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AEROSPACE & DEFENSE 2020

WHAT YOU NEED TO KNOW FOR THE YEAR AHEAD

AVIATION WEEK NETWORK

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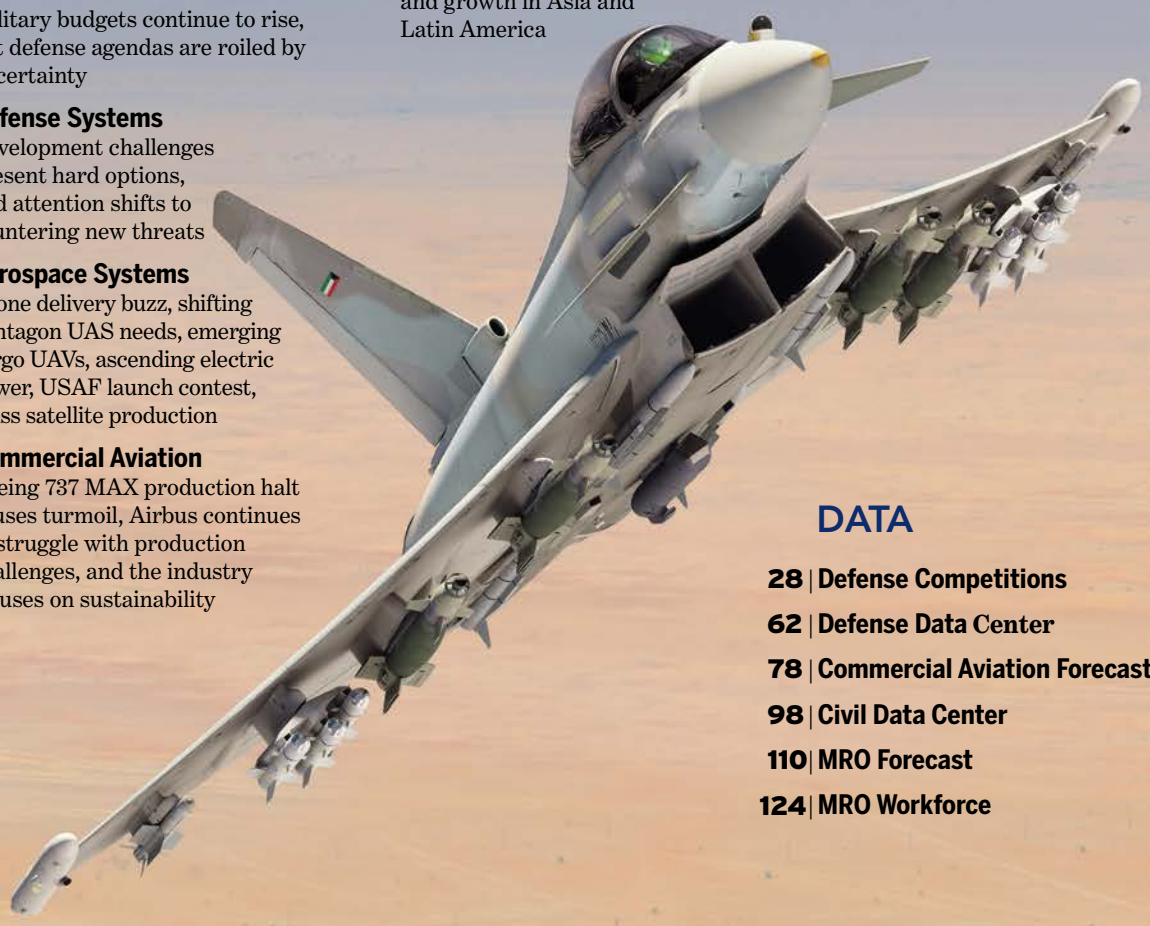

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ON THE COVER

As the new decade begins, advances in digitization, electrification and other technologies are shaping product development decisions ranging from commercial airliners to combat aircraft and advanced rotorcraft to air taxis. Aviation Week looks at the issues, from sustainable aviation to superpower rivalry. Airbus A350 photo by Anthony Pecchi.

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PRODUCTION DIS

Michael Bruno Washington, **Guy Norris** Los Angeles,
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Boeing's drastic decision to suspend 737 MAX production in the face of managing a growing fleet of idle aircraft and continued uncertainty over when the model will be approved to return to service is sending shockwaves through the airline industry, posing new questions for suppliers, operators and the manufacturer itself.

Boeing plans to focus on reducing the backlog of undelivered MAXs when the model is cleared to fly.

MARK WAGNER/AVIATIONIMAGES.COM

> BOEING WILL SUSPEND BUILDING MAXs IN JANUARY

The Chicago-based company on Dec. 16 said it would stop building new MAXs in January, following the planned late-December holiday break. It did not provide a specific date for the pause or speculate when production would resume. No furloughs are planned, and the P-8 Poseidon maritime patrol aircraft line will not be affected.

"This decision is driven by a number of factors, including the extension of certification into 2020, the uncertainty about the timing and conditions of return to service and global training approvals, and the importance of ensuring that we can prioritize the delivery of stored aircraft," Boeing said in its Dec. 16 statement.

The Society of Professional Engineering Employees in Aerospace (SPEEA), the union that represents affected workers, said, also on Dec. 16, that Boeing "expects the shutdown to be measured in weeks, not days," and the union reiterated that "there are currently no plans for layoffs of SPEEA-represented employees."

The move will stop the accumulation of undelivered MAXs which has grown to about 400 since the model was grounded in mid-March following its second fatal accident in five months. Boeing halted deliveries immediately after regulators grounded the 387 aircraft in service, and in April it cut monthly 737 production to 42 from 52.

Boeing says once the MAX is cleared to return, it will prioritize clearing the backlog of stored aircraft, suggesting a production resumption will not come in lockstep with regulatory approval. The reason: Boeing has no idea when its entire global customer base will be able to take MAXs again.

While most foreign regulators' intentions remain unclear, Boeing had been confident the FAA would complete its review of changes to the MAX flight-control software and training and clear the model to return in late 2019. The company also cautioned that any significant holdups

RUPTION

> GROWING BACKLOG OF UNDELIVERED MAXs INFLUENCED DECISION

would force it to reevaluate production plans.

In the last several weeks, the FAA made clear that its review of final documentation and validation of emergency procedures and training modules will continue into 2020 (see page 12). Several other regulators are planning independent reviews that likely will keep MAXs grounded in some regions for months, even after they are cleared to return in the U.S. This, combined with having the total of about 800 idled and stored aircraft ready to join the global fleet, was enough to sway Boeing's thinking.

"We will continue to assess our progress toward return-to-service milestones and make determinations about resuming production and deliveries accordingly," the company says.

