecting substance where needed. Faury met with Aviation Week Executive Editor for Commercial Aviation **Jens Flottau** at Airbus headquarters in Toulouse. With air travel all but impossible throughout the spring, it was their first in-person meeting in several months.

AW&ST: **You cut production by around 40% to respond to the COVID-19 crisis. When do you expect a recovery?** We don't think we'll see 2019 delivery rates again before 2023 to 2025. We made a very early [production cut] in the beginning of April because we had to. There was a lot of guessing and assumptions, but it turned out we were not too wrong. We still will be making minor adjustments, as in normal times. We have growing clarity for the short term—2020 and 2021. It's more difficult to assess when the recovery will come. The single-aisle market will recover before the widebodies.

So your initial guess was pretty accurate? For the short term, yes. We still think that 40 narrowbodies per month is the right rate for 2020 and 2021. It might change a bit, but not significantly. I am not suggesting I know where it will be in 2024. I don't. We have models and are preparing to be able to ramp up again. It is likely that the recovery will see massive demand, so the ramp-up will have to be steep. I see that in 2022 or 2023, a bit later for widebodies.

But we have to be super-humble. The shape of the traffic recovery itself is still to be seen. There should be a relatively stable recovery in the summer and the second half for domestic flights, and long-distance travel should have largely recovered by the middle of next year. This is the kind of timeframe we need on the traffic side for us to resume 2019 deliveries between 2023 and 2025.

Are you assuming a second coronavirus wave in your models? There will be small second waves, but we are not assuming a major second wave next winter as big as 2020 in terms of impact on traffic. As long as there is no vaccine, there will be ups and downs, small confinements and reopenings.

You plan to eliminate 15,000 positions within one year. To what extent is there a danger that Airbus is losing substance and experience that it will need once the demand returns? We cannot escape the developments affecting the airlines and the industry as a whole. This crisis is unprecedented, and its scale requires us to adapt quickly to the new market environment to secure the future of our company. Going through this transition, we will work with our social partners in order to limit the social impact of our COVID-19 adaptation plan. We will rely on the full set of measures available while retaining our skills, competencies and know-how as much as possible so we can be ready to meet our customer demand when the market recovers.

You are still in the middle of deferral discussions with your customers. We are working with all customers. There are as many different situations as we have customers, and it changes almost every day. The situation is extremely difficult. Any new agreement will be painful but has to be acceptable for everyone. That is the balance we need to strike.

There was a point in time when the customers really had difficulties defining the way forward. They were grounded; some of them had no liquidity for the coming months. They had to go through their own crisis management. The timing differed, depending where on the globe they were based and when they were impacted by COVID-19. Some now


J.V. REYMONDON/AIRBUS

have a defined battle plan and others are still negotiating the situation. Sometimes we have intermediate agreements with them to gain more time. We are getting more visibility, and everyone is betting on a certain speed of traffic recovery. But we are still negotiating with a lot of uncertainties in front of us.

EasyJet recently negotiated a very precise agreement with you that detailed the new delivery sequence. Is that the kind of blueprint deal that you are trying to achieve with every customer? Yes, that is what we are trying to achieve with airlines—new contractual agreements that give visibility to the customer and to us.

Given reduced production rates, is the current industrial footprint with assembly lines in five different locations sustainable? We will not invest money now to restructure when we know that we have a setup that works. It's more complex than our competitor's, and that comes with benefits that will be very important in a more fragmented world. Being very American in the U.S. in Mobile, Alabama, and being a strong partner in China in Tianjin will have value. Airbus has learned over the years to manage complexity. It is one of our strengths. We have to live with less revenue in the short term, but in the long term aviation will come back.

Speaking of the short term, small aircraft seem to be benefiting from the lower traffic volumes. Do you think that there will be a behavioral shift—with airlines no longer focusing on unit costs but on trip costs and thus smaller aircraft? The business model of airlines is mainly fixed costs and variable revenues. When you are in a stable environment, you are more interested in costs per seat-kilometer. When there is risk, you have to minimize your exposure, therefore you focus on cost per trip and smaller modules. I think that is what we will see for the next few years. Smaller planes on the same routes, point-to-point as much as possible. Small modules with long range are likely to be a winner, at least for a certain period of time. The A220 and the long-range versions of the A321neo should really make a lot of sense, along with the A350 for longer distances.

Airbus has cut the A330neo rate to two a month. Its biggest customer, Air Asia X, is facing difficulties, and the in-service fleet is relatively young. Is the program now in question? No. The rates are lower, but some of the production slots are for military variants, which de-risks the program. The A330neo is not more impacted than others. It's an aircraft with good economics. That we had to cut rates now doesn't say anything about the medium and long term. We'll stick with that product, to be very clear.

On top of COVID-19, Boeing is also facing the problems with the 737 MAX. Will that lead to a permanent shift of market share in Airbus' favor? We have seen so many changes since the end of 2018, when Boeing was unreachable, that we have to remain humble. We are focusing on our customers and not really thinking about market share for the moment. Obviously, today's market share reflects the grounding of the MAX, but Boeing is working on getting it back into service, and when it is, the picture will change again.

Are you concerned that Boeing might somehow find the money to launch a clean-sheet successor to the MAX sooner than expected? That question was on the table before COVID-19, but the pandemic is pushing it off the table. I don't see anyone launching a new plane with this level of uncertainty on so many fronts, in particular a competitor [focused on] returning the MAX to service. It is for them to say what they intend to do, but I think their priority is somewhere else.

How much will Airbus benefit from the termination of Boeing's deal to acquire a controlling share of Embraer's commercial aircraft business? It depends on what happens. They will have to find a way forward. Their previous plan was to sort of mirror what we did with the A220, and it made sense from my point of view. Events have led to a different situation. This raises questions for Boeing probably to a bigger extent than for Embraer.

The French and German governments released financial support packages for the industry that are tied to technology targets. Will these force the industry to accelerate innovation? We played a role in the discussions with the government. [The package] is designed to develop the technologies to prepare for the next generation. Obviously, the post-COVID-19 world will be even more focused on the environment. We're not being forced; it is an opportunity. It is not designed to launch programs and therefore not related to your question about a new plane. It is designed to prepare the launch of a new plane at a later stage with a package of technologies that does not exist today and that we need to develop and mature. COVID-19 is in some respects slowing us down [in making] big investments for which you need certainty and visibility. But it is an accelerator when it

comes to increasing your agility and flexibility to adapt to future trends.

So it seems the first target is a regional aircraft? Ah, people are trying to give different names to what we are doing. We are focusing on technologies designed for the next generation of planes. It has not been decided what will be the first program. It will probably be at the low end of the market, but I can't tell you where.

But there is a timeline the French government has defined? Ask them. I can tell you what we discussed with them and what we think is reasonable. It is the entry into service of the first fully decarbonized plane by 2035. It is really something I believe in because it means launch of the program in 2027 or 2028. We have to mature the technologies by 2025; then you have two years to prepare the launch, consult the suppliers, define the general architecture and work the business case. Will the aircraft cover the whole range of the narrowbody segment, from the A319 to the A321XLR? Probably not. Single-aisle is now a very broad segment. Our competitor wanted to cover it with a MAX and the [new midmarket airplane]. We would be wrong to try to think of the aircraft of the future by looking at today's structure of the market.

There seems to be a push toward hydrogen technology rather than electric flying. Yes. However, the two are not opposed. A hydrogen car is an electric car with the energy stored in hydrogen instead of batteries. The difference is not the powerplant, but in energy storage. When we go to hydrogen in aviation, we have two different ways to use it on board. One would be to burn hydrogen and the other to run on a fuel cell, which is like a car or train powerplant on a plane, with many more constraints.

Which option do you prefer? We don't know yet. They probably don't have the same timeframe, complexity or investment requirement. That's why we're looking at different routes. We can accelerate [the process] by looking at all of them at the same time. There is more investment going into innovation now and not only in aviation. There is cross-fertilization with other means of transport. We are on the hydrogen council with many other industries including cars, shipping, energy—everybody is there.

AIRBUS

Pegasus is one of the few airlines continuing to take delivery of Airbus narrowbodies, like this A321neo, during the crisis.

Without COVID-19 and the government initiatives it triggered, would you have talked about entry into service in 2035? We were already on the 2035 assumptions. I think I said a year ago that in order to reach our target to halve emissions by 2050, we needed entry into service around 2035 of planes that are significantly decarbonized. The acceleration is probably around the idea that we are pursuing several paths in parallel, which is not necessarily what we had in mind six months ago.

How hopeful are you that European defense cooperation is going to stabilize your military business? Eurodrone is going in the right direction and paves the way for the [Future Combat Aircraft System (FCAS)], which is going from a German-French cooperation to a German-French-Spanish project. These are real European defense projects in which Airbus plays a big role. I think we have the DNA to make them successful. Europe feels the need to prepare for the sovereignty of the future, which includes the air and space power to protect your territory from the skies. I am very happy and optimistic that this is moving forward.

What is happening [politically with the U.S.] unfortunately accelerates the fragmentation of the world, leading to the need to protect ourselves—to ensure the security of Europe with European means and tools and systems. It makes a lot of sense for us to be in defense, space and helicopters. A year ago, I made a firm statement that we are an aerospace group that is not only about commercial aviation. This crisis proves that it is very important to have different pillars and maybe grow defense and space more than before.

Life in France is slowly returning to normal after the COVID-19 lockdown. How has your daily routine changed? We all went through the same experience, adapting week by week. What was particular to Airbus is that we are exposed to the rules of the many, many countries in which we are operating. One of the many challenges we had to face when we put together a crisis group to handle the situation was getting access to all the different rules. We have a very complex and synchronized supply chain, and with countries introducing lockdowns at different times and with different rules, it was supercomplex. We largely had to work remotely. One of the big risks during the lockdown was losing control of the production system.

Were you mainly in Toulouse? I was stuck in Paris at the very beginning, then I was in Toulouse, and then I started to commute. We had to organize private aircraft so we could bring the management team together. Now we are traveling again on commercial airlines.

THE BIG RESET

> AIRBUS' PRODUCTION PLANNING INCLUDES SUPPLIER AND EMPLOYEE CONSIDERATIONS

> EMBRAER REVAMPS FOR POST-PANDEMIC PERIOD AFTER BOEING DEAL COLLAPSE

> ATR, DE HAVILLAND HOPE TO BENEFIT EARLY

Jens Flottau Frankfurt

AIRBUS

Airbus reduced A350 production to six from 9.5 aircraft per month.

If commercial aerospace industry production decisions were defined strictly by customer demand and no other considerations, the best move manufacturers could make at this stage of the COVID-19 pandemic would be simply to shut down temporarily and reopen when things get better. As the most recent monthly delivery figures for Boeing and Airbus show, hardly any customer is taking delivery of new aircraft and probably none want to. The few exceptions are providing a very limited stream of revenue to an industry on the brink.

That OEMs still are producing aircraft in spite of the overwhelming odds they are facing indicates the complexities of their business and the many other factors they need to take into account. The bottom line is that stopping production is generally not a feasible option for many different reasons.

Therefore, the industry's main players need to find the least, but still extraordinarily expensive, way to muddle through what is likely to be a dismal two years in which the worst combination of factors comes to play:

- No demand for new aircraft, yet the Boeing 737 MAX is expected back in service (and production) in the next few months.
- Airbus, until only a few months ago pushing hard to maximize output, is now forced to reverse course and slow down an industrial machine that was stretched to its limits.
- The business case for Embraer's E2 family was based on the assumption of significantly higher output than for the E1, yet the company is now dealing with the exact opposite trend for an aircraft that was struggling to gain traction in the market even before the pandemic closed off the previous outlook.

That there will be structural change for the industry at least in the short- and medium term is evidenced by Mitsubishi's decision to freeze flight-testing of the M90 and shelve work on the already redesigned M100.

There were three regional jet manufacturers with realistic prospects for global sales two years ago—Bombardier, Embraer and Mitsubishi. Embraer is on its own for the foreseeable future. Ironically, those aircraft that were struggling to find acceptance outside and, to an extent, even inside their home markets, such as the United Aircraft Corp. (UAC) Superjet and the Comac ARJ21, are still around and blocking broader access to what would be attractive targets for Embraer.

That factor will become more im-

OPTIMISTIC

> COVID-19 is successfully contained, leading to a sustained recovery of air travel in the summer and stronger aircraft deliveries in 2021.

NEUTRAL

> Air travel recovery remains volatile until at least early 2021; production outpaces deliveries until the end of next year.

PESSIMISTIC

> A second pandemic wave stalls air travel again; further production cuts are implemented with recovery starting in 2022.

portant in the narrowbody market once the Irkut MC-21 and Comac C919 near service entry.

Airbus made a decision to cut production in April and sees no need for major revision (see page 38). The cut was a 33% reduction compared with 2019 levels and around 40% when measured against an output increase planned for 2021. Airbus was producing roughly 60 single-aisle aircraft per month in 2019 and planned to hit 63 in 2021 and then grow by about one additional monthly delivery every year. By 2025, Airbus could have been building 67 or 68 A320neo-family units per month.

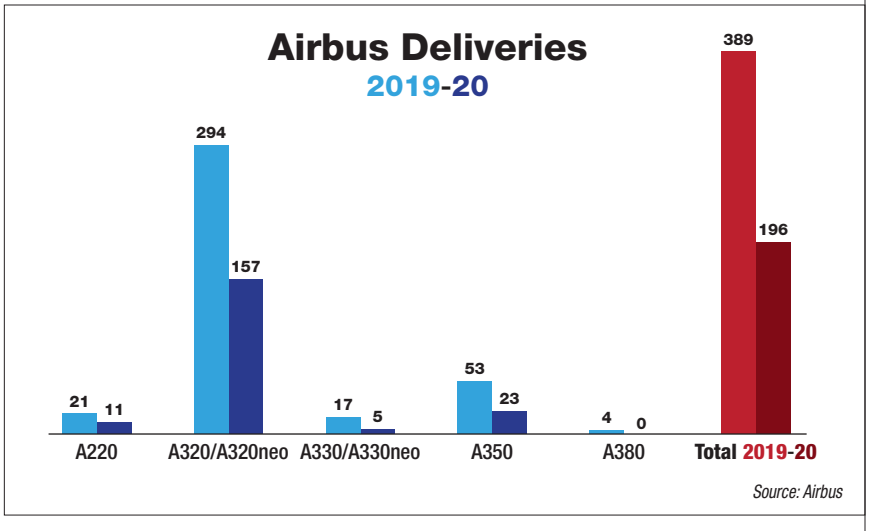
There are multiple reasons Airbus selected rate 40. The main one is that it is the threshold below which management believes the Airbus supply chain could go from severe turbulence to destruction. Key suppliers, stretched to their financial limits already, would not be able to survive lower rates. That in turn means Airbus is producing a substantially greater number of aircraft than demand would justify.

While Airbus saw a substantial recovery of deliveries in June compared with May, the level is still much below precrisis and current production rates. The manufacturer delivered 36 aircraft during the month, 31 of which were A320neo-family units. The other five were one A220-300 to Air Canada and four A350-900s: two to Iberia and one each to SAS Scandinavian Airlines and Air France. But there were just 24 deliveries in May, so June numbers represent a 50% increase.

The manufacturer received no new orders in June; an order for one A330-900 was canceled. Total firm net orders for the year stand at 298—365 gross orders less 67 cancellations.

Airbus will be producing more aircraft than it delivers until the end of 2021, according to Faury. By then, airlines are expected to take delivery of 40 narrowbodies per month again, but by then Airbus will have built up an inventory of completed yet undelivered aircraft waiting to be flown in scheduled service later.

In some ways, although for completely different reasons and at a lower scale, the situation is similar to that of the Boeing 737 MAX with hundreds of completed aircraft to be rolled out to customers, likely from this fall. The unwanted supply of MAXs is going to burden airline balance sheets in 2021 if they were unable to defer or cancel the orders. At some point, Boeing will flood the market with the MAX backlog, and Airbus will try to deliver a large number of A320neo-family aircraft.



For now, Airbus also plans to build eight widebodies per month: six A350s and two A330neos. It is taking significant financial risk in keeping rates at these levels, betting on the need to protect its ability to rebuild capacity in the years to come.

Keeping intact as much of the supply chain as possible is one main reason for the relatively high level of production; the other one is internal. Airbus has an interest in keeping as many people employed as it can, assuming it will need them sooner or later for engineering work and, subsequently, in the factories. Given a 40% output reduction, 36,000 of the 90,000 positions in the Airbus commercial aircraft business were at risk mathematically. Measured in terms of actual demand, it is probably a significantly higher number. Yet Airbus announced it will reduce employment groupwide by only 15,000. That is one-sixth of the commercial unit's workforce and includes 900 positions at its German aerostructures affiliate Premium Aerotec that were to be cut independent of COVID-19 to deal with that company's specific troubles.

Negotiations with unions are ongoing, and Faury hopes to reach agreements with all of them by the fall so positions can be eliminated by next summer. In Europe, restructurings of this kind traditionally take years to be completed, so the targeted speed shows the urgency of the situation.

One factor not to be ignored is politics. While the French and German governments, both Airbus shareholders, officially stay out of running the business, they have made it clear publicly that they expect layoffs to be limited to an absolute minimum. Both have stepped up support for aerospace by providing billions of euros in research funds from which mainly Airbus will benefit as it is designing the next generation of aircraft. The programs not only will provide welcome financial support but also will be helpful in retaining engineers who would otherwise be without work. The combination of factors means Faury's team has to find ways to cut the targeted number of positions largely by voluntary measures: unpaid leave, early retirement and, to a large extent, reductions to part-time work.

The pandemic does not seem to be stopping long-term research into a more sustainable aircraft, which Airbus expects to introduce into revenue service around 2035. The exact definition of that aircraft in range and size is going to redefine Airbus' product strategy even prior to its arrival. In all likelihood, the aircraft available 15 years from now will cover the lower end of the narrowbody segment at best. The larger A321neo-size part of the market, which also happens to be the fastest growing, is to be covered by a more conventional design.

In the nearer term, the A321XLR remains Airbus' only substantial

development program. With suppliers in the process of producing the first parts specific to the XLR, the aircraft's schedule has not changed. Its first flight is planned in 2022 and first delivery in 2023, in time for what the industry hopes will be a return to 2019 traffic levels.

Airbus' move to take over the C Series program from Bombardier and broaden its portfolio to include any aircraft down to 100 seaters—right into Embraer territory—prompted discussions at Embraer about teaming up with a big partner for its commercial aircraft division.

For two years following the preliminary agreement to hand over majority control of Embraer Commercial Aviation to Boeing, management worked on disintegrating the Brazilian aircraft manufacturer, moving employees into what was going to be Boeing Brasil Commercial and others into what was left of Embraer. An entirely separate corporate information technology system was built for the new unit and, as it was about to go live, employees were sent home for an extended company holiday over five weeks to restart based on the system. No aircraft were delivered during that time.

That was in January 2020. Then the pandemic began to spread globally, and on April 25, Boeing terminated the proposed partnership agreement. Embraer was sent back to square one. Its way forward will be turbulent, its prospects unclear. There are factors from which it will benefit, but they may well be outweighed by the new burdens.

The Embraer reset is all-encompassing. Just weeks after the Boeing deal collapsed, its main internal sponsor, Embraer Commercial Aviation President and CEO John Slattery left to become CEO of GE Aviation. He was succeeded by former sales chief Arjan Meijer.

In all likelihood, Embraer will have to go it alone for the foreseeable future. Industry sources say China and Russia have been in touch to discuss a possible investment into the company, but given geopolitics, the risks of any such tie-up would far outweigh the benefits even if an agreement on industrial and commercial terms could be reached. But who would come up with anything near the more than $4 billion Boeing had once agreed to pay for the entity in the new environment? And why would Embraer's board accept anything well below that?

Azul took delivery of its first Embraer 195-E2 in September 2019 but deferred most of the order.

JENS FLOTTAU/AW&ST

Embraer therefore is aiming to reintegrate, to the extent possible, the commercial aircraft division into the group. One item to be watched will be whether Meijer will try, as Slattery did, to make decisions for the unit as independently from the group as possible or coordinate much more with Embraer CEO Francisco Gomes Neto. Early indications are, insiders say, that Neto will become a lot more involved with the commercial unit.

A reintegrated, possibly more centralized Embraer is facing a much-changed market. Unlike Airbus and the A220, it cannot offer joint deals between its E2 family and a larger (Boeing) narrowbody. That will make it much more difficult to compete with the A220 and achieve what was its earlier strategic target: to get into the mainline carrier segment. Instead, it looks tied to its traditional niche of offering large regional jets.

Within that segment, a lot has changed. Demand for new aircraft is down to essentially zero for now and likely to stay there for some time just as Embraer was planning to ramp up production of the E2 family and trying to recover the development cost for the latest generation of the E-Jets.

While Embraer has not communicated any decisions, it is widely expected to shelve certification testing of the E175-E2 for as long as possible to cut back on capital expenditures. There are no orders for the smallest of the three E2 variants anyway. It does not comply with U.S. scope clauses and in spite of the deep crisis, there is no indication that scope relief is nearing. Furthermore, Embraer's existing offering for the niche, the E175-E1, has a monopoly for the foreseeable future. Mitsubishi is finalizing the last deliveries of its recently acquired Bombardier CRJ program. At the same, it has shelved flight-testing of its own M90 and development of the E175-E2 competitor M100.

Embraer's medium-term plans now are also highly unlikely to include a new turboprop that Slattery had pushed the board to approve. That project was always tied to being able to complete the Boeing deal because of the investment necessary. Now, Embraer is not only under intense pressure to contain costs wherever possible, but also is watching Europe invest billions of euros into research on new propulsion technologies, in particular hydrogen, that could form the basis for a new generation of regional aircraft emerging in 2030 or later.

Turboprop manufacturers ATR and de Havilland Canada are facing the same market headwinds as everyone else. The Longview Aviation unit had just taken over control of the Dash 8-400 program from Bombardier in 2019 and was forced to pause production because of COVID-19 in March. It announced a restart in May, though it has not resumed "full-scale production."

ATR will not disclose its current, lower production rate.

Faury told Aviation Week that Airbus has no plans to change its position in the joint venture with Leonardo. Both old rivals de Havilland and ATR hope they will benefit early from a traffic recovery as airlines prefer smaller, less expensive units to "test the water temperature," as ATR CEO Stefano Bortoli puts it.

—With Thierry Dubois in Lyon

ESA Proceeds With Large-Scale Earth-Observation Program

> AGENCY PLAYS KEY ROLE IN EU'S ENVIRONMENTAL ENDEAVOR

> OPEN DATA TO HELP DIGITAL TWIN EARTH PROJECT

Thierry Dubois Lyon

As the European Space Agency and the EU firm up decisions on follow-on missions in the Copernicus Earth-observation program, European satellite manufacturers expect to be awarded a total €2.55 billion ($2.9 billion) in contracts for deliveries in 2025-27.

The move means Copernicus, in its current form, has been successful enough for European Space Agency (ESA) member states to fund its continuation at greater-than-expected levels.

It also epitomizes the growing emphasis on two key domains for the European Commission (EC): environmental friendliness and digitalization, which are seen as defining the future of the 27-country union. For the aerospace industry, further orders from the public sector may be expected to follow the same priorities.

Contracts have yet to be signed, but three winners can be named already: Airbus, OHB System and Thales Alenia Space. They will build Earth-observation spacecraft that will precisely monitor climate change and its causes and consequences as well as help agriculture. Six missions will each comprise two satellites.

Copernicus is an EU program, and ESA runs its space segment. ESA and EU memberships overlap but are not identical, which complicates funding and decision processes. For instance, ESA uses the "fair geographical return" rule (geo return), a concept also known as "global balance," under which the industry in each partner country should receive a share of the work that is proportional to the country's contribution.

The overall package is cofunded by ESA member states and the EU. It therefore relies on future funding from the EU's Multiannual Financial Framework. In addition, the various members will need to make a joint decision about moving from predevelopment to full development. A so-called decision point is planned for the second half of next year.

ESA

By the end of 2021, ESA has been cleared to spend €540 million—"only ESA money," says Josef Aschbacher, ESA's director of Earth-observation programs. "Key design activities" may start now.

The agreement that has just been reached allows ESA to go ahead with negotiating contracts for the 12 satellites in detail, Aschbacher says.

The first of the six new Copernicus missions, CO2M, is about anthropogenic carbon dioxide monitoring. It will carry a near-infrared and shortwave-infrared spectrometer to measure atmospheric CO_2 produced by human activity. OHB System, headquartered in Germany, will lead the development with a contract valued at €445 million. "The payload we offered was maybe too complex," says Philippe Pham, Airbus head of Earth observation, navigation and science.

Six new missions, essentially focusing on environmental monitoring, are being launched as part of the EU's Copernicus program.

CO2M will distinguish anthropogenic sources and sinks from others, Aschbacher explains. Under the EC Green Deal, the EU is aiming to become carbon neutral by 2050.

CO2M should launch by 2025 for EU member states to be able to comply with the 2015 Paris Agreement. Each signatory should begin to report CO_2 emissions and absorption in the 2023-28 period.

The Copernicus Hyperspectral Imaging Mission (CHIME) will return detailed information for sustainable agricultural and biodiversity management. Thales Alenia Space France will lead CHIME's development under a contract valued at €455 million. OHB and Leonardo are the main subcontractors.

The Copernicus Imaging Microwave Radiometer (CIMR) mission will provide observations of sea-surface temperature and salinity and sea-ice concentration. Thales Alenia Space

Italy will lead CIMR's development under a €495 million contract.

The L-band Synthetic Aperture Radar (ROSE-L) mission will carry an L-band synthetic radar altimeter that penetrates through vegetation. It will support forest management and monitor subsidence—which is linked to earthquakes and landslides, for instance—and soil moisture. Thales Alenia Space Italy will lead ROSE-L's development under a €482 million contract. Airbus will provide the payload.

Thales Alenia Space expects a total €1.8 billion in orders from the three missions for which it was chosen as the prime contractor and the two where it will act as a payload supplier. CEO Herve Derrey anticipates contract signings in the coming weeks.

The Copernicus Polar Ice and Snow Topography Altimeter (Cristal) mission will carry a multifrequency radar altimeter and microwave radiometer to measure and monitor sea-ice thickness and overlying snow depth. Airbus Defense and Space in Germany has a €300 million contract to lead Cristal's development.

The Copernicus Land Surface Temperature Monitoring (LSTM) mission will carry a high-spatial-temporal-resolution thermal infrared sensor to provide observations of land-surface temperature for sustainable agriculture and drought prediction. Airbus Defense and Space in Spain has a €375 million contract to lead the development. "LSTM is key to secure our position in dual infrared technology, in terms of performance and cost," Pham says.

For both Cristal and LSTM, Airbus is using its Astrobus platform, but some components are being chosen with geo return in mind, so suppliers may be different from those that Airbus taps for export, he notes.

Each Copernicus mission starts with a "prototype flight model," which undergoes longer and more demanding tests than the following "flight model," he explains. Both are intended to fly. Their development takes place in staggered schedules, Pham says.

In addition to being devised to help with the climate crisis, the new Copernicus missions are expected to play a particularly relevant role in the EC's digital agenda. The plan is to make European data available in the cloud to European users, Aschbacher says. Copernicus data—currently 300 TB per day—is free and open. "But European users should get . . . tools such as high-performance computing so they have a competitive advantage," he adds.

Copernicus will contribute to the Digital Twin Earth project, aimed at simulating potential evolution scenarios for the planet. Last year, controversy emerged between French President Emmanuel Macron and his Brazilian counterpart, Jair Bolsonaro, about the Brazilian portion—almost two-thirds—of the Amazon rain forest. Should the forest be seen as a common asset for humanity or purely as Brazilian territory? For a science-based answer, a full model of the Earth may show the impact of a 10%, 20% or higher reduction of the forest's surface, Aschbacher emphasizes.