The uncertainty raises lots of questions for suppliers, and little information has emerged from managers in the days following the OEM's announcement. Key factors include whether the company actually cuts orders to suppliers, whether they receive financial assistance from Boeing or others, and whether they or Boeing decide to furlough or shed employees.

Suppliers are in a wait-and-see mode until January, when Boeing should be providing more information as it actually cuts MAX production and reports 2019 financial results to Wall Street on Jan. 28, 2020.

"Boeing has not released anything about what they're actually going to do production-wise," says Jason Cox, president of 320-employee Cox Machine in Wichita. The majority of Cox's work is for Boeing and on the 737 MAX.

The Wichita Eagle reports that Kansas Gov. Laura Kelly has volunteered that her state, home of leading 737 supplier Spirit AeroSystems and many of its smaller subcontractors like Cox, may have to step in and help pay workers to keep them on the assembly line. Spirit CEO Tom Gentile told her the company is not expecting layoffs but no decisions have been made.

> TALKS WITH SUPPLIERS ARE JUST BEGINNING

"We continue to work closely with our Boeing customer to support it during the grounding of the 737 MAX fleet," Spirit says. "Should Boeing make a decision to change its production rate on the MAX and expectations for suppliers, we will work with them to understand the impact to Spirit AeroSystems." Spirit referred additional questions to Boeing.

Previously, Spirit had told its suppliers it was going to continue at its current production rate of 52 737 shipsets a month for the next two years, says Ed Ball, Metal Finishing Co. vice president of sales and marketing. Spirit reiterated that in August. "Now, that could change tomorrow," Ball stresses. "As of right now, that's what we've been told and that's what we're working to. As of right now, we're going to stick with what they've said."

The abrupt shutdown could have a potentially significant impact on Leap 1B engine provider CFM. The GE Aviation-Safran joint venture spent all of 2018 attempting to catch up with Boeing's accelerating MAX production rate. It only achieved parity in 2019, several months after aircraft production was reduced to 42 per month, in the wake of the MAX grounding. Having stabilized production at just over an estimated 80 Leap 1Bs per month, including spares, the company until mid-December was readying its own supply chain for the anticipated resumption of deliveries and gradual increase in the production rate that Boeing had signaled for late 2020 and into 2021.

However, with the timing of both these milestones now uncertain, CFM appears to be pulling back. Safran CEO Philippe Petitcolin told French business magazine *L'Usine Nouvelle* CFM should produce at least 30 engines per month, noting it is "easier to ramp up when you already have production than to start from scratch." He said it was "too early" to speculate if the adjustments would lead to layoffs.

Beyond saying it is "working closely with Boeing," GE is offering little. Its work on the 1B includes all final assembly and testing in addition to building engine cores.

The consensus among analysts is that engine production rate changes will be driven by several factors beyond Boeing's needs, including lead times and demand for spares. Given the breadth and structure of their portfolios, Safran and GE also have some flexibility.

"From a GE manufacturing perspective, depending on duration, the business could produce spare engines, buffer stock or repurpose equipment for other programs," says Credit Suisse analyst John Walsh. "This is because GE's manufacturing is focused around value streams (e.g., fan foils) versus engine programs. Aftermarket revenue on other programs also provide an offset."

Canaccord Genuity analyst Ken Herbert, who has deep ties within the aerospace supply chain, expects suppliers to maintain some level of MAX-related production despite Boeing's formal halt. "While Boeing will likely keep most suppliers running at some level, it will be supplier-by-supplier analysis, depending on a number of factors," he says.

Bernstein analyst Doug Harned concurs: "The supply-chain plan will be tailored by suppliers, depending on operational and financial strength."

Spirit, which derives about 50% of its annual revenue from the 737 program, is most at risk, several analysts say. Smaller publicly traded parts providers at risk include Ducommun, 15%; Hexcel, 10%; and Astronics, 7%.

"We believe Boeing will do all that is possible to ensure that its suppliers are able to maintain their 737 employees, to ensure that once Boeing is able to start deliveries of the 737 again it has the ability to ramp up production as quickly as possible," Herbert says.

Indeed, maintaining workforce quality and quantity has been a challenge since at least 2018, when Boeing, Spirit and other suppliers struggled to hire and bring on-line enough workers to meet Boeing's march to a 737 monthly production rate of 57, which was slated to be in place this past summer. Now, the potential loss of talent, access to funding and other incremental risk to the supply chain all point to "substantial uncertainty" about Boeing's ability to raise rates once

the production pause ends, according to Herbert.

Others agree. "We can expect a negative ripple effect across the aerospace industry in 2020," Accenture Global Aerospace & Defense Lead John Schmidt tells Aviation Week. "This impact is likely to be more significant than prior rate reductions because of the complexities facing suppliers in restarting idled production lines back up to full production rates."

In notes to debt investors, credit rating agency Fitch just highlighted the new spending and cash demands while Moody's Investors Service and S&P Global Ratings notched down their overall corporate outlook for Boeing by one degree. Still, all three agencies agree Boeing's ability meet new demands is strong.

Meanwhile, Boeing is expected to continue to take the brunt of the costs associated with the production rate decrease and pending pause—and by all accounts, it can. "Fitch believes Boeing's credit profile can support the current MAX stresses due to substantial liquidity, financial flexibility, access to the capital markets and revenue diversification," the agency reported Dec. 17. "Aside from the MAX, Boeing's products and markets are healthy. Overall, Boeing had a strong credit profile for its 'A' rating before the MAX grounding, and Fitch's ratings for the company incorporated the periodic stress periods that arise in the commercial aviation sector."

Still, Boeing is expected to continue the suspension of shareholder buybacks, possibly into the second half of 2021 and likely will take out more debt. Fitch expects Boeing's debt will nearly double in 2019, to around $27 billion, as a result of $10.5 billion of long-term issuance and several billion dollars of shorter-term commercial debt. Debt likely will continue to rise in the first quarter of 2020, potentially peaking in 2020 and 2021. Fitch expects Boeing will pay down debt, especially its higher-interest corporate loans.

Managing the financial aspects of a production interruption appears more straightforward than Boeing's labor and logistical challenges. While the company is not providing specifics, it says the roughly 5,000 Renton, Washington-based MAX production-line employees "will continue 737-related work or be temporarily assigned to other teams in [the area of] Puget Sound."

This indicates mechanics will be distributed to assist with everything from out-of-sequence 737 work at Renton to supplemental work on other assembly lines at Everett, Washington, as well as associated support work at Boeing Field and other facilities in the Seattle area.