EXECUTING THE PLAN

L3Harris Technologies is celebrating its first anniversary as a combined company after predecessors L3 Technologies and Harris Corp. came together in the summer of 2019. The merger created a so-called "sixth prime" defense contractor that enjoyed growing civil aerospace work through pilot training, simulation, avionics, FAA support and NASA work. But the merger was envisioned long before COVID-19 upended the aerospace and defense marketplace. Like other companies, Melbourne, Florida-based L3Harris is adapting. Chairman and CEO **Bill Brown** (left) and Vice Chairman, Chief Operating Officer and President **Chris Kubasik** (right) talked with Senior Business Editor **Michael Bruno** about the past year and looking ahead.

AW&ST: **You just completed the first year of a three-year plan to integrate L3Harris Technologies. How is it going?** **Brown:** Chris and I couldn't be prouder of the broader leadership team and all the employees for all that we've accomplished over the last year to make this merger successful. And it has been a success in an environment that is truly unprecedented in many ways. Strategically, if you remember a year ago, we set out to leverage our broader scale and complementary technologies to create sort of a new agile, innovative mission solutions prime that goes across all of the domains. I think we have proven that out through a lot of the revenue synergies we've already started to capture in the big pipeline ahead of us operationally, and we're making really good progress. We're also building a strong culture of operational excellence within the company to sustain our performance beyond the integration period.

Many financial analysts have named L3Harris a favorite stock pick. You have a $300 million goal for cost takeout from the merger, and you just accelerated that by a year to 2021. Do you feel pressure to do even more? **Brown:** I think maybe what people are excited about is that we were underpenetrated internationally. So we have opportunities to grow there. We're going after broader end-to-end mission solutions and we're starting to capture synergy.

So we believe we have an opportunity to gain share in a defense market, in a global market. But we also have really good execution on the cost side to allow earnings per share to grow and margins to expand, regardless of what happens on the top line. I think that's what investors are excited about—just that execution on the fundamentals. If we hit $300 million next year and we keep running it into that third year—calendar 2022—it should be better than we first expected.

The merger was marketed in part about becoming a sixth prime defense contractor with accompanying heft. Did it work? How are you growing? **Kubasik:** We see a lot of opportunities in the classified environment dealing with command and control, with integrating capabilities from both legacy companies. We put in 41 proposals—neither one of us would have primed or put these bids in had we not merged. That gives you an idea of volume. A lot of these start out relatively small, whether they're with DARPA or other agencies where you're downselected as one of three, and then a year from now you get another opportunity and keep going. We're pretty pleased. We've had eight awards so far.

About 20% of annual revenue comes from international sales. Can you still grow there? **Kubasik:** There is a couple of billion dollars of opportunity on the international front. We have a pretty big presence in Australia, Canada and the UK. We haven't seen any budget pressures for 2020. Do we expect many for 2021? That will be something we watch. Most of these countries fund defense as a percent of GDP, so if GDP drops, maybe there's an impact there in the out years. But we continue to see a lot of interest in the Pacific region. And, of course, the Mideast is somewhere that both companies had worked in historically and continue to work.

Since the merger was announced in October 2018, you have been busy with divestitures. Are you interested in more acquisitions, especially as prices may drop for some targets due to COVID-19? **Brown:** It's early to talk about it, frankly. We're busy; we've got a lot of stuff going on just integrating the companies, stabilizing it, taking costs out, improving systems, capturing revenue opportunities and dealing with the COVID pandemic. We believe we're adding a lot of value by focusing on building fundamentals, building a strong foundation upon which to grow over time, and [acquisitions] will play a role. It's not on the near-term horizon. We've got our hands full just executing our game plan as we see it today.

Your commercial aerospace businesses took a hit from COVID-19

L3HARRIS

along with the rest of the marketplace. How much of a setback is that to the business model? **Brown:** That business might be evolving in the future, but it's not a big part of the company. Commercial aerospace, which is all the pilot training and academy work plus avionics, is less than 5% of the company. Roughly speaking, it's about $500 million of revenue this year—down 30-40%, about $300 million. We do see that business under pressure, and we see that also in the pilot training side. It's very difficult to train new pilots when you can't have them come to your academies, or have airline pilots that aren't flying. They're not going to be in the training systems. So that does slow pretty dramatically.

Both of you are veteran leaders and have seen downturns before, but how does COVID-19 differ?

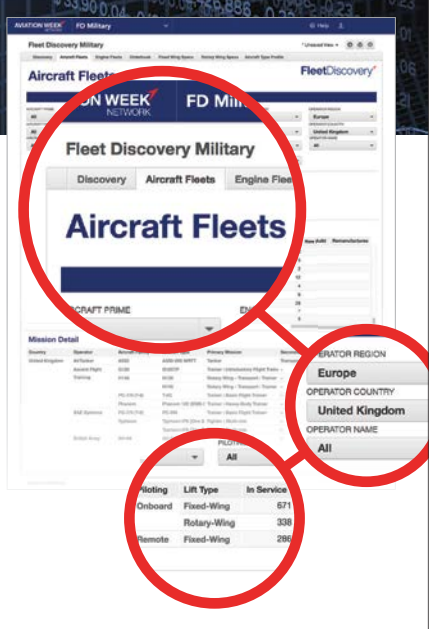
Kubasik: This is clearly one of the more significant declines. You look at all the different events over history that have caused commercial aerospace to hit a bump, and most of those have bounced back relatively quickly from events like 9/11 or SARS. This one is global in nature, and I think the whole discussion is going to be about the recovery. Ultimately, I think people are going to get back on planes and fly, clearly.

We've found some ways to be a little more efficient with Zoom and Skype, and maybe there are fewer business trips. If everything gets back to the same way we were pre-COVID-19, we will have missed an opportunity to reimagine the future of the workplace and productivity.

Brown: There are implications for the overall supply base, on both the aerospace and defense sides. Clearly we need more resilience. This has a great impact on some of the smallest suppliers on which we're leaning to survive. This is not a temporary situation where you advance cash and things get better in three months. This is going to be a longer-term downturn, and we have to make sure that those precious small suppliers who are very vulnerable can see their way through this crisis. Larger companies can; the concern is really the smallest ones.

FleetDiscovery

Fleet Discovery Military



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AVIATION WEEK NETWORK

A 'BIG IDEA'

> USAF DIGITAL CENTURY SERIES STUDY DUE BY END OF JULY

> 15-YEAR SERVICE LIFE PROJECTED FOR NEXT FIGHTER

Steve Trimble Washington

In the two-day span of July 13-14, the U.S. Air Force signed an order for new Boeing F-15s for the first time in 19 years and revealed the results of an internal analysis that points to adopting a dramatic change in acquisition strategy for the next generation of fighter jets.

The Air Force already operates six different types of fighters and attack aircraft and is designing a new trainer—the Boeing T-7A—with a built-in capability to perform a light attack role.

But the combination of the Fairchild Republic A-10, Boeing F-15C/D and F-15E and Lockheed Martin F-16, F-35A and F-22 still is not enough.

U.S. AIR FORCE PHOTOS

The U.S. Air Force operates a depot for the F-35A at Hill AFB, Utah—F-35 pilots are pictured being briefed there by a maintenance officer—but a pending internal analysis indicates the next fighter aircraft will not need a heavy maintenance cycle.

In 2016, the Air Force started developing a concept under the Next-Generation Air Dominance (NGAD) program for a new air superiority fighter that could replace the F-22 and F-15C/D fleets by 2030.

A year later, however, the Air Force learned that the F-15C/D cannot be affordably sustained until an NGAD replacement enters the fleet. Already the Air Force is facing a bill to replace canopy sill longerons on each F-15C/D, and maintenance checks also revealed a surprise requirement for an expensive wing replacement.

Rather than spend $10 million for new wings and longerons on each aging F-15C/D, the Air Force decided it was cheaper and faster to replace the 220-aircraft fleet with at least 144 F-15EXs. Although based on the F-15E fighter-bomber, the F-15EX features a new, lighter wing and critical performance upgrades funded by Qatar and Saudi Arabia that restore much of the aircraft's air-to-air competitiveness compared with the F-15C/D.

The search for the NGAD replacement for the F-22 continued but became more complicated. The early NGAD studies likely focused on potentially disruptive technologies for air warfare, building on the Air Force Research Laboratory's investment in tailless, supersonic airframes with broadband stealth characteristics, along with fuel-saving adaptive propulsion and directed-energy weapons.

By mid-2018, however, the Air Force's focus for NGAD expanded. Instead of exploring only disruptive aerospace technologies, Air Force leaders also decided to investigate how NGAD could disrupt the industrial model for designing, building and sustaining a fighter.

In October 2019, the Air Force opened the Digital Century Series office within the Air Force's Lifecycle Management Center. For nearly 10 months, that office has been crunching the numbers on two basic options. The first is a traditional acquisition approach aided by new digital engineering tools featuring a downselect to a prime contractor and a single aircraft type. The second is a radical break from that approach: The Air Force is commissioning aircraft designs from multiple suppliers that would be produced in small batches and ideally be retired from service before the first heavy maintenance check.

The Digital Century Series staff is about three weeks away from completing its analysis, but the results already appear conclusive, says Will Roper, Air Force assistant secretary for acquisition, technology and logistics. "The business case is coming together," Roper told journalists on July 14. "I believe it's going to be cheaper to procure airplanes this [alternative] way than it will be with the major production line."

If so, the NGAD aircraft—whether a singular type or plural—promise to be as revolutionary to the defense industry as to the art of air warfare.

The Defense Department selected Lockheed in 2001, for example, to design and develop three F-35 variants, which took nearly 19 years to complete. Lockheed opened a production line in 2007, with deliveries currently projected until 2046, according to the latest Selected Acquisition Report on the F-35 program. Finally, Lockheed

The first of two Boeing F-15EXs ordered by the Air Force on July 13 is already in final assembly.

owns the design rights, so for now, it controls a monopoly on potentially seven or more decades of sustainment costs. The Pentagon, however, is trying to negotiate the transfer of some design rights from Lockheed in exchange for a performance-based logistics contract.

If Roper's vision for the NGAD program is adopted, the acquisition strategy for the combat aircraft that will follow the Air Force's F-35A into development could not be more different.

"Right now, it appears to be trending that the Digital Century Series [model] is slightly cheaper—maybe significantly cheaper—than a traditional acquisition, even [if the latter is] leveraging digital engineering. If that is the case, being able to keep two or three competitors continually designing—where there's always a design opportunity, but only one is going to get pulled into small-lot production—keeping that running perpetually sounds awesome," Roper says.

"Compare that with picking one vendor, and only one vendor, and hoping that 30 years later, you still have a competitive industry base that can build the next amazing aerial thing," Roper adds. "I believe this model can work for satellites and for weapons as well."

The key to closing the business case for the Digital Century Series approach is the ability to save costs during the sustainment phase. The Air Force's analysis shows that sustainment costs for the current fleet rise significantly after an aircraft reaches 15 years in service. At that point, sustainment costs leap 3-8% annually, Roper says.

"So if you can kill that part of the program life cycle, it gives you a lot more flexibility on [the up-front] price point," Roper says. "If you say, 'I'm not going to keep the airplane longer than 15 years; I'm not going to have a depot line that's open to maintain it. I'm [also] not going to do full-scale fatigue testing and all of those different things that add sustainment costs that get bigger and bigger the longer we keep the airplane. I'm also not doing any modernizations . . . to keep systems relevant or to stay ahead of obsolescence.' You kill that part of the program [cost] because you're going to buy a new airplane."

The catch in the Digital Century Series model is the implied disruptive impact on the defense industry, which Roper acknowledges.

The defense contractors now "are losing money in design and then making it back in later production and mainly modernization and sustainment, which is where the big dollars are," Roper says.

That means the Air Force—and, by extension, Congress—must be willing to spend more money up front to incentivize multiple companies to specialize in making a profit from designing aircraft rather than sustaining them.

The Digital Century Series strategy is also premised on the impact of a new set of digital engineering tools pioneered by the automotive industry. The goal is to create a digital replica of a new aircraft design that can be used to derive models to predict aerodynamic performance, manufacturing tasks and sustainment costs down to the level of individual line-replaceable units.

Boeing adopted such a model-based systems engineering approach for the Qatar-funded redesign of the wing and forward fuselage of the F-15E. Although Boeing has not transferred design rights for the F-15EX to the Air Force, company officials view the aircraft's digital engineering process as an "enabler" of the Digital Century Series initiative.

"Digital engineering is changing everything," Roper says. "We can build airplanes simpler with smaller numbers of people with simpler tools than we've been able to do since the 1970s. The idea is that you could return to a form of acquisition we have not had since the early Air Force, and that's a big idea."

Tempest Goes Trilateral

- SAAB SPENDING £50 MILLION ON UK FCAS HUB
- TECHNOLOGIES ARE BEING MATURED TO SUPPORT YEAR-END BUSINESS CASE SUBMISSION

Tony Osborne London

Ninety percent of Britain's front-line combat aircraft are crewed, but British Defense Secretary Ben Wallace says he expects a "major reversal" of these proportions by 2040.

Wallace's speech at the opening of a virtual Farnborough Airshow on July 20—a message reminiscent of the late Duncan Sandys' 1957 defense white paper that declared the manned fighter redundant and guided and ballistic missiles to be the future of Britain's defense—may hint at a radically altered Royal Air Force (RAF) with heavy fielding of swarming UAVs and other additive capabilities such as "loyal wingmen" dominating fleets. But Wallace's comments also touched on the trajectory for the UK-led Tempest Future Combat Air System (FCAS), which is targeted to begin to replace the UK's fleet of Eurofighter Typhoons from 2035.

TEAM TEMPEST

Air Chief Marshal Mike Wigston, Chief of the Air Staff, said at the RAF's annual air power conference on July 15 that he intended any FCAS to be optionally manned. Sandys' defense plan sent reverberations through the UK aerospace industry, but the vision for the Tempest calls for a similar fundamental revolution.

BAE Systems says its factory of the future will subsume the need for heavy, fixed and long-lead tooling—halving production time compared with previous programs. And industry is looking to new players for cybersecurity technology from the banking world and materials technology from the automotive sector, companies from outside the typical defense industrial base.

Two years since the announcement of Team Tempest—the industry consortium of BAE Systems, Leonardo, MBDA, Rolls-Royce and the British government's Combat Air Strategy that coalesced at the 2018 Farnborough Airshow—the group is growing for the first time, with the inclusion of Bombardier UK, Collins Aerospace, GE UK, GKN, Martin-Baker, Qinetiq and Thales UK. The additions to the team come in the form of a first wave of industrial agreements, with BAE hinting that more industrial partners will follow. Of the new partners, Collins announced it had been contracted by BAE to provide advanced actuation capabilities.

Sweden's Saab announced also on July 20 that it is investing £50 million ($58 million) into the creation of an FCAS center in the UK. The facility will serve as a hub for the company's participation in the FCAS and represent Stockholm's first tentative steps into the venture. Saab does not name the Tempest specifically, with CEO Micael Johansson hinting that Sweden's involvement is focused more on the technology rather than the future platform. "Saab's FCAS strategy ensures that the technology is in place to support a long-term future air capability and also to support continuous upgrades of Gripen E for decades to come," Johansson said.

While the international partnership model for the Tempest has yet to be finalized, British officials have suggested that the partnerships could be agile and scalable. In other words, allowing nations to "partner in a way that suits them," Richard Berthon, the UK Defense Ministry's Combat Air acquisition program director, previously told Aviation Week (*AW&ST* July 13-26, p. 52).

Johannsson said nations looking to refresh their fleets with the current generation of fighters, like the Gripen or Typhoon, should not be concerned about the push to deliver the Tempest during the 2030s. "A strong joint partnership around a future combat air system will also guarantee Gripen and Eurofighter access to new technologies," Johannsson said. Existing customers, he said, should see the FCAS as a "seal of approval as we safeguard continuous fighter development."

Trilateral studies to develop the Tempest are underway as year-end business case submission deadlines loom.

Until now, the work between the national partners had been on a bilateral basis. The aim was "to define our common objectives," BAE Systems CEO Charles Woodburn says. But this work has now extended into trilateral studies that include "assessing how we can start to realize the huge potential for collaboration across our three nations," Woodburn says.

Although the talks are now trilateral in nature, the UK says it is still keen to see more international partners "join our flightpath to discovery," Wallace adds.

Industry is already beginning to think trilaterally, with GKN Aerospace in Sweden confirming it will work with Rolls-Royce in the UK and Avio Aero in Italy on feasibility studies for a future fighter jet engine. GKN states it was contracted in the first quarter of 2020 by Sweden's defense materiel agency, FMV, to conduct a study in collaboration with Rolls-Royce.

Few details have emerged on the 60 technology demonstration programs currently being developed and matured by Team Tempest in support of the UK Future Combat Air System Technology Initiative (FCAS TI). Michael Christie, BAE's head of Future Combat Air Systems, says work on maturing the technologies ready to support the business case submission to the British government at the end of this year has seen the partners "at least achieve or exceed" the maturity targets set, doing so "at great pace" and providing "fundamental evidence to the business case."

"Every one of these [60] projects will deliver a UK, European or world first," says Cecil Buchanan, the RAF Rapid Capability Office's chief scientist.

Faster Pace Needed for Eurofighter Enhancements

- EUROFIGHTER NATIONS MOVING TOWARD LONG-TERM EVOLUTION PLAN
- SECOND SAUDI TYPHOON ORDER IS LIKELY TORNADO REPLACEMENT

Tony Osborne London

The Eurofighter's recent renaissance and future evolution plans are a positive step for Europe's ambitions to build future combat aircraft, but fast decision-making by the partner nations is needed, says the managing director of BAE Systems' air business, Chris Boardman.

The European fighter, jointly developed by Germany, Italy, Spain and the UK, is enjoying something of a renaissance—with orders from Kuwait and Qatar as well as the potential of top-up buys from Germany and Spain that could push production of the fighter out to the mid-2020s and later. But finalizing how the aircraft should evolve is still the subject of extensive debate.

The end of Hawk production could be in sight as BAE completes batches of the jet trainer for Qatar and Saudi Arabia. Efforts to maintain continuity, such as a recent campaign in Kuwait, have not succeeded.

"The bit we are trying to get to a conclusion is the Long-Term Evolution [LTE] of Typhoon," Boardman tells Aviation Week.

"The four nations are having debates about the requirements," he says. "They will not all be the same . . . but they need to be harmonized."

Approvals need to be granted by all four partner nations before the LTE initiative, revealed at last year's Paris Air Show, can move ahead. The LTE plan is essentially a midlife update for the fighter, one that will bring it into the information age and serve as a steppingstone toward the European Future Combat Air System and part of the UK's Tempest initiative and Combat Air Strategy. In the UK, Boardman says there is a "near-term focus" on concluding commitments for Radar 2, a derivative of the Euroradar Captor-E active, electronically scanned array (AESA) radar planned for UK aircraft. Radar 2 will feature an electronic attack capability, but Boardman suggests that the decision-making process is being affected by the novel coronavirus pandemic. As a result, he is urging governments to make decisions more expeditiously. "From an industrial point of view, we need to be quicker on that issue," Boardman says.

Boardman is encouraged, however, by Germany's decision to adopt the Mk. 1 AESA radar for Tranche 2 and 3 models of the aircraft. But he notes that the radar programs have to be "carefully managed," as there are now essentially three different radars in the Eurofighter program. "I am happy that the German nation has made a commitment," he says. "We hope it lays the groundwork for more Eurofighters into the Luftwaffe."

It could also bolster export campaigns.

BAE remains hopeful of securing a follow-up Eurofighter order from Saudi Arabia. Riyadh signed a memorandum of intent in March 2018 to purchase an additional 48 Eurofighters to join its fleet of 72 aircraft. Nevertheless, licensing issues as a result of the German prohibition of arms sales to Saudi Arabia and the halting of new UK export licenses for defense equipment to the kingdom has challenged progress. The British government announced in July that it would restart arms exports to Riyadh.

"We are not in a sales mode with Saudi Arabia," Boardman says. "If you look at the Saudi Air Force and the decisions it has to make, it needs to replace its [Panavia] Tornadoes at an appropriate time.

"The aircraft is the centerpiece of the Royal Saudi Air Force," he suggests. "It's been utilized well and heavily, so let's not try to sell it. Let it sell itself."

While the future of the Eurofighter looks bright, less certain is the future of BAE's highly successful Hawk jet trainer.Although the type has been buoyed by orders from the Middle East in recent years, including a batch being assembled in Saudi Arabia, orders look set to dry up once nine aircraft for Qatar are completed.

"We put a lot of effort into trying to get continuity," Boardman explains, noting recent efforts to sell new-build aircraft to Kuwait were unsuccessful.

ROYAL AIR FORCE

"Restarting [production] lines is costly," Boardman says. "There are lots of people in the world who are trying to sell the training aircraft—having invested heavily in them—so it is whether you can be competitive in that situation." Boardman does not rule out the possibility that a sizable order could enable Hawk production to resume, but he says it would be a challenge to be competitive.

A future jet trainer is not out of the question: Some level of live flying will still be needed by future fighter pilots, despite advancements in synthetics.

"Will there be training aircraft needed in the world going forward?" Boardman asks rhetorically, noting that the U.S. Air Force is pursuing the development of the T-X platform, and the U.S. Navy is beginning to look at a replacement for the T-45 Goshawk, derived from BAE's Hawk. "Certainly, yes; but what level and what volume? That is the fundamental question," he adds.

Despite what Boardman describes as some "hiccups" in component production for the F-35 because of the COVID-19 crisis, the situation has now "stabilized," and the company is working toward its 2020 operational plan.

FUTURE SHOCK

> LENGTHY UPGRADE LIST TO TRANSFORM THE F-35's ROLE

> SCHEDULE PRESSURE GROWS ON COMPUTER UPGRADE

> FIRST BLOCK 4 UPGRADES ARRIVE LATE AND FLAWED

Steve Trimble Washington

THIS IS THE VISION FOR THE LOCKHEED MARTIN F-35 PROGRAM IN 10 YEARS:

■ A worldwide fleet of more than 2,000 fighters is in service with a still-growing list of customers. Sales are spurred by a unit procurement price and cost per flight hour equal to or only slightly higher than a fourth-generation fighter. Yet the newly modernized Block 4 fleet of F-35s boasts 25 times more computing power than the version of the aircraft operating today, enabling the software-based onboard fusion engine to mine data from a far more advanced set of active and passive sensors.

■ As the situational awareness in cockpit expands, the pilots have a variety of new weapon options available: the ability to carry six Lockheed Martin AIM-260 or Raytheon AIM-120 advanced medium-range air-to-air missiles internally; a maritime strike capability of the Joint Strike Missile; and the use of new long-range strike missiles, such as the future Stand-in Attack Weapon (SiAW) internally and possibly a hypersonic cruise missile carried externally. Meanwhile, the Lot 22 F-35 rolling off Lockheed's assembly line in 2030 also can access a new class of air-launched attritable stores that add vast new sensing capacity, multiply weapon loadouts and, depending on the mission, serve as kinetic options themselves.

■ By 2030, the F-35's role has already evolved from standard counterair and strike missions. The Army and Navy now use the F-35's sensor data remotely to guide their interceptors to knock down incoming missiles. The Air Force's decentralized command-and-control system relies on the F-35's processing power, sensor data and communication hooks to orchestrate a wider attack in all domains. F-35 pilots still train to perform traditional fighter missions, but the role the aircraft plays defies the vocabulary of the Air Force's designation system.

A decade may seem too short for such an evolution in one program, but it is possible. Ten years ago, the F-35 was still in crisis mode: With the flight-test fleet grounded for most of 2009, the supply chain was reeling. Ashton Carter, who was then the undersecretary of defense for acquisition, technology and logistics, later acknowledged that proposals to cancel the program had been briefly considered during that period.

To date, Lockheed has delivered more than 500 F-35s to nine countries, with another three countries signed up for still more. The unit flyaway cost of an F-35A will fall to $77.9 million for aircraft delivered in 2022 as part of the 14th lot of yearly production.

In plotting the program's next decade of development, a similar narrative of early struggles is becoming clear.

The F-35 Joint Program Office (JPO) identified the first 66 hardware and software upgrades listed under the Block 4 Follow-on Modernization in a report to Congress in May 2019. The first eight upgrades were due to enter service in 2019, but because of unexpected complications, only one of them—an automatic ground-collision avoidance system—was released to the operational fleet on time. Other improvements, such as an interim full-motion video capability for the Marine Corps' F-35B fleet, fell behind due to later hardware deliveries, according to a Government Accountability Office (GAO) report released in May.

The JPO also adopted an agile development process for Block 4. The upgrades are still organized in four major increments—Block 4.1, 4.2, 4.3 and 4.4—and smaller batches of new capabilities are released in six-month cycles, a process called Continuous Capability Development and Delivery (C2D2). Lockheed, for example, is scheduled to complete development of 30P5 software in the third quarter of this year, which will be followed by software drops called 30P6 in the first quarter of 2021 and 30P7 in the third quarter of 2021. The agile development method is intended to reduce the scale of delays caused by a release of a large batch of flawed software every two years, but it is not a panacea. As the software from the first C2D2 release entered testing, new problems appeared, such as Block 4 software code causing "issues" for Block 3F functions that had been working, according to the GAO.

The next major advance for the Block 4 program should arrive in 2023. This Block 4.2 configuration will be the first to include Technical Refresh 3 (TR-3) hardware, which

OPTIMISTIC

- After short-term stagnation, global defense spending resumes growth and Lockheed delivers 4,000 F-35s overall.
- Despite early concerns, Lockheed completes the Block 4 modernization program on-time and on-budget.

NEUTRAL

- Global defense spending stagnates through 2040, increasing downward pressure on programs of record.
- Block 4 modernization suffers some delays and overruns but does not affect aircraft procurement.

PESSIMISTIC

- Global defense spending enters a long-term decline, setting off a 1990s-style "procurement holiday" for fighters.
- TR-3 Refresh and Block 4 are delayed significantly, with cost overruns leading to further cuts in the procurement budget.

AIRMAN 1ST CLASS BRYAN GUTHRIE/U.S. AIR FORCE

A U.S. Air Force F-35A performed a flight test in May at Nellis AFB, Nevada, with GBU-49 laser-guided bombs. New upgrades will add the Raytheon GBU-53/B Stormbreaker, among other weapons, to the F-35's arsenal.

includes a new integrated core processor, an aircraft memory system and a panoramic cockpit display system. As the first cockpit computing for the F-35 since Block 3i appeared in 2016, the TR3 will enable a leap in sensing capability, especially for the BAE Systems ASQ-239 electronic-warfare system.

The TR-3 upgrade, however, also is facing development challenges. The F-35 JPO is seeking a $42 million increase in spending on TR-3 in fiscal 2021 to offset higher "technical complexity."

"Suppliers are challenged to meet a demanding schedule with one holistic hardware-software system; therefore, interim releases of hardware [will] reduce risk and enable parallel software development," the Air Force said in a budget justification document for fiscal 2021.

The latest F-35 selected acquisition report (SAR), which was released by the Defense Department in early July, reports similar issues with TR-3, citing specifically higher costs due to additional support needed to help one supplier manage the complexity of a field-programmable gate array used in the new processor system. The development of the integrated core processor and the aircraft memory system also are suffering delays, according to the annual SAR.

As the TR-3-equipped Block 4.2 configuration arrives in the fleet, the F-35's power to sense targets and threats passively should rise enormously. The upgrade also paves the way for a critical update to BAE's electronic-warfare system, especially the jamming techniques generators embedded in Racks 2A and 2B of the ASQ-239. BAE also plans to upgrade the wing-leading-edge-mounted receivers in Bands 2, 3 and 4 as well as activate new Band 5 receivers from broad spectrum coverage from very low to extremely high radio frequencies. Aided by the more powerful processors introduced by TR-3, the F-35 may be able to develop jamming techniques as it encounters new signals not previously stored in the aircraft's mission data files. Such a capacity for so-called cognitive electronic warfare is becoming critical as adversaries shift to software-defined radios and frequency-hopping radar arrays.