Some employees are expected to be drafted for the 777/777X lines, which are assembling a mix of 777Fs, 777-300ERs and 777-9s. The newer 777-9s are being assembled in the 40-24 building at Everett, where Boeing has set up a temporary low-rate initial-production (LRIP) line to avoid disrupting the current 777-300ER/200F assembly in the adjacent 40-25 building.

Under the company's original plan from 2018, around 30 airframes were expected to pass through the LRIP line before 777X production fully transitioned to building 40-25 in the early 2020s. However, that assumed at least two of the 30 would be the initial test versions of the shorter-fuselage 777-8, and given the delay to that derivative announced in mid-2019, it remains uncertain whether these will remain part of the pretransition LRIP tally.

Prior to the planned January stoppage,

Boeing had suspended production of the 737 twice since assembly of the first aircraft began in 1965.

Other Renton workers also may be brought in to support the 767 line, which is accelerating to an increased delivery rate of three per month as work on commercial freighters and the KC-46A military tanker variant step up.

Mechanics also may be drafted to work on readying other parts of the Renton production system for the stretched 737-10, the first of which is being prepared for the start of flight tests. The aircraft, which is the final variant of the MAX and the last derivative of the 737 family, was rolled out to employees at Renton on Nov. 22, and is expected to make its first flight early in 2020. Ground tests are focused on assessing loads on the derivative's new "shrink-link" main landing gear leg design.

Prior to the planned January stoppage, Boeing had suspended production of the 737 twice since assembly of the first aircraft began in 1965. For the first five years of the program, the initial -100 and -200 variants were produced at Boeing Field's Plant 2 and completed at the nearby Thompson Building, where the P-8 military derivative is now produced. Assembly was transitioned to Renton in 1970 when Boeing consolidated production of the 707, 727 and 737 narrowbody airliners at one site.

However, even with the changeover between the two lines there was little disruption with the rollout of the final Boeing Field-produced 737 (Line No. 271) on Nov. 3, 1970, and the emergence of the first Renton-produced aircraft (Line No. 272) just two weeks later.

Although the 737 experienced tough market conditions, with only 36 aircraft being delivered in 1970 and 14 in 1972, Boeing never stopped production, although occasionally it did consider shutting down the line permanently due to poor demand. The first serious interruption to the line came 25 years later in late 1997, when the transition to the first 737 Next Generation was underway in parallel with a doubling in production rate from 8.5 per month in late 1996 to a planned 17 per month by the end of 1997.

Overwhelmed by a series of engineering changes made late in the program, unexpected certification issues and supplier shortfalls, the company opted to "rebalance" the 737 line in late 1997. Although production of aircraft already in the system continued, and suppliers kept delivering their products, no new airframes were admitted to the assembly line for 25 days. Similar issues occurred on the 747 production line at the same time, and Boeing opted to pause the line for several weeks.

The second major interruption occurred in 2008 when members of the International Association of Machinists and Aerospace Workers struck for 57 days. Although the company had weathered several periods of industrial upheaval, the 2008 strike was the first of its kind to cause a full production shutdown of the line. The walkout cost the company $1.8 billion and reduced 2008 deliveries by 105 aircraft to 375.

Check 6 *Aviation Week editors discuss the coming MAX production halt's effects:* **AviationWeek.com/podcast**

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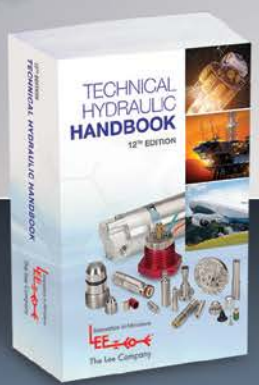

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Boeing 737 Pilots Focus On Modified Procedures

- THE FAA IS EXAMINING MANUAL TRIM OPERATION SCENARIOS
- PROCEDURE'S NUANCES NOT WELL UNDERSTOOD
- STEPS ARE PART OF FINALIZING NEW TRAINING REQUIRED FOR THE MAX'S RETURN

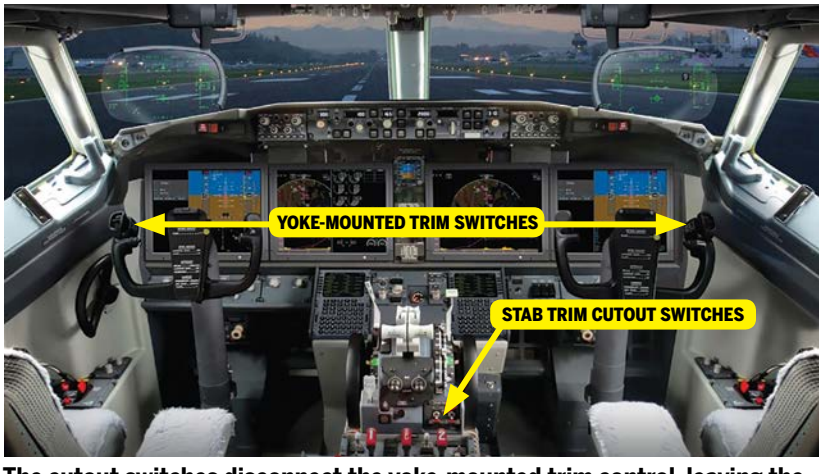
Sean Broderick Washington

Most of the outstanding items on the Boeing 737 MAX's return-to-service checklist relate to training and flight-deck procedures, and the detailed attention they are receiving from the FAA is helping convince pilots the agency and Boeing are, at last, on the right path.

"We started out with a very thin draft of new training," says Dennis Tajer, chair of the Allied Pilots Association Communications Committee and an American Airlines 737 captain. "We now have four or five really good modules."

The most recent draft modules include detailed information on the Maneuvering Characteristics Augmentation System (MCAS) flight-control law that Boeing has modified. The training explains the MCAS' role—commanding nose-down stabilizer to enhance pitch and stall characteristics by providing increasing stick force per G during certain flight profiles—as well as demonstrates how the updated flight-control computer (FCC) software prevents the system from activating when it should not.

COLLINS AEROSPACE



The cutout switches disconnect the yoke-mounted trim control, leaving the manual trim wheel for moving the horizontal stabilizer.

Among the key outstanding items: validating emergency procedures during a runaway stabilizer, which is how Boeing characterizes an unintended MCAS activation. A last-ditch recovery step is cutting power to the stabilizer trim motors and using the 737's manual trim wheels to move the stabilizer.

Many pilots were surprised to discover that aerodynamic forces created during a runaway stabilizer condition can render the trim wheel nearly impossible to move. If one pilot is pulling back on the yoke—a natural reaction to counteract uncommanded nose-down inputs—the force on the elevator, part of the horizontal stabilizer, increases. This makes the stabilizer harder to move. Add in an airspeed increase that a nose-down attitude introduces and the situation becomes more challenging.

This is what both flight crews faced in two fatal MAX accidents. Prior to the first one, Lion Air Flight 610 (JT610) in October 2018, pilots did not know the MCAS existed. Boeing had determined its function was transparent to pilots and it therefore did not need to be included in the flight manuals or training.

Critically, Boeing believed an uncommanded MCAS activation would be diagnosed quickly as runaway stabilizer and be managed by following the appropriate checklist. When the Lion Air crew did not respond in this way, Boeing and the FAA decided a reminder of the runaway stabilizer procedure would suffice while Boeing was taking a few months to update the MCAS software. But the March 10, 2019, crash of Ethiopian Airlines Flight 302 was linked quickly to the MCAS as well, leading to the grounding of the 387-aircraft MAX fleet and a deeper examination of where Boeing and the FAA had gone wrong.

Among the many findings: The complexity of the manual trim-wheel procedure, which applies to all 737s, was not well understood. The new 737 training modules emphasize that pilots may need to use two hands to crank the wheel during a runaway trim scenario. It also says "unloading" the stabilizer—attempting to reduce airspeed and take the counterintuitive step of not pulling back on the yoke even though the aircraft is trimmed nose down—may be necessary to move the trim wheel.

While the updated manual-trim procedures are an improvement, pilots want even more detailed information. In June, the FAA conducted tests to quantify how different airspeed and trim settings affect manual trim wheel forces, and is expected to share the results as part of additional information 737 pilots will be reveiving as a result of the MAX-related return-to-service evaluations.

The tests are part of several areas outside of the MCAS changes that regulators mandated Boeing institute before the MAX is cleared to return to service.

"[It is] night and day on the number of areas that they are seeking to improve" compared to Boeing's initial proposed MCAS changes soon after JT610, says Tajer. "That's good. But it didn't come without prodding and pushing from pilots. We have to look at what else can we do better."

The timing of the MAX's return remains unclear. The FAA still is waiting for Boeing to submit its final package detailing the changes. A Joint Operations Evaluation Board report, composed of the FAA Flight Standardization Board (FSB) team and representatives from Brazil, Canada and Europe, still must evaluate training needs. The FSB is expected to issue a report on the minimum training curriculum, which will have a 30-day public comment period. The FAA also will review all final design documentation, as will the Technical Advisory Board of independent experts advising the agency.

PRATT & WHITNEY GTF™ ENGINES GAIN MARKET MOMENTUM

Pratt & Whitney continues to see strong orders and a growing network of customers for its revolutionary Geared Turbofan™ (GTF) engine family. Recent wins add to the GTF order book, which now totals more than 10,000 engine orders and commitments with more than 80 customers. Several of these airlines have also signed multi-year contracts for Pratt & Whitney's EngineWise® Comprehensive service agreements, dedicated to sharing the company's engine expertise and fleet intelligence with customers so they can optimize engine performance and keep their operations running smoothly.

The most recent deliveries continue to add to the ever-growing commercial fleet, which now totals more than 550 GTF-powered aircraft across 40 operators since the engine entered service in 2016. This September, the Embraer E195-E2 aircraft, the largest in the E-Jets E2 family, was delivered to Azul Brazilian Airlines, leased through AerCap.

GTF orders during the last 12 months include JetSMART's selection of the GTF engine for its order of 85 A320neo family aircraft; Delta Air Lines' additional order for a total of 95 exclusively GTF-powered A220 aircraft; E195-E2 orders from KLM Cityhopper (up to 35), exclusively powered by the GTF engine; SMBC Aviation Capital's order of 20 additional GTF-powered A320neo family aircraft and Aviation Capital Group's order of up to 20 additional GTF-powered A320neo family aircraft.

Aircraft powered by GTF engines have been delivered on six continents over the past year, including the first Airbus A220 aircraft to African operators Air Tanzania and EgyptAir; the first Airbus A321neo aircraft to Hungarian carrier Wizz Air, Vietnam Airlines and Philippines-based Cebu Pacific; the first Airbus A320neo aircraft to Chinese airline Air Macau, leased through BOC Aviation; the Airbus A320neo family aircraft to Air New Zealand; the first Airbus A320neo aircraft to Chilean operator JetSMART; the first Airbus A321neoLR aircraft to Canadian airline Air Transat, leased through AerCap; the Airbus A220 and A320neo aircraft to U.S. operators Delta Air Lines and JetBlue; and the first E190-E2 to Switzerland-based Helvetic Airways.

Current in-service engine performance has more than lived up to the GTF's early promise. Since entering the market, GTF engines have compiled more than 3.7 million engine revenue hours and demonstrated an ability to reduce fuel burn by 16 to 20%, saving customers a staggering 200 million gallons of fuel, totaling $375 million in savings to date. The GTF also significantly reduces regulated emissions, which has led to 1.9 million metric tonnes of carbon emissions avoided so far, and lowers the noise footprint by 75%. Engines in service are saving approximately 100 gallons of fuel and reducing CO^2 emissions by one metric ton per flight hour.

The GTF's performance is having a significant impact on how and where airlines fly. For example, the engine's impressive reduction in fuel burn allows operators the ability to open new markets, creating options for routes that didn't exist before and making more point-to-point destinations available to the flying public.

Game-changing technologies set the GTF apart from its competition. The engine's revolutionary architecture allows for further evolution and performance enhancements.

The company invested more than 20 years and $10B in the engine, maturing new technologies that enable its impressive results. To meet the production demands of a historic engine ramp, Pratt & Whitney has invested in its 21st century, global production facilities to deliver its products quicker and with the highest quality. Along with its MRO network partners, the company is investing millions to increase maintenance capability to support the in-service fleet.

Find out more about Pratt & Whitney's GTF engines at https://pwgtf.com.

Widebody Market Weakness Shows Signs of Permanent Structural Change

BOEING

- AIRBUS AND BOEING WITNESS WIDEBODY MARKET WEAKNESS
- A321XLR SALES SUCCESS HURTS OTHER PROGRAMS

Etihad Airways ordered 25 Boeing 777Xs in 2013 but has cut back on its aggressive expansion.

Jens Flottau Frankfurt and **Michael Bruno** Washington

When Boeing happily announced a seemingly big new widebody order at the recent Dubai Airshow, it was well worth looking at the small print—because it was neither big nor new.

Boeing simply converted part of an earlier commitment for 150 777Xs to include some much smaller 787-9s. And when Airbus announced a United Airlines deal for 50 A321XLRs that shocked its competitor earlier this month, the European manufacturer also had to make major, painful concessions: It allowed United to defer an order for 45 A350s by five years.