If the current schedule is maintained, the TR-3 and Block 4.2 upgrades arriving in Lot 15 aircraft will include more than improved computing power. Lockheed is modifying the internal weapons bay to enable the "sidekick" upgrade, which increases the Raytheon AIM-120 missile loadout by 50% to six missiles. As the Lockheed AIM-260 becomes available, the same loadout will become possible with a missile measuring the same length as the AIM-120 but with significantly more range.

The same modification also accommodates the dimensions of the Air Force's new SiAW missile, which adds a new warhead to the Navy's Advanced Antiradiation Guided Missile-Extended Range. An Israeli-funded program to add wing-mounted fuel tanks to the F-35's loadout options also should become available and would increase the range by 25% if the mission does not require minimizing the aircraft's profile on radar.

By the end of the decade, operating the F-35 could be very different from how the aircraft's designers in the late 1990s had anticipated. The Air Force's Skyborg program seeks to introduce a new family of ground- and air-launched aircraft that can serve as autonomous teammates, or wingmen, for F-35 pilots. "Skyborg" itself refers to the development of a new autonomous control system that can be trained to perform a diverse set of missions. The Air Force expects F-35 pilots to use the Skyborg-equipped aircraft much like reusable munitions; in other words, a missile that can be fired and, if no worthy target appears, recovered and used again.

The capabilities envisioned by the F-35's designers two decades ago are now available in operational aircraft, albeit several years later than originally envisioned and for higher procurement and operating costs. As the next decade unfolds, the JPO and Lockheed will seek to add capabilities that have become defined only within the last decade and to adopt several concepts, including Skyborg and SiAW, that have emerged only recently. The history of the F-35 program is characterized by overpromising and underperforming in the development phase. As Block 4 development transitions from concept to reality, the challenge will be avoiding similar missteps.

Rising Pressures Cloud Optimistic F-35 Sales Outlook

- U.S. AIR FORCE AND MARINE CORPS SEND CONFLICTING SIGNALS
- UAS AND F-15EX INCREASE F-35 COMPETITION

Two F-35As (above, right) flew last year with a pair of Spanish Air Force Eurofighter Typhoons. The F-35B is a candidate to replace the Spanish Navy's Harrier jets.

MASS COMMUNICATION SPC. 2ND CLASS DOUGLAS PARKER/U.S. AIR FORCE

Steve Trimble Washington

Lockheed Martin has marketed the F-35 successfully to 14 countries over nearly 20 years. Subtracting Turkey's canceled program for 100 jets, Lockheed still boasts commitments from 13 countries to buy nearly 3,220 F-35s, with deliveries projected out to 2046. Three more countries with a combined requirement for about 200 fighters are evaluating the F-35 in competitive tenders, and another five have publicly discussed a long-term interest in acquiring the aircraft.

That is the good news for the only supersonic, stealthy fighter with a short-takeoff-and-vertical-landing variant on the export market today.

But that otherwise optimistic sales outlook is clouded by resource constraints, shifting priorities and new technological advances that threaten a large portion of the planned orders in the F-35 program of record. Moreover, the recent expulsion of Turkey from the program because of its acquisition of Russian military hardware highlights rising pressure from political interference on high-profile foreign arms sales.

The U.S.-led F-35 Joint Program Office declared in 2009 that total sales of the F-35 could reach 6,000, but more than a decade later government and Lockheed officials prefer to size the global market at around 4,000. Even the more modest projection may depend on maintaining the original orderbook of the U.S. Air Force, the program's largest customer, with an official requirement for 1,763 F-35As.

Although Air Force leadership remains fully committed, cracks have appeared in the service's long-term programming. In March, Air Combat Command (ACC) announced a goal to achieve a long-term fighter fleet composed of 60% F-35s and Lockheed F-22s and 40% among Boeing F-15s, Lockheed F-16s and Fairchild Republic A-10s. The Air Force inventory today counts about 2,190 fighters overall, leaving room for a total of about 1,315 F-22s and F-35s combined to achieve the 60% goal. If about 180 F-22s are removed from the equation, the Air Force would be left with a total fleet requirement for 1,135 F-35As.

The Marine Corps, which plans to buy 357 F-35Bs, faces similar pressures. In March, the Marine Corps announced plans to cap F-35B squadrons at 10 aircraft each, eliminating plans to field nine of 14 F-35B squadrons with 16 aircraft. The decision appears to create an inventory surplus of about 54 jets, but the Marines have not made any changes to the program of record.

Similar constraints are visible in other countries. The UK is in the midst of a defense review with officials scrutinizing plans for the Royal Air Force and Royal Navy to acquire a total of 138 F-35Bs, of which only the first 48 are funded so far. Alongside plans to upgrade the Eurofighter Typhoon and develop the Tempest next-generation fighter, the Defense Ministry will have to balance resources carefully.

The military technology advances add further pressure. The U.S. Air Force is developing a new class of low-cost attritable unmanned aircraft systems (UAS), which the service envisions performing as reusable munitions to augment the sensor and weapons capabilities of aircraft such as the F-35. As the technology matures, the ACC sees the potential for using swarms of attritable UAS to replace hundreds of the Air Force's oldest F-16s, which are due to enter retirement in the second half of the decade.

But demand for the F-35 still is growing in other areas. The U.S. government's recent approval of 105 F-35s for Japan shows how the international program still can expand. Japan originally acquired 42 F-35s in 2014 to replace an aging fleet of McDonnell Douglas F-4s. The newly approved acquisition would expand the F-35 fleet to replace Japan's oldest F-15s. Israel, meanwhile, already has ordered 50 F-35s. As a political leadership crisis moves toward stability, Israel soon could sign a follow-on order for up to 75 new jets, with the F-35A and F-15EX splitting the deal.

Other countries still are seeking to enter the program. Singapore has been approved by the U.S. to order up to 12 F-35Bs. In January, the prime minister of Greece announced plans to order F-35As after a batch of upgraded F-16s are delivered in 2024. The U.S. government also has named Romania and Spain in Europe as potential F-35 buyers. In the Middle East, the United Arab Emirates and Saudi Arabia are busy absorbing new Dassault Rafale and F-15SA jets, respectively, but are likely to consider the F-35 in the second half of the decade.

F-35 Propulsion Upgrade Moves Forward Despite Uncertainty

> ENHANCEMENT PACKAGE REPLACES "GROWTH OPTION"

> NEW F-35 PROPULSION ROAD MAP DUE IN SIX MONTHS

Steve Trimble Washington

Stabilizing the production system and securing a funded, long-term upgrade plan are now the main objectives for Pratt & Whitney's F135 propulsion system for the Lockheed Martin F-35.

Although first delivered for ground-testing 17 years ago, the F135 remains a lifeline in Pratt's combat aircraft engines portfolio for new-development funding. The U.S. military engines market is entering an era of transition with great uncertainty for the timing of the next major combat aircraft program.

The transition era begins with the likely pending delivery of Pratt's most secretive development project. In 2016, the U.S. Air Force named Pratt as one of seven major suppliers for the Northrop Grumman B-21 bomber. The Air Force also has set the first flight of the B-21 for around December 2021. That timing means Pratt is likely to have delivered the first engine for ground-testing. At some point within the next year, Pratt should be planning to deliver the first flight-worthy engine to Northrop's final assembly line in Palmdale, California, to support the Air Force's first B-21 flight schedule.

As the bomber engine development project winds down, the propulsion system for the next fighter aircraft continues to be developed, but without a clear schedule for transitioning to an operational system.

The Air Force Research Laboratory's Adaptive Engine Transition Program (AETP) is sponsoring a competition to develop an adaptive engine that can modulate the airflow into and around the core to improve fuel efficiency and increase range. The AETP competition is between Pratt's XA101 and GE's XA100 designs, with the first engines set to be delivered for ground-testing by the end of this year or early next year.

As 45,000-lb.-thrust-class engines, the first AETP designs are optimized for repowering the single-engine F-35, but the F-35 Joint Program Office (JPO) has established no requirement to replace the F135 for at least another five years. A follow-on effort within the AETP is developing a similar engine for a next-generation fighter, but neither the Air Force nor the Navy have committed to a schedule for transitioning the technology into an aircraft-development program. That leaves Pratt's F135 as the only feasible application for inserting new propulsion technology for a decade more.

MCSN MICHAEL T. FORBES II/U.S. NAVY

An F-35B completed the first landing at sea on the USS Wasp in 2013. The Joint Program Office is considering thrust upgrades to increase the F-35B's "bring-back" payload to a carrier.

After spending the last decade focused on completing development of the F-35 and upgrading the software, electronics and mission systems, the JPO is developing a road map to improve the propulsion system through 2035.

As the road map is being developed, program officials also are seeking to stabilize the engine production system. Pratt delivered about 600 F135s to Lockheed through the end of last year, including 150—or about 25%—in 2019 alone. The JPO signed a $7.3 billion contract with Pratt last year to deliver another 509 engines in 2020-22, or about 170 a year.

Although Pratt exceeded the delivery goal in 2019 by three engines, each shipment came an average of 10-15 days behind the schedule in the contract. The fan, low-pressure turbine and nozzle hardware drove the delivery delays, according to the Defense Department's latest annual Selected Acquisition Report on the F-35. Lockheed's production schedule allows more than two weeks before the engine is needed for the final assembly line, so Pratt's late deliveries did not hold up the overall F-35 schedule, says Matthew Bromberg, president of Pratt's Military Engines business.

F135 deliveries finally caught up to the contract delivery dates in the first quarter of this year, but the supply chain and productivity disruptions caused by the COVID-19 pandemic have set the program back. About five engines scheduled for delivery in the second quarter fell behind the contractual delivery date, Bromberg says. The pressure will grow as a loaded delivery schedule in the second half of the year adds pressure on deliveries, but Pratt's supply chain managers expect to be back within the contract dates in the first quarter of next year, he says.

The F-35 program's political nature also has caused program disruptions. The Defense Department's expulsion of Turkey from the F-35 program last

year also banished the country's supply chain, which contributed 188 parts to the F135. In particular, Alp Aviation produces the Stage 2, 3, 4 and 5 integrally bladed rotors (IBR) for the F135.

As of early July, about 128 parts now made in Turkey are ready to transition to other suppliers, of which about 80% are based in the U.S., according to Bromberg. The new suppliers should be requalified to produce those parts in the first quarter of 2021 and ready to meet production rate targets for Lot 15 aircraft, which will begin deliveries in 2023.

"The overriding objective was to move with speed and diligence along the transition plan and ensure we are ready to be fully out of Turkey by about Lot 15," Bromberg explains. "And we are on track for that."

As Pratt transfers suppliers, the company also has to manage the effect on potential upgrade options. Alp Aviation, for example, had announced a research and development program to convert the finished titanium IBRs to a more resilient nickel material.

For several years, Pratt has sought to improve the performance of the F135 above the baseline level. In 2017, the company unveiled the Growth Option 1.0 upgrade, which is aimed at delivering modular improvements that would lead to a 5% or 6% fuel-burn improvement and a 6-10% increase in thrust across the flight envelope. The Marine Corps, in particular, was seeking additional thrust to increase payload mass for a vertical landing, but the proposed package did not go far enough to attract the JPO's interest.

"It missed the mark because we didn't focus our technologies on power and thermal management," Bromberg says.

A year later, Pratt unveiled the Growth Option 2.0. In addition to providing more thrust at less fuel burn, the new package offered to generate more electrical power to support planned advances in the aircraft's electronics and sensors, with the ability to manage the additional heat without compromising the F-35's signature in the infrared spectrum.

Last fall, the JPO's propulsion management office teamed up with the Advanced Design Group at Naval Air Systems Command to analyze how planned F-35 mission systems upgrades will increase the load on the engine's thrust levels and power generation and thermal management capacity. In May, the JPO commissioned studies by Lockheed and Pratt to inform a 15-year technology-insertion road map for the propulsion system. The road map is due later this year or in early 2021, with the goal of informing the spending plan submitted with the Pentagon's fiscal 2023 budget request.

As the studies continue, a name change to Pratt's upgrade proposals reveals a fundamental shift in philosophy. Pratt's earlier "Growth Option" terminology is gone. The proposals are now called Engine Enhancement Packages (EEP). The goal of the rebranding is to show the upgrades no longer are optional for F-35 customers.

"As the engine provider and the [sustainment] provider, I'm very interested in keeping everything common," Bromberg says. "The idea behind the Engine Enhancement Packages is they will migrate into the engines or upgrade over time. We don't have to do them all at once. The [digital engine controls] will understand which configuration. That allows us again to be seamless in production, where I would presumably cut over entirely, but also to upgrade fleets at regularly scheduled maintenance visits."

Pratt has divided the capabilities from Growth Options 1 and 2 into a series of EEPs, with new capabilities packaged in increments of two years from 2025 to 2029.

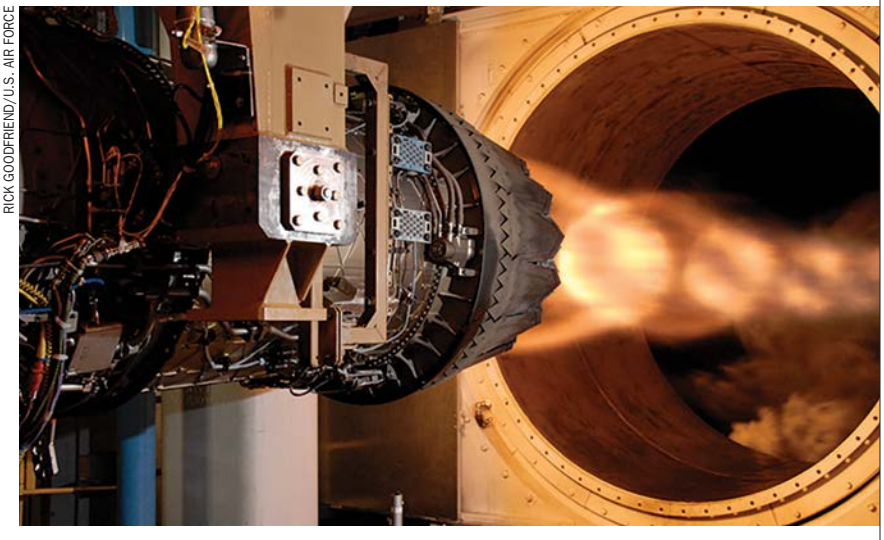
"If you go all the way to the right, you get all the benefits of Growth Option 2, plus some that we've been able to create," Bromberg says. "But if you need less than that and you're shorter on time or money, then you can take a subset of it."