The two arrangements, future iterations of which could well turn out even worse for the manufacturers, are symptoms of the same malady: Widebody demand in general is weak. The weakness affects the industry's most modern products, including the A350, the Boeing 787 and the 777X. And while both OEMs have for some time taken comfort in the perceived security of this being a temporary slowdown, there are now very serious indications that they must instead deal with a structural shift that leaves them massively exposed, with programs yet to be amortized over long periods and based on calculations that may need adjusting.

Several things are happening simultaneously. Airlines are discovering they can soon operate narrowbodies, namely the A321XLR, on a substantial part of their long-haul networks at much lower capital expenditure and economic risk. Airbus says it has orders and commitments for more than 400 of the aircraft since the launch at the 2019 Paris Air Show. The combined net order intake for Airbus and Boeing widebody models for the past two years stands at 407 aircraft—122 at Airbus and 285 for Boeing. Net orders are the number of new orders minus cancellations in a given time period.

Second, the big three Gulf carriers are no longer providing the kind of shelter from market weakness elsewhere: Boeing recorded 277 firm gross orders for the 777X in 2014, its last big-selling year for the aircraft. It would have been only 127 without the Emirates commitment and only 42 without somewhat smaller deals with Qatar Airways and Etihad Airways.

While air transport has continued to grow impressively over the past five years, only now slowing its rate of expansion, much of the growth has been driven by short-haul and low-cost carriers. Trade tensions and disputes have dampened international business travel. The only certainty of the short-to-medium-term outlook is its uncertainty. To add to the troubles, the transition process from the A330 to the A330neo and from the 777 to the 777X has been much slower than Airbus and Boeing had hoped.

Airbus has received 157 net orders for the A350-900 in five years, supposedly its highest-volume widebody program. The larger -1000 recorded just 18 net orders those same years. Surprisingly, the A330neo program has been by far the best-selling Airbus widebody in the past five years when cancellations are taken into account. Its net orders stand at 299 from January 2014 to November 2019. The first-generation A330 came second at 178 net orders. All the outstanding A380 orders have been canceled as a result of the termination of the program in 2021.

The Boeing side is not much different. The company has seen a drizzle of orders for the 747-8F, with a large UPS order extending the life of the program by some years. However, it appears unlikely that more commitments will come through in time for Boeing to be able to sustain production. Nevertheless, the venerable 767 has received a decent number of orders that sustains production, and Boeing has launched a study into the possibility of reengining the aircraft.

Both the 777 and 787 are victims of changes in strategy by some of their biggest customers, mainly the Gulf

Key Widebody Programs
Combined Net Orders, 2014-19*

Airbus	
A330	178
A330neo	299
A350-900	157
A350-1000	18
A380	-55
Boeing	
747-8/747-8F	35
767	141
787-8	-19
787-9	371
787-10	55
777-300ER	123
777X	249

*Through November 2019
Note: Net orders = new orders minus cancellations

Sources: Boeing, Airbus and Aviation Week Network Fleet Discovery

carriers. Etihad has effectively canceled most commitments placed at the 2013 Dubai Airshow and is placing brand-new A350-1000s that it could not cancel into long-term storage. Emirates finally confirmed its 787 order, but at the expense of parts of the 2013 777X order. The carrier is expected to take about 20% fewer aircraft, and Etihad is seeking ways to cancel its commitment for 25 aircraft entirely. The airline had already cut 20 787s from its backlog of 51, much like it had reduced its A350 order from 62 to just 20 aircraft earlier this year.

In 2019, Boeing has had more 777X cancellations than orders. There were no orders for the 777X in 2018 and only 30 combined in 2015-17. The 185 orders for the 777-9 and 35 for the 777-8 recorded for 2014 were all from Gulf carriers.

The 787 has been Boeing's volume widebody program for a number of years. But a deeper look at the models reveals the relative success has been almost entirely due to the 787-9. On a net basis, Boeing lost 19 787-8 orders over the last five years. It received 55 net orders for the 787-10 and 371 orders for the 787-9 since 2014.

The uncertainty is also growing. Agency Partners estimates about one-third of the A350 backlog is looking shaky, as it includes carriers such as Iran Air and Libyan Airlines that may never take the aircraft. The analysts also believe "it is increasingly likely that United will eventually cancel its A350 order." The commitment, placed nine years ago, has been changed multiple times in terms of numbers, types and timing. Now United is one of the airlines sending clear messages to the market that it sees a major opportunity in long-haul narrowbody operations, given that it has identified the A321XLR as a suitable replacement for its aging 757-200 fleet.

The consequences for the manufacturers are severe. Boeing is already reducing 787 output to 12 aircraft per month from 14. The transition from the 777 to the 777X now looks like a much more lengthy process because of engine and other development issues, with first deliveries to Lufthansa and Emirates pushed into 2021. That only nine customers have bought the 777X and no lessors have come forward could indicate airlines' angst about operating large aircraft such as the 747-8 and the A380 is also affecting the large twins.

Over the summer, Boeing began warning suppliers, investors and others that escalating trade tensions between the U.S. and China—its largest single market—would threaten prospective aircraft sales, particularly those of the lucrative twinjet 777 and 787 families (*AW&ST* Sept. 30-Oct. 13, p. 39).

According to a December Jefferies report, widebodies have a 29% share of the domestic Chinese market, representative of long-distance flights within its borders. Indeed, across Asia it is common for short-haul routes to operate both narrowbodies and widebodies, such as the Sapporo-Tokyo and Fukuoka-Tokyo routes in Japan, where both the Boeing 777 and 737 NGs are operated. On a flight basis, the top 25 routes for widebodies have an average distance of 917 nm, Jefferies says.

But as the world's No. 1 and No. 2 economies struggle to reach just a "Phase 1" trade truce, relief in the form of resumed Chinese orders appears far away. When Boeing in October announced its 787 rate cut to 12 a month will start in "late 2020," the move was surprising only in that it beat many analysts' prediction that a reduction was due by 2021 at least.

Airbus has just completed its initial production ramp-up of the A350 to 10 aircraft per month and has decided not to go higher, given market uncertainties. "The emerging gap in the A350 skyline worryingly mirrors that for the Boeing 787 and suggests that pricing for new orders could deteriorate significantly and hence depress A350 profitability," Agency Partners analyst Sash Tusa writes. He believes Airbus will be forced to cut A350 production in late 2022 and go to below seven aircraft per month from 2024 if nothing material changes.

The success of the A321XLR has had a dampening effect not only on current widebodies but also on Boeing's proposed new midmarket airplane (NMA), which is conceived as the new smallest widebody. "Airbus sales of the A321XLR seem to doom [the NMA]," Bloomberg Intelligence says in a December report. "The smaller size of narrowbodies allows service between smaller cities, which might make larger aircraft dilutive to fares and profits," Bloomberg's George Ferguson and Francois Duflot write. "They also provide the flexibility to switch to many different city pairs, improving airline agility."