Meanwhile, the Air Force continues to fund AETP development as a potential F135 replacement. As the propulsion road map is finalized, the JPO will decide whether Pratt's F135 upgrade proposals support the requirement or if a new engine core is needed to support the F-35's thrust and power-generation needs over the long term.

Previously, Bromberg questioned the business case for reengining the F-35 by pointing out that a split fleet of F135- and AETP-powered jets erodes commonality and increases sustainment costs. Bromberg also noted it is not clear the third-stream technology required for the AETP can be accommodated within the roughly 4-ft.-dia. engine bay of the F-35B.

Now Bromberg says he is willing to support the JPO's decision if the road map determines a reengining is necessary. "If the road map indicates that they need significantly more out of the engine than the Engine Enhancement Packages can provide, we would be the first to say an AETP motor would be required," Bromberg says. "But we think a lot of the AETP technologies will make those Engines Enhancement Packages viable."

RICK GOODFRIEND/U.S. AIR FORCE



A new upgrade strategy could result in modifications to the F135—pictured during a test inside the Sea Level 3 cell at Arnold Engineering Development Complex in Texas—in the short term and a replacement engine in the long term.

Defense Ministry Wants Japan's Next Fighter Flying in 2028

> THE AIRCRAFT HAS A NEW NAME, THE F-X

> FULL-SCALE DEVELOPMENT LOOKS SLATED FOR 2022

Bradley Perrett Beijing

The Japanese defense ministry proposes to fly the first prototype of the country's next fighter in 2028 and begin deliveries to the air force seven years later. More immediately, the government and industry must soon decide on the contracting arrangements for the program.

Since a plan presented to the ruling Liberal Democratic Party (LDP) on July 7 includes starting to build the first prototype in 2024, the ministry must intend to launch full-scale development in 2022. The proposed schedule includes tradeoff studies in concept design beginning next year, by which time British or U.S. development partners would be involved.

The tradeoffs may be made in small ranges because the ministry has pretty clearly told the world what it thinks Japan needs. Its concept designs prepared since 2013 have consistently envisaged long endurance, less than extreme flight performance and internal carriage of eight air-to-air missiles (six of long range and two of short range). The aircraft would therefore be vastly larger than the type it is intended to replace, the Mitsubishi Heavy Industries (MHI) F-2.

Moreover, the ministry implicitly defended its concept in the presentation by twice emphasizing that the proposed fighter should carry "enough" air-to-air missiles.

The project has a new name, the F-X, succeeding the former moniker of the Next-Generation Fighter and, before that, the Future Fighter.

Japan's inclination to begin F-X work so early clashes with the schedule of Britain's proposed BAE Systems-led Tempest fighter program, with which the F-X effort could be associated to share costs. Full-scale development of the Tempest is not supposed to begin before 2025. The ministry specifically raises the possibility of working on the F-X's engine with Britain, which may mean Rolls-Royce could be involved even if BAE were not.

The early schedule therefore seems to advantage the U.S. contenders for collaboration with Japan—which the ministry says are Boeing, Lockheed Martin and Northrop Grumman, local media report. Those cooperation partners would have to be paid by Japan rather than the U.S., which has no imminent fighter program that can be shared with even a close ally.

LDP member of Parliament Sato Masahisa and journalist Takahashi Kosuke published the ministry's slides from the presentation online.

The schedule for the fighter program envisages a rush of actions by the end of this year. Officials said a decision on contracting arrangements should be made this month, according to the *Asahi* newspaper. After that, according to the presentation, the ministry will request F-X funds in September and believes a Japanese prime contractor or prime contractors should be chosen in October. By the end of the year, the choice between a British and U.S. partnership should be made, along with parliamentary allocation of money for the fiscal year beginning April 1.

Four possible contracting arrangements are under consideration. One is Japan's usual practice of separately contracting for airframes, engines and avionic equipment. For example, this was the setup for Japan's previous fighter and the Kawasaki Heavy Industries P-1 maritime patroller, but the ministry does not recommend it this time.

"In the cases of F-2 and P-1, there were multiple prime contractors, but aircraft of the fifth-generation and later need tighter coordination to achieve higher stealthiness," the ministry says.

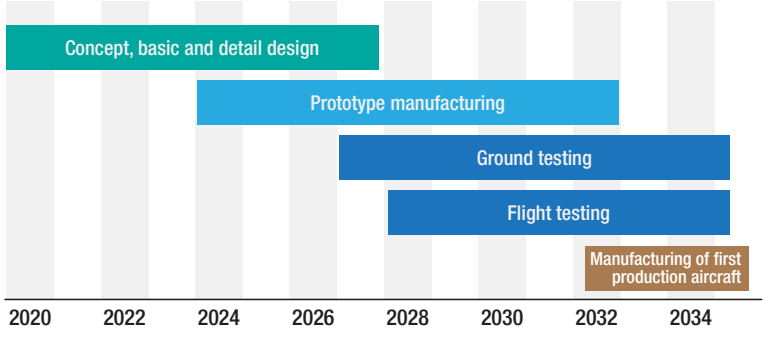
Of the other contracting arrangements, each is seen to have disadvantages, and none is specifically recommended. One would be to have a single prime contractor, as was done with the MHI X-2 fighter technology demonstrator. The disadvantage would be the lack of contractual obligations between the ministry and the engine and avionic companies. The program might not fully reflect the needs of the user—that is, the Japan Air Self-Defense Force.

Another option is to set up a special-purpose company for the job, the ministry says. Its engineers would come from Japan's current aerospace companies, each of which would choose how large a share—and therefore how large a risk—to take. The taxpayer would need to pay for a new head office.

The last listed possibility would be a joint venture. There would be no new company, but each participant would bear unlimited liability. Risk-sharing would have to be defined, and the program could be paralyzed if the partners could not agree.

MHI has most of Japan's expertise as a fighter airframe prime contractor, while Mitsubishi Electric developed the radar for the F-2. IHI is the only possible Japanese engine supplier and has built a technology demonstrator engine for the prospective program. MHI built 94 F-2s; a similar number of F-Xs is likely. Japan has spent or will spend ¥228 billion ($2.13 billion) on research and development in relation to the F-X in 2010-25, the ministry says.

Proposed F-X Schedule



Source: Japanese Ministry of Defense

ARROW 4.0

- ARROW WEAPON SYSTEM DEVELOPMENT PROGRESSES AS IRANIAN MISSILE THREAT EVOLVES
- KHORRAMSHAHR MISSILE POSES NEW THREAT
- DEVELOPMENT IS ONGOING FOR NEW ARROW 4 AND UPGRADED ARROW 2

Steve Trimble Washington

Building on three generations of the Arrow Weapon System, Israel's Upper Tier missile interceptors are in line for new upgrades as the Iranian missile threat continues to evolve in new and surprising ways.

A 2019 test staged in Alaska demonstrated the shoot-look-shoot capability of the Arrow 3 interceptor.

U.S. MISSILE DEFENSE AGENCY PHOTOS

The 34-year-old collaboration between Israel Aerospace Industries (IAI) and Boeing at the integration level has delivered a multilayered defensive system with a now-demonstrated ability to shoot down Syrian SA-5 missiles at medium altitude as well as Israel-designed Silver Sparrow targets to simulate intercepts of medium-range ballistic missiles (MRBM) in space.

In a fateful coincidence, Israel's missile defense organization in July 2019 demonstrated the critical "shoot-look-shoot" capability of the Arrow 3 during a series of test launches in Alaska just ahead of a monthslong spike in regional tensions with Iran.

In September, about two dozen Iranian unmanned aircraft systems (UAS) and missiles struck oil facilities in Saudi Arabia. The U.S. military retaliated in January by killing Qassem Soleimani, commander of Iran's Islamic Revolutionary Guards Corps (IRGC), in Iraq. Five days later, the IRGC launched between 13 and 22 short-range ballistic missiles—U.S., Iraqi and Iranian sources reported different numbers—at a major U.S. military base in Iraq, causing damage but no fatalities.

The attacks highlighted Israel's nearly four-decade quest to erect a multilayered defensive system against a wide variety of threats, from unguided rockets to recently upgraded MRBMs equipped with maneuvering reentry vehicles and potentially dispersible submunitions.

Israel declared the Arrow 3 interceptor operational in January 2017. By intention or coincidence, Israel's declaration came a week before Iran announced completing a successful test of a new MRBM called the Khorramshahr. Acquired from North Korea's stockpile of Musudan missiles—themselves derived from the Soviet R-27, according to the Center for Strategic and International Studies' Missile Defense Project—Iran said the liquid-fueled Khorramshahr introduced the country's first multiple independently targetable reentry vehicle (MIRV) technology, although analysts say its size likely limits the warhead to unguided submunitions.

The Khorramshahr, however, reflects both the current limits and steady improvement of Iran's already large ballistic missile arsenal. Likewise, the launch in April of the IRGC's first satellite—reportedly a cubesat—also reflects a step toward longer-range and more sophisticated

ballistic missiles. In addition to the Khorramshahr, Iran fielded the Emad variant of the Shahab-3 MRBM, guided by an inertial navigation system and featuring a maneuverable reentry vehicle (MARV) warhead to dramatically improve accuracy.

Israel introduced the Arrow 2 Block 1 in 2000 less than two years after the first test launch in Iran of the Shabab-3, an indigenous version of North Korea's Nodong missile. The Arrow 3 Block 5 appeared on the heals of Iran's acquisition of the Korramshahr. As Iranian capabilities continue to evolve, Israel seeks to ensure its Upper Tier missile defense layer is prepared.

"We are working in cycles of development," says Boaz Levy, executive vice president of IAI's Systems, Missiles and Space group. "We always look toward the next generation, and—since we have Arrow 3 right now—it's kind of logical that we would have Arrow 4 in the future."

The Arrow 3 expanded the intercept envelope of Israel's Upper Tier by about four times compared to the Arrow 2, but it is unclear what the requirements will be for the Arrow 4. As Iran's MRBMs become more sophisticated, Israel's defensive technology must adapt to discriminate warheads and MIRVs from more numerous and advanced decoys.

"We are really working on [the Arrow 4] capability these days, so in the near future when the threat will emerge and we have the need to counter a new type of capability, we will have the vehicle to do so," Levy says. "So Arrow 3 exists and, as I mentioned, Arrow 4 is our future capability. Unfortunately, I will not be able to describe what it is, and it is something that we will have to wait until we will be permitted to speak about it."

As the Arrow 4 system continues being worked on within IAI, the Israel government is developing the 2025 Missile Defense Architecture to define the reference threats and capabilities over a 10-15-year period, according to U.S. budget documents.

The future architecture will build on an existing Arrow Weapon System with several fielded elements, including the Arrow 2 and Arrow 3 missiles, Elisra Citron Tree battle management system, IAI Hazelnut control center and Elta Systems Green Pine and Super Green Pine radars. Since the activation of the Arrow 3 in 2013, the Israeli system has provided defensive coverage over the entire country. In addition to Israel-owned Patriot PAC-3 missile batteries, the U.S. has also deployed the TPY-2 radar for the Terminal High-Altitude Area Defense System to Israel.

Israel keeps a tight rein on information about periodic updates to the major systems, but announcements by export customers have filled in some of the gaps. For example, Israel declared the Super Green Pine radar operational in 2010, with the activation of the Green Pine "Block B." Eight years later, South Korea announced buying two Green Pine Block C radars for missile defense.

Officially, Israel's ground-based radar network is deemed sufficient for detecting missiles launched over the horizon, as the curvature of the Earth allows for enough detection warning to support multiple intercept attempts by Arrow missiles at incoming MRBM warheads while still in space.

"Ballistic missile defense means that your threat will always come from a high altitude," Levy explains. "That's why over-the-horizon [radar] is not such an important thing that we put our effort into it. Since the radar is looking up, the threat will be acquired by the radar. That's why the radars that are deployed in Israel offer sufficient acquisition time and accuracy to cue our interceptors on time."

Nonetheless, U.S. budget documents show Israel is pursuing additional radar tracking options for over-the-horizon detection.

"Arrow Block 5 development incorporates a Long-Range Detection Suite (LRDS) that consists of an unmanned aerial vehicle (UAV) Airborne Early Warning System and SharpEye Radar for increased sensor range, early detection and enhanced raid size capacity," say budget justification documents released by the U.S. Missile Defense Agency (MDA) in February.

In addition to fielding the Arrow 3 and developing the Arrow 4, Israel also is actively pursuing upgrades for the Arrow 2. The original indigenous weapon in Israel's Upper Tier layer (the initial Arrow concept was scrapped in the late 1990s) has performed reliably over two decades. In its first test in battle, the Arrow 2 intercepted a Syrian SA-5 that was targeting an Israeli Air Force F-16 returning from a strike mission. The Arrow 2 also has been successfully tested against a series of Sparrow-series targets, including Black and Blue Sparrows, simulated Scud-type missiles.

The evolution of Iranian missile capabilities includes threats that fly at lower altitudes than the Khorramshahr, so the endoatmospheric intercept capability of the Arrow 2 remains important in Israel's missile defense architecture. Israeli sources offer no new information about potential upgrades, but the MDA, which is partly funding the Arrow program, provides some detail.

"In addition, a new variant of Arrow 2 (M6) interceptor will be developed," the MDA says, without elaborating.

An early version of the two-stage Arrow 2 interceptor was fired from a mobile launcher during a 2004 test.