Any new Boeing narrowbody likely would be designed around a higher passenger capacity, roughly 200 seats, and probably include a variant that could go beyond the range of the A321XLR. Ferguson and Duflot say the soonest a replacement could be ready is likely the latter 2020s, with development approaching $10 billion. "We believed all along that any NMA would be wrapped up in a redesigned narrowbody, so the MAX grounding may have only pushed back the timing," they say.

Jefferies analysts Sheila Kahyaoglu and Greg Konrad concur. "Boeing has yet to decide on a potential NMA, but the grounding of the 737 MAX could potentially shelve any decision as well as the difficulty of creating the economics that aircraft want at the target price," they note in a December report.

Electric Progress

> ELECTRIC BEAVER CERTIFICATION ANTICIPATED IN 2022

> PARTNERS PLAN TO ELECTRIFY OTHER AIRCRAFT TYPES

Graham Warwick

A 63-year-old aircraft, a 37-year-old airline and a 10-year-old startup came together on Dec. 10 in Vancouver to close the decade with an aviation milestone—the first flight of an all-electric commercial aircraft.

The modified de Havilland Canada DHC-2 Beaver, powered by a 560-kW (750-hp) MagniX electric motor, made a 4-min. flight from Harbour Air's seaplane terminal on the Fraser River adjacent to Vancouver International Airport.

The Beaver is not the first electric-powered aircraft by far, but those flown previously have been either all-electric light aircraft or general aviation types modified to hybrid-electric propulsion. The Beaver is part of the fleet at Harbour Air, the largest seaplane airline in North America.

"Today, we made history," said Greg McDougall, CEO and founder of Harbour Air, an 8,000-hr. Beaver pilot who flew the battery-powered aircraft on its short first flight. The modified aircraft was noticeably quieter than the piston-engine original.

The 1956-built Beaver's Pratt & Whitney radial engine had been replaced with MagniX's Magni500 motor under Harbour Air's ePlane project to electrify its commercial seaplane fleet beginning in 2022—which includes Beavers, de Havilland Canada DHC-3T Turbo Otters and DHC-6 Twin Otters.

Distinguished by its reshaped nose housing the direct-drive motor and a new Hartzell four-blade propeller, the prototype has a cabin full of lithium-ion batteries. Taking the aircraft to its maximum gross weight, the batteries provide enough energy for a 15-min. flight with a 25-min. reserve.

"When trading the weight of the standard engine and fuel system with the Magni500 propulsion system and batteries, the trade-off becomes range," says MagniX CEO Roei Ganzarski. "Instead of the standard 455 mi. a Beaver can do on a full tank of fuel, the electric Beaver is limited to 100 mi. It fits Harbour Air's operations, as most of their flights are within that range profile."

The 297-lb. motor was derated to 450 hp to match the Beaver's original engine. But Harbour Air's longer-term focus is on repowering its workhorse, the larger Otter, which has a Pratt & Whitney PT6A turboprop and will use the full 750-hp output of the MagniX motor as well as house the batteries in the belly area.

The batteries, used by NASA in space applications and considered proven for flight, have a relatively low energy density. "While perhaps not the most power-dense, these are good enough to start small-scale operations with short ranges of up to half an hour," says Ganzarski.

Certification will have two phases, says McDougall. "In Step 1, MagniX will certify the components under the FAA. Once that is complete, Step 2 is for us to certify the installation under Transport Canada," he says. "Once we are certified, the installation can be used on all Beavers globally. We also intend to certify the installation on several other aircraft types."

The Magni500 propulsion system is planned to be certified under Part 33 regulations, says Ganzarski. The Beaver modification will be a supplemental type certificate under the latest Part 23 Amendment 64 rules. "We estimate completing all certification in 2022," says McDougall.

The electric-powered Otter is expected to have at least 30 min. of flight time—enough for most of Harbour Air's island and coastal routes—plus a 30-min. reserve. Every 1 min. of flight will require 1 min. of battery recharging using a Tesla-style supercharger, which fits within the airline's turnaround times.

A modified Beaver completed its first flight on electric propulsion in Vancouver.

HARBOUR AIR

Flying more than 500,000 passengers a year on 30,000 flights in the environmentally conscious Pacific Northwest, Harbour Air bills itself as North America's first carbon-neutral airline. Since 2007, the airline has offset carbon emissions from aviation fuel used through an agreement with local company Offsetters Climate Solutions.

Founded in Australia in 2009 to develop advanced electric motors, MagniX relocated its headquarters in 2018 to Redmond, Washington, to focus on aircraft propulsion. The company's first motor is the 260-kW Magni250, which is an option to power Israeli startup Eviation's Alice, an all-electric, 11-seat regional aircraft that uses three motors.

MagniX and Eviation are both owned by billionaire Richard Chandler's Singapore-based investment company Clermont Group. The prototype Alice is expected to fly in 2020 at Moses Lake, Washington, where aerospace engineering company AeroTEC operates a flight-test center. MagniX is also teamed with AeroTEC to modify a Cessna 208B Caravan to electric propulsion, with the Magni500 motor replacing a PT6A turboprop. The electric Caravan is planned to fly early in 2020.

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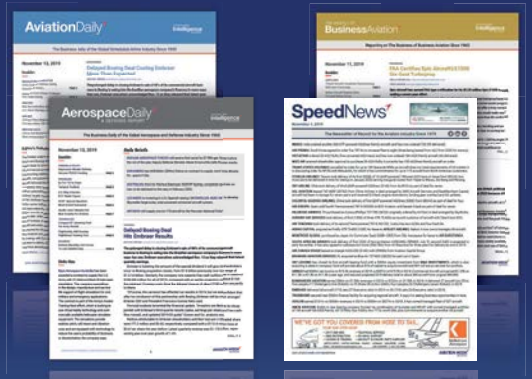

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Rocket Lab, Wallops Island Spaceport Expect Big U.S. Launch Growth

> ROCKET LAB TO LAUNCH USAF STP-27RM MISSION BY SPRING

> MID-ATLANTIC REGIONAL SPACEPORT IN TALKS TO BRING IN MORE COMMERCIAL LAUNCHERS

Michael Bruno Wallops Island, Virginia

Rocket Lab looks set to loft as many as a dozen small-satellite payloads a year into low Earth orbit (LEO) for the U.S. government starting in early 2020—including on short notice—as the Electron rocket maker unveils its inaugural launch plans from its new spaceport home.

"We're ready to support on a call-up basis at the drop of a notice," Rocket Lab founder and CEO Peter Beck says. "It's great to have a U.S.-based launch site to service U.S. customers on U.S. soil."

Speaking to Aviation Week during a ribbon-cutting ceremony on Dec. 12 for Launch Complex 2 (LC2), the company's newest launch facility at the Mid-Atlantic Regional Spaceport (MARS), Beck and other officials from the U.S. Air Force, NASA and Virginia Space were visibly pleased with their achievement. At the ceremony, executives and officials confirmed the inaugural mission from the site will be a dedicated flight for the Air Force in the spring.

"Rocket Lab's launch site at the Mid-Atlantic Regional Spaceport at Wallops Island, Virginia, strengthens the United States' ability to provide responsive and reliable access to space," said Col. Robert Bongiovi, director of the Air Force Space and Missile Systems Center's Launch Enterprise. "We look forward to Rocket Lab successfully launching the STP-27RM mission from Launch Complex 2 next spring, which will test new capabilities that we will need in the future."

Rocket Lab selected MARS for LC2 about a year ago due to the wide orbital inclinations the site can support as well as the accelerated construction time frame. Construction began in February; the site was operational just 10 months later. More than 150 local construction workers and contractors were involved, with many Virginia-based companies supplying services, hardware and materials. Locally built infrastructure includes a 66-ton launch platform and the 7.6-ton strongback for the Electron launch vehicle, supplied by Virginia-based company Steel America.

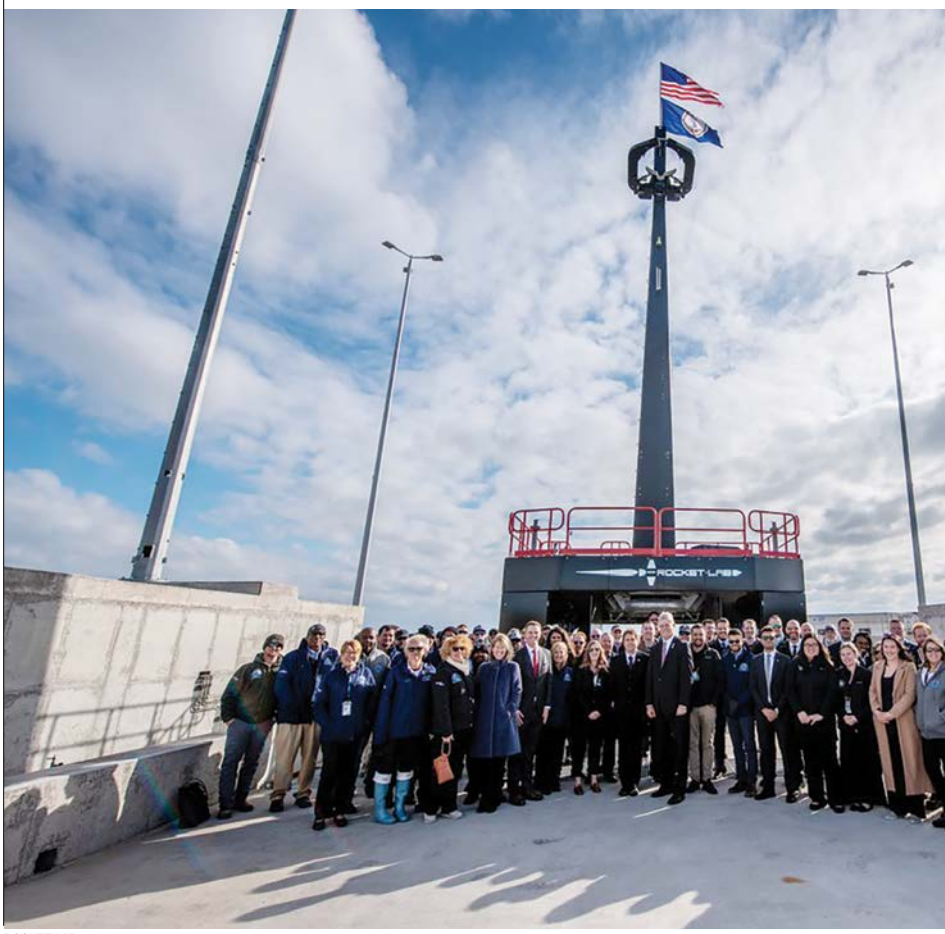
"The fact that we have an operational launch site less than a year after construction began is a testament to the hard work and dedication of the Virginia Space and NASA teams, as well as to the unwavering support of our local suppliers," says Shaun D'Mello, Rocket Lab's vice president for launch.

It helps that LC2 is almost a copy of LC1—on New Zealand's Mahia Peninsula—except for specialized grounding due to the different geology of Virginia's eastern shore. "We designed LC1 to be easily deployable to other sites," Beck says.

Electrons launched from LC2 still will be built in Huntington Beach, California, at the company's headquarters—as they are before being shipped to LC1. Rocket Lab representatives say they do not expect to alter their supply chain or manufacturing system with the new Virginia spaceport site, although there could be as many local launch suppliers for LC2 as the 300 for LC1.

In addition to the launchpad itself, LC2 will also be home to an integration and control facility located within the Wallops Research Park for processing payloads and Electron launch vehicles prior to liftoff.

The company says LC2 is tailored



U.S. Air Force, NASA and Virginia Space representatives are joined by a Rocket Lab team, led by founder and CEO Peter Beck (center left), at the new U.S. launch complex.

ROCKET LAB

specifically for U.S. government missions to provide responsive launch for small satellites from U.S. soil. It can support up to 12 missions per year, supplementing the 120 launches possible from LC1, which will remain dedicated to commercial sector business.

A Dec. 12 report from Frost & Sullivan forecasts a total number of 20,425 satellites that will be launched through 2033, with North America leading the way, followed by Europe. "Such demand could take the small-satellite launch services market past the $28 billion mark by 2030 and present significant growth opportunities throughout the industry," the consultancy writes in the December report. Frost anticipates high-volume demand for component manufacturers, dedicated launch service providers and low-cost ground-station services.

The growth also bodes well for the spaceport business, especially front-runners like MARS.

More new-space launch providers could make the MARS site their home, Virginia Space CEO and Executive Director Dale Nash tells Aviation Week. As such, Virginia Space officials are in discussions with several other companies, he says. There is room for 2-4 more launch providers at MARS, on top of Northrop Grumman and now Rocket Lab. "That still leaves a fair amount of capability," Nash notes.

NASA's environmental study for MARS covers up to six launchpads, but since 0A and 0B are so close to each other, their impact counts as one. Northrop Grumman uses 0A for its Antares rockets that loft Cygnus cargo ships to the International Space Station (ISS). Rocket Lab's LC2 will use 0B for its Electron. Together, the companies envision around 14 launches a year, most of which would be Electrons.