MEASURING UP

> THE PANDEMIC TESTS THE SMALL SATELLITE INDUSTRY'S RESILIENCE AND RESOURCEFULNESS

> ABOUT 600 SATELLITES LAUNCHED SO FAR IN 2020

Irene Klotz Cape Canaveral

California startup Swarm Technologies was five days away from launching its first commercial tranche of satellites when the COVID-19 pandemic prompted Europe to shut down the Guiana Space Center in French Guiana, grounding an Arianespace Vega rocket, its ride to orbit.

"We continually joke, 'Man, if we had just hit the [launch] button on the way out,'" Swarm co-founder and Chief Technology Officer Benjamin Longmier tells Aviation Week.

Swarm, along with 20 other customers sharing the Vega flight to orbit, are still awaiting liftoff. Travel and work restrictions eased in June, but then poor weather closed in on the South American spaceport, bumping launch to Aug. 17 to allow time to recharge batteries in the rocket and payloads.

Launch delays are nothing new in the space industry, but the economic and logistic challenges posed by COVID-19 closures are giving startups such as Swarm unplanned opportunities to test their business acumen.

"When we saw COVID turning up in China, the first thing we did as a team was buy a large set of parts for the satellites and ground stations just to have it in our lab, assuming that supply chains were going to be disrupted, delayed and even destroyed in some cases," Longmier says. "We spent a large amount of money on parts in anticipation that we would need them."

Payloads aboard the upcoming Vega proof-of-concept ride-share mission—and the rocket's first flight since a July 2019 accident—include eight spacecraft owned by Spire Global, a data and analytics company that provides meteorological data, ship and aircraft tracking and other services using 88 spacecraft already in orbit.

Spire has significantly scaled up sales of weather data during the pandemic, helping to fill a 75-90% gap in real-time data previously provided by commercial airlines. "There are sensors on the planes that collect data on temperature, wind and humidity and transmit it real-time to meteorological organizations around the world," says Johan Varghese, Spire's product marketing manager for aviation.

The data is used in computer models that underpin accurate forecasting. Now, with air traffic diminished by the pandemic, agencies are buying satellite-based radio occultation data from Spire. This data is gathered by analyzing signals from GPS and other navigation satellites as they cut through the limb of Earth's atmosphere, relative to the Spire spacecraft's lines of sight. The system can collect data from the ground up to 75 mi.

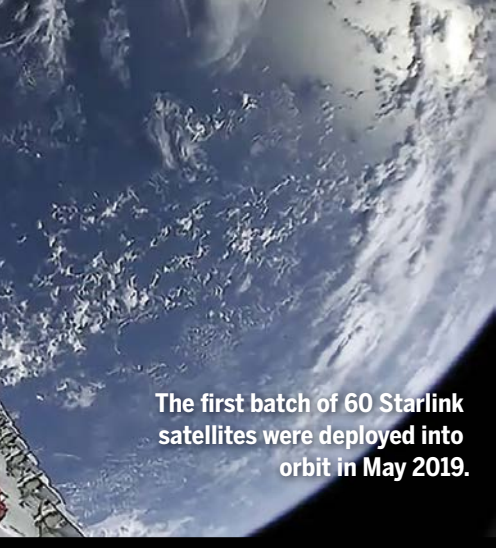
"This has been a good opportunity for our technology to become kind of key and substitute for the lack of [aircraft] data," says Varghese.

Other companies have not fared as well. The biggest stumble came from broadband satellite operator OneWeb, which filed for Chapter 11 bankruptcy protection on March 27, six days after launching a batch of 34 spacecraft into orbit.

The company's primary backer, Tokyo-based Softbank, declined to provide additional financing after its market value collapsed as the coronavirus pandemic engulfed the planet. OneWeb is now in the process of being acquired by a consortium owned by the UK government and Indian telecommunications company Bharti Global (*AW&ST* July 13-26, p. 70). The

Dozens of smallsat companies are operating in low Earth orbit. This view was taken by NASA's Dscovr satellite on July 16, 2020, at a distance of 983,900 mi.

TOP: SPACEX. CENTER: NASA EPIC TEAM. BOTTOM: SPACEFLIGHT.



The first batch of 60 Starlink satellites were deployed into orbit in May 2019.

Spaceflight in July unveiled the Sherpa-FX orbital transfer vehicle to deploy smallsats on ride-share missions.

plan remains subject to approvals, including court confirmation.

OneWeb's bankruptcy filing was followed in April with aspiring internet of things startup Sky and Space Global turning over control of the company to an accounting firm in Australia, where it is publicly listed. The procedure, known as "voluntary administration," is similar to a bankruptcy filing.

"We are seeing the impacts of the pandemic in some of the bankruptcies taking place," says Manny Shar, head of analytics at Bryce Space and Technology. "This is kind of a sign of the challenging times that are taking place."

While OneWeb regroups, competitor SpaceX has continued launching satellites for its global internet broadband service, Starlink. Of the nearly 600 spacecraft put into orbit this year—already a record—418 were SpaceX Starlinks. The satellites were launched in seven Falcon 9 flights, four of which occurred after the pandemic triggered widespread shutdowns in the U.S.

SpaceX plans to begin rolling out commercial internet service via Starlink this fall. The initial constellation will consist of about 1,500 satellites, with plans to expand the network to 4,400. The company has approval from the U.S. Federal Communications Commission to operate 12,000 satellites.

So far, the pandemic is not delaying plans by longtime satellite operator Telesat to expand into low Earth orbit (LEO) with a new network. The decision on the primary contractor—essentially a two-way race between Thales Alenia Space and Airbus Defense and Space—is expected to be announced this year.

"These LEO constellations—if you get them right—I believe will be absolutely disruptive to the market," Telesat President and CEO Daniel Goldberg tells Aviation Week. "We're just plodding along, staying focused, trying to execute on our plan and not get too delayed."

The company has not yet secured all the funding it needs to build, launch and operate the 300-member Telesat LEO constellation. But despite pandemic-triggered worldwide recessions and economic instability, Goldberg believes the multiple billions of dollars needed to finance the project will be available.

In addition to tapping its own deep pockets—Telesat has more than $1 billion cash on its balance sheet—the Ottawa-based company plans to raise financing through export credit agencies, including the U.S. Export-Import Bank.

"Governments right now are very focused on restimulating their economies in the face of the economic carnage wrought by COVID," says Goldberg. "Certainly, the export credit agencies, I believe, will be one of the levers governments will pull to support their domestic industries.

"I think those agencies were always going to be receptive to our project. It may well be the case that they're even more keen now, given that it's a big project, it's high-profile, and it generates a lot of jobs for the suppliers," he adds.

Private investment in space companies has been growing since 2015, with a record $5.7 billion raised in 2019, according to Bryce Space and Technology.

"We're probably not going to see anywhere near the numbers we saw in 2019—that would be a surprise and a shock if we do, but that's probably not going to be the case," says Shar. "That's not to say that [venture capitalists] have stopped investing. Obviously, they're looking out for those companies that are generating revenue and perhaps are lower down on the risk spectrum, particularly companies that are stable with government revenue."

The top investment deals from April to June were: a $125 million Series M round for SpaceX, $38 million Series B for China's Commsat, $19 million Series B for Australia's Myriota, $14 million Series A for China's Space Pioneer, $10 million preseed round for India's Vestaspace Technology and $6 million Series A for Japan's PD Aerospace, according to an April-June 2020 quarterly report by Space Capital, an early-stage venture capital firm.

"With [domestic] U.S. infrastructure investment . . . declining 91% from [the first quarter], we see a number of international companies on the top investments list. In particular, two notable investments in China show signs that the country may be recovering from COVID," the report notes.

Overall, venture capital investment in space is up 4% for the first six months of the year compared to the same period in 2019. "While the first half of 2020 was overwhelmed by the COVID-19 pandemic, the significant momentum in the space economy continues," the report concludes.

Rocket Lab Electron Falters on 13th Flight

> FIRST INFLIGHT ANOMALY FOR ELECTRON

> PREPARATIONS UNDERWAY FOR NEXT MISSION

Irene Klotz Cape Canaveral

If there had to be a booster failure, best that it be of the nonexplosive, telemetry-rich variant such as what Rocket Lab, which has been delivering small satellites into orbit since 2018, is now grappling with.

"It's a day you hope never comes," Rocket Lab founder and CEO Peter Beck tells Aviation Week. "But unfortunately, in just about every rocket's history, the day does come. We were well prepared for it.

"The great thing—if there is a great thing—is that it was a very graceful failure. The vehicle is highly instrumented—we run up to 30,000 channels of data streaming—so that makes our lives much easier in tracking down the root cause.

ROCKET LAB

The glowing nozzle of the Electron rocket's second stage just before the video link was lost following the launch on July 4.

"I don't want to speculate on root cause at this time. We need to give the team the time to really work it out because there are always mitigating factors to the root cause, and you spend more time proving what it wasn't than proving what it was."

Rocket Lab's 13th Electron rocket lifted off at 5:19 p.m. EDT on July 4 from the company's privately owned spaceport on New Zealand's Mahia Peninsula, aiming to put seven satellites into 310-mi.-high sun-synchronous orbits.

The nine liquid-fueled Rutherford engines powered the 55-ft.-tall booster for the first 2 min. 35 sec. of flight, then shut down as planned, allowing the spent first stage to separate.

A single, vacuum-optimized Rutherford fired up 6 sec. later for what was expected to be a 6-min. 21-sec. burn.

Rocket Lab's live webcast lost video feed from the second stage about 5 min. 40 sec. into the flight, but telemetry continued, showing a peak altitude of 121 mi.

Beck later said the anomaly occurred earlier than that, about 4 min. into flight, which was after the rocket shed its payload fairing and about 2.5 min. before a battery hot swap was to take place to power the second stage into orbit.

"We lost the flight late into the mission," Beck wrote on Twitter. "I am incredibly sorry that we failed to deliver our customers' satellites today. Rest assured we will find the issue, correct it and be back on the pad soon."

Rocket Lab declined to say if its contracts with customers Spaceflight, Planet and British startup In-Space Missions, which were sharing the ride, include reflights.

"We are of course disappointed, while at the same time always aware that launch failures are part of the business of space," said Seattle-based Spaceflight, which had arranged for the ride of an Earth-imaging satellite owned by Japan's Canon Electronics. "We have faith in all our launch vehicles, including Electron, and look forward to many more successful launches with them."

Canon's CE-SAT-1B was the largest of seven payloads lost aboard the Electron. The 147-lb., cube-shaped spacecraft was designed to image objects on the ground as small as about 3 ft., Canon says. Following launch of its tech demo CE-SAT-1 in 2017, Canon announced plans to build a fleet of Earth-imagers based on its EOS 5D Mk. 3 camera.

The accident also claimed five Earth-observation nanosatellites owned by San Francisco-based Planet. The shoebox-size spacecraft, known as SuperDoves, were advanced versions of Planet's medium-resolution Dove satellites. The company operates a fleet of more than 120 Earth-observation satellites that provide daily images of Earth's landmasses.

"While it's never the outcome that we hope for, the risk of launch failure is one Planet is always prepared for," Planet said in a statement.

Planet plans to launch 26 more SuperDoves on the upcoming launch of Arianespace's Vega rocket and several more satellites on other boosters over the next 12 months.

Making its space debut was In-Space Missions, based in Bordon, England, which owned Faraday-1, a six-unit cubesat outfitted with a variety of experimental payloads.

"It really was a very cool little spacecraft," In-Space Missions wrote on Twitter. "Two years of hard work from an incredibly committed group of brilliant engineers up in smoke."

Faraday-1's technology demonstrations included a software-defined radio from Airbus Defense and Space that could be reprogrammed in orbit, 360-deg. optical video imaging, radio spectrum monitoring, applications for internet-linked machines and an assessment of an adaptive optics-corrected ground-based laser. In addition to Airbus, Faraday-1 customers included Kleos Space, Lacuna Space, the Space Environment Research Centre in Canberra, Australia, Canadensys Aerospace and Aeternum.

While the accident investigation is underway, Rocket Lab is continuing with preparations to launch its next mission. "The rocket has a lot of heritage on it now," Beck says. "We've actually sent the next vehicle's first-stage booster to the launch site. There are teams working on [it] in parallel with the investigation."

ASK THE EDITORS

What Are the Airliner Fuel Storage Challenges of Hydrogen Power?

Aviation Week Senior Propulsion Editor Guy Norris responds: Hydrogen propulsion holds significant potential to reduce climate impact in flight by as much as 75% when used in engines for direct combustion and as much as 90% when used in fuel cells to power electrically driven hybrid engines or distributed propulsion systems. Although liquid hydrogen (LH_2) has three times the gravimetric energy density of jet fuel, it has a low volumetric density (approximately 2.4 kWh/liter compared with 10.4 kWh/liter for kerosene). This creates a huge challenge for aircraft designers because hydrogen fuel will require about four times the volume of jet fuel to carry the same onboard energy.

Even assuming lightweight tanks can be developed, the volumetric density issue means hydrogen propulsion will—at least for the near to mid-term—be best suited to smaller regional, short- and medium-range aircraft. Although hydrogen fuel is technically feasible for use in longer-range aircraft, the size of the fuel tanks would result in much longer or larger fuselages and greater energy demand, resulting in costs as much as 50% higher per passenger. For the longer term, however, it is possible that new volumetrically efficient airframe designs such as blended wing body (BWB) configurations would enable hydrogen to be considered for future long-range applications.

According to a recently published independent review of hydrogen-powered aviation prepared by McKinsey & Co. for the European Union's Clean Sky 2 research initiative, developers are considering multiple options to enable fast-tracking service entry of hydrogen-powered aircraft so they could have a material impact on the climate before 2050. The initial evolutionary option is to develop versions of current tube-and-wing designs in which engines and fuel systems are adapted to run on LH_2.

For an Airbus A320/Boeing 737-size aircraft flying on typical ranges up to 1,100 nm (2,000 km), for example, the issue of fuel volume would be handled by stretching the fuselage to accommodate LH_2 tanks behind the passenger cabin. Power would be provided by a hybrid system that combines hydrogen-burning turbine engines sized for takeoff and climb with an 11-megawatt fuel cell to generate the bulk of power for cruise.

Compared with current aircraft, overall range would be about 25% shorter, and design speed would be reduced to about Mach 0.75, but carbon dioxide emissions would be zero while overall climate impact would be 70-80% less. Although cost per available seat-kilometer would be more than 20% greater, this would be partially offset by better energy efficiency.

Revolutionary options, while still including the addition of LH_2 tanks in the main fuselage, center on the development of fuel cells for commuter and regional aircraft. These would power a distributed propulsion system made up of electrically driven propulsors. However, this option would not meet the energy demands of medium- and long-range aircraft. Until BWB and other alternative configurations become available, the most realistic solutions will continue to be evolutions of existing airframes. In these, large turbofan engines would be adapted to burn LH_2, and extra fuel tanks would be contained in extended fuselages.

The bottom line is that carrying an A320 or 737-800 passenger load in an A321- or 737-10-size fuselage may be economically and technically feasible, but the scaling effects make this increasingly challenging with larger airliners such as the A350 or 787. Fuel tank technology, therefore, is a critical pacing factor governing the speed and extent to which hydrogen power will be adopted. The McKinsey report indicates a 50% reduction will be necessary in overall LH_2 tank mass compared with current prototypes. Measured in terms of a gravimetric index (the weight of LH_2 fuel mass in relation to the full weight of a tank filled with maximum LH_2 load), a successful evolutionary short-range airliner will require an index of 35% while long-range aircraft will require 38%. Only improvements of this scale, the report argues, will allow weight and volume to be reduced to the point at which these concepts become operationally practical.

AW&ST ARCHIVE

The idea of hydrogen fuel is not new, as witnessed by Soviet-era flight tests of the Tupolev Tu-155—a specially modified hydrogen- and natural gas-fueled Tu-154 variant pictured here in *AW&ST* (May 16, 1988, p. 62)—but new technologies could potentially make it practical by the 2030s.

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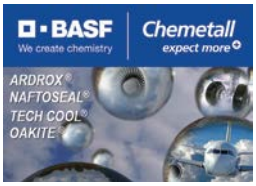

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Aviation Week & Space Technology
JULY 27-AUGUST 16, 2020 VOL. 182, NO. 15
(ISSN 0005-2175)

Aerospace Calendar

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email: aero.calendar@aviationweek.com

July 30-Sept. 2—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations. See rtca.org/content/upcoming-committee-meetings

Aug. 1-6—Small Satellite Conference (SmallSat 2020): Space Mission Architectures. Virtual event. See smallsat.org

Aug. 4-5—vFuze (Next-Generation Fuzing for Next-Generation Weapons Systems). Virtual event. See ndia.org/events/2020/8/4/vfuze-2020

Aug. 4-6—Space and Missile Defense Symposium. Virtual event. See smdsymposium.org

Aug. 9-13—AAS/AIAA Astrodynamics Specialist Conference. Virtual event. See space-flight.org/docs/2020_summer/2020_summer.html

Aug. 12-13—Civil Avionics International Forum 2020. Chinese Society of Aeronautics and Astronautics. Shanghai. See galleon.eventbank.cn/event/9th-annual-civil-avionics-international-forum-2020-25450

Aug. 20-21—Space Warfighting Industry Forum (SWIF). Virtual event. See ndia.org/events/2020/8/19/space-warfighting-industry-forum#

Aug. 24-26—AIAA Propulsion and Energy Forum and Exposition. Virtual event. See aiaa.org/propulsionenergy

Aug. 25-28—UAS West Virtual Symposium. Virtual event. See asdnews.com/news/defense/2020/06/26/uas-west-virtual-symposium

Aug. 31-Sept. 1—2020 Humans to Mars Summit (H2M). National Academy of Sciences Building. Washington. See exploremars.org/summit

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Aug. 11-13—Urban Air Mobility Virtual. Virtual event.

Aug. 25-26—Aerospace Manufacturing Conference. Virtual event.

Sept. 2-3—Military Aviation Logistics & Maintenance Symposium (MALMS). Dallas.

Sept. 15-16—Commercial Aviation Industry Suppliers Conference-Europe. Virtual event.

Sept. 16-17—Aero-Engines Europe. Virtual event.

Sept. 22-24—Aero-Engines Asia-Pacific. Virtual event.

Sept. 23-24—MRO Asia-Pacific. Virtual event.

Oct. 8-10—Routes Asia 2020. Chiang Mai, Thailand.

Oct. 19—Aviation Week Laureates Awards. McLean, Virginia.

Oct. 20-21—Aviation Week DefenseChain Conference. McLean, Virginia.

Oct. 21—Aviation Week Program Excellence Awards and Banquet. McLean, Virginia.

Oct. 27-29—MRO TransAtlantic. Virtual Event.

Oct. 27-29—ap&m Europe. Barcelona, Spain.

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VIEWPOINT

A Flight Plan for the COVID Recovery

By **Stephen Timm**

KARIM SAHIB/AFP/GETTY IMAGES

The industry we love is hurting. Not long ago, airports were packed, airplanes were full, and a record number of passenger miles were logged. Commercial air transport was not just strong, it was thriving. At its peak, our sector supports 65.5 million jobs and $2.7 trillion in global economic activity. But in the COVID-19 pandemic, commercial traffic has been down as much as 90%. With regions around the world in varying stages of recovery—and some still regressing—stops and starts to overall air travel are to be expected.

The reality is that this recovery will take years, not months. The pandemic is affecting the world's health and the global economy—and these two things are inextricably linked. The actions commercial aviation is taking right now will determine how strong it will be when this pandemic is behind us. I am encouraged because companies across our industry are shifting from being competitors and customers to becoming collaborators with one shared mission. Together, we must take control of the health and safety measures we put in place in airports and on airplanes, just as we are doing in our own companies.

BEING ADAPTABLE IS CRUCIAL; WE NEED TO INTEGRATE ADVANCES QUICKLY.

The commercial aviation industry needs an interassociation, interagency approach, including active participation from government. This is vital, because government plays a role in the commercial aviation system, along with manufacturers, airlines and airports. A joint government/industry-led task force will provide the momentum and expertise needed to restore confidence in air travel.

What steps are needed? To jump-start our industry, we must educate the public that safety measures are in place today. We need to create an ongoing, consistent experience for those flying anywhere in the world. This can be accomplished by layering in additional safety measures and messaging in two phases: short term and long term.

Short Term. It is vital to bolster passenger confidence by telling travelers what to expect at the airport and in the air. We may know the measures in place, but we need to tell those who are ready to fly—and keep telling them. At many airports, biometric systems enable faster, touchless screening and check-in. Physical distancing is enforced in lines and waiting areas with signs, floor markers and barriers. Everyone can now take up to 12 oz. of hand sanitizer through TSA security checkpoints to stay vigilant with hand hygiene.

On airplanes, HEPA air filtration systems remove 99.99% of particles, including viruses. Many airlines are sanitizing before, during and after every flight and mandating face coverings for crew and passengers.

We must also drive a consistent passenger experience. The confidence this information can instill could be shaken if flyers don't see similar technologies and procedures when traveling through major airports and with different airlines. As an industry, we determine what we do in airports and on airplanes, and together we can define and implement the playbook that creates greater consistency.

Being adaptable in the short term is crucial. Once additional layers of protection are ready, such as robust testing before flights, we need to integrate those advances quickly.

Long Term. Airports, airlines, suppliers, medical experts and government agencies must unite to create a change that is experienced curb to curb—from airport arrival through boarding and the flight itself to the destination airport exit.

Redesigning terminals, increasing the use of biometrics, conducting health screenings and contact tracing, adding touch-free solutions and introducing antimicrobial surfaces and UV disinfectant systems are bold and long-lasting ideas being discussed across our industry. Bringing them to life will create a modern journey that keeps people even more protected.

And we need these systems in place while the COVID-19 vaccine is being developed—and even after it is being administered—to make commercial aviation less susceptible to a threat of this magnitude.

Changes of this scope will take time—and it won't be the work of one person, one company or one sector of our industry. The work being done by the Aerospace Industries Association and Airlines for America are great examples. We must also think globally. Our collective voice and expertise will determine our destiny.

It will take all of us to keep the industry we love up and running long-term. And I believe we will do it.

Stephen Timm is president of Collins Aerospace.

SpeedNews

Commercial Aviation Industry Suppliers Conference – Europe

A VIRTUAL EVENT

SEPTEMBER 15-16, 2020
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Designed for Leaders and Decision-makers from OEMs to Suppliers in the Commercial Aviation Suppliers Industry

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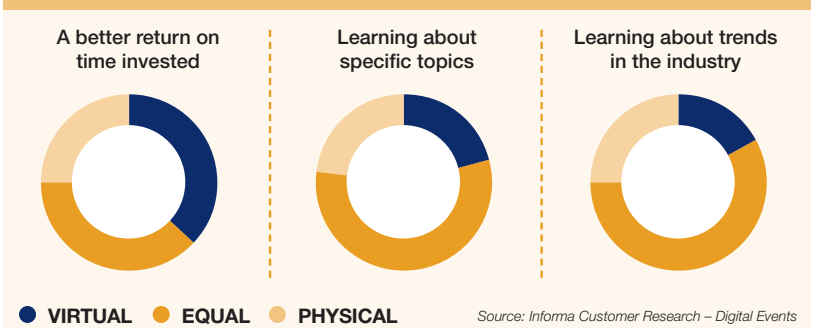
While COVID-19 makes it unsafe for us to gather face-to-face, we want to make sure you and your organization can receive up-to-date information. In fact, the current state of our environment makes digital transformation even more imperative for all of us!

This **virtual** event will provide delegates — equipment manufacturers, material suppliers, aviation industry analysts, financial institutions, and marketing executives — with important updates about the commercial aviation industry. Aircraft and engine manufacturers will present status reports on product strategies and market developments. Industry experts will present production and delivery forecasts and review the current environment and economic status of the industry. Supply chain management, industry restructuring, maintenance and subcontractor issues will also be addressed.

WHICH FORMAT IS BETTER FOR...



Source: Informa Customer Research – Digital Events

Topics focus on key components driving the industry:

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- Raw materials and manufacturers supply chain
- Managing supplier risks and investments
- OEM product strategy and market developments
- Aircraft production and delivery forecasts
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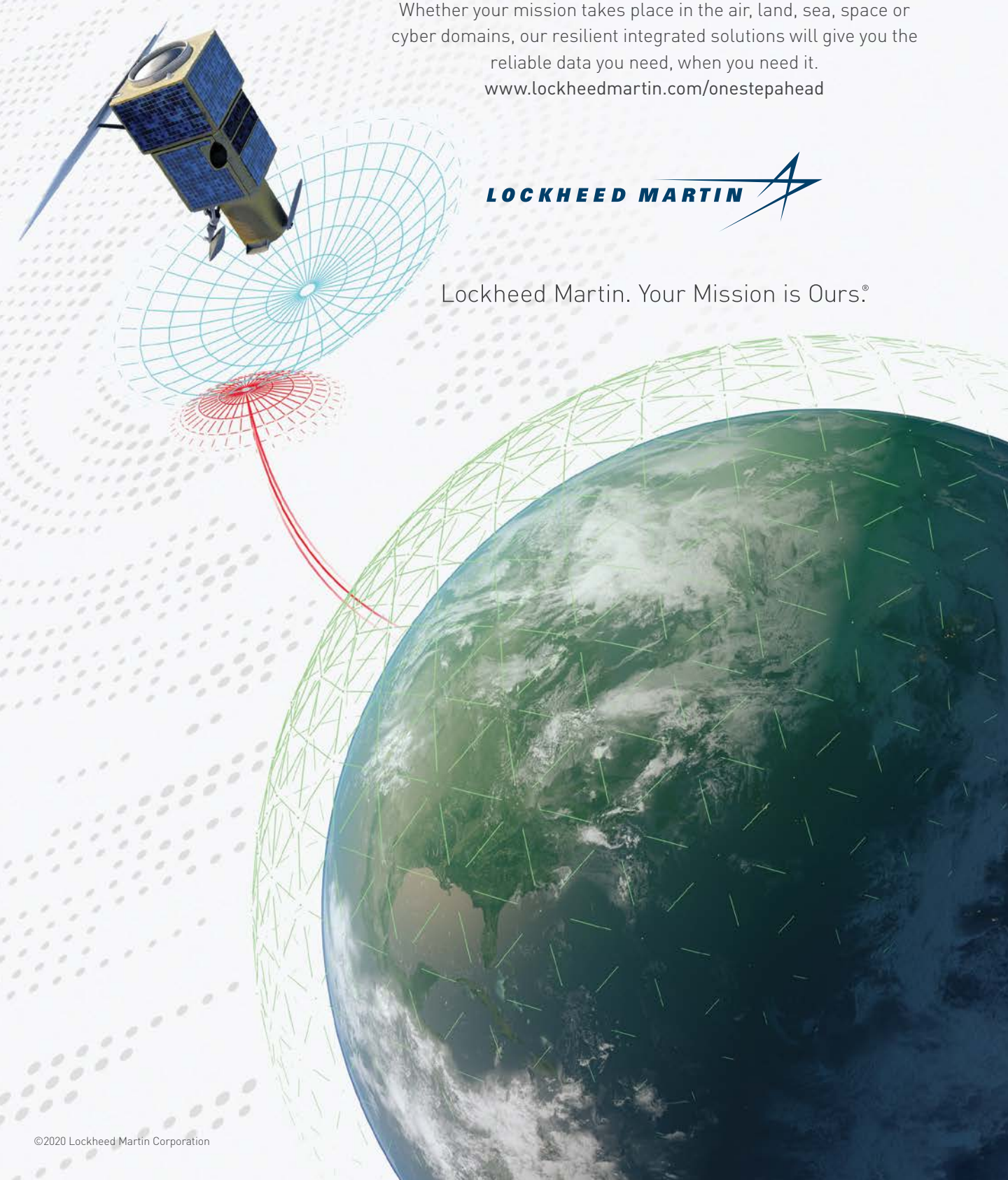

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