However, the competition is hot, according to the Space Foundation's fourth-quarter 2019 issue of *The Space Report*, published the same day as the Wallops ceremony. According to the report:

- Around the world, there are 40 active spaceports—10 in development and at least 13 proposed.
- The U.S. has five times as many active, in-development or proposed spaceports compared to its nearest competitor, Russia, which has five active sites and no new known ones in development. China is third with four active spaceports.
- In 2018, with 198 spacecraft launched, the U.S. averaged 5.8 spacecraft per launch. Russia, with 60 spacecraft put in orbit, averaged 3.8 spacecraft per launch. China delivered 105 payloads to space, averaging 2.6 spacecraft per launch.
- In the last decade, according to NASA's Ames Research Center, commercial rocket development has reduced the typical space launch cost by a factor of 20 while NASA's launch cost to the ISS has declined by a factor of four.
- The average price per kilogram for a launch prior to 2000 was $18,500. In 2018, SpaceX's Falcon 9 rocket price per kilogram to launch a payload into LEO was $2,719.
- With three U.S. spaceports alone, state investment in New Mexico, Virginia and California totals $455 million.

Air Force Space Policy Guru Loverro Tackles NASA Human Spaceflight

> REASSESSMENT OF SLS COST AND SCHEDULE ARE UNDERWAY

> HUMAN SPACEFLIGHT TAKES HALF OF NASA'S BUDGET

Irene Klotz Cape Canaveral

Like many children growing up during the Apollo Moon program, Douglas Loverro wanted to become an astronaut. In 1972, he headed off to the U.S. Air Force Academy to pursue his dream.

Loverro ended up on a different path, developing and managing Air Force and National Reconnaissance Office space programs, including military satellite communications, the GPS network and classified space systems. In 2013, Loverro was tapped by President Barack Obama as deputy assistant secretary of defense for space policy.

After 45 years of government service, Loverro in 2017 became a private consultant, but that gig did not last long: On Dec. 2, he started working at NASA as the new associate administrator for human exploration and operations (HEO).

"This is the pleasure and excitement of my career," Loverro told employees during an agency-wide town hall meeting the following day. "I could not have passed this up. . . . The things we do in space affect the entire world. I'm not sure I'm ready for this challenge yet, but I have a great team at HEO."

Loverro will need to hit the ground running. Three human spaceflight programs in development for a decade are scheduled to reach critical milestones in the next few months. Boeing is poised for an uncrewed trial run of the CST-100 Starliner to the International Space Station (ISS), with the launch scheduled Dec. 20.

SpaceX is expected to follow Jan. 4 with a Crew Dragon inflight abort

demonstration. If those uncrewed flight tests go well, both companies will be in position for flight tests to the ISS with astronauts in early 2020, the first orbital spaceflights from the U.S. with humans since the space shuttles were retired in 2011. Operational ISS crew-rotation missions will follow—possibly before the end of 2020—after analysis, certifications and reviews.

Meanwhile, the long-delayed core booster for the Space Launch System (SLS) rocket—designed to carry 77 tons (70 metric tons) into low Earth orbit—is due to ship out from NASA's Michoud Assembly Facility in New Orleans in late December for a full-duration static test-firing next year at the Stennis Space Flight Center in Mississippi. One of Loverro's first decisions will be to set a new launch date for the SLS debut mission, which is expected to send an uncrewed Orion capsule on a test flight around the Moon. Officially, the mission, known as Artemis 1, is on the books for December 2021.

Loverro also will be challenged to figure out ISS staffing during any gap between the end of flight-service contracts with Russia's state space corporation Roscosmos and the start of rides aboard SpaceX's Crew Dragon and Boeing's Starliner.

And then there is Artemis and the multibillion-dollar effort to expedite by four years the first human landing on the Moon since the last Apollo lunar mission in 1972, the year Loverro received his bachelor's degree in chemistry from the Air Force Academy. Loverro will help form the Trump administration's fiscal 2021 budget request, due to be unveiled in February, as well as spearhead the effort for an initial $1.6 billion this year to kick off commercial partnership agreements for development of human-class lunar landing systems.

Overall, NASA's human spaceflight programs account for about half of the agency's current $21 billion annual budget.

"We can't use funding as the crutch upon which we say we can't make the objectives that we've been asked [to achieve]," Loverro said during a question-and-answer session at the town hall meeting. "Our job is to create the vision that allows us to get to the Moon. To convince Congress that the program is worth supporting is one thing, [but] we're not going to get every dollar we ask for every year. We have to treat funding just like any other issue that comes up in the program. We're going to have technical, engineering and science issues—issues across the board—and funding is one of those. We can't let that be the single determinant of success."

NASA Administrator Jim Bridenstine, who shared the stage with his new associate administrator, stepped in to reply to employees' thornier questions such as why he replaced Loverro's longtime and highly respected predecessor, Bill Gerstenmaier. "It was time, in my view, to find a leader who had a long history of making programs run on schedule and on budget," Bridenstine said. "I think Doug is that kind of leader, not to take anything away from Bill Gerstenmaier."

Loverro will have an early opportunity to test his management mettle. The SLS and Orion programs, which already have cost taxpayers more than $30 billion, will need additional funding to cover development, flight test and production costs. An October letter from the Office of Management and Budget to Senate Appropriations Committee Chairman Richard Shelby (R-Ala.) pegged the price of an SLS to fly a spacecraft to Jupiter's moon Europa at $2 billion.

Bridenstine said he expects costs to be much less, perhaps in the $800-900 million range if the agency can make SLS block buys. Negotiations for the third SLS core stage with prime contractor Boeing are underway.

Loverro, like Bridenstine, is steadfast about sticking with SLS and Orion for the Artemis Moon program, but acknowledges launchers in development by SpaceX, Blue Origin and other companies may end up taking on more of NASA's heavy lifting.

"The fact of the matter is the only system we have today that has been designed specifically to get men and women to the Moon is the SLS. That program is absolutely mandatory in my view right now," Loverro said. "We have a long plan for exploration that will require us to utilize the best U.S. industry can provide. Certainly we will make decisions along the way as to what makes most sense as developments of all of those systems come forward."

He added: "Part of being a leader is being willing to admit that we have to change the plan. I think we've got a good plan. I think we will find elements of the plan that have to be changed.

"We will find comments from outsiders that are critical to incorporate and, quite frankly, I invite those. My job for the next three months is to examine all of those things, to figure out where we are in the baseline of the program and what we need to change and raise, even more, our chances of success."

JOEL KOWSKY/NASA

Doug Loverro began work Dec. 2 as NASA's associate administrator for human exploration and operations.

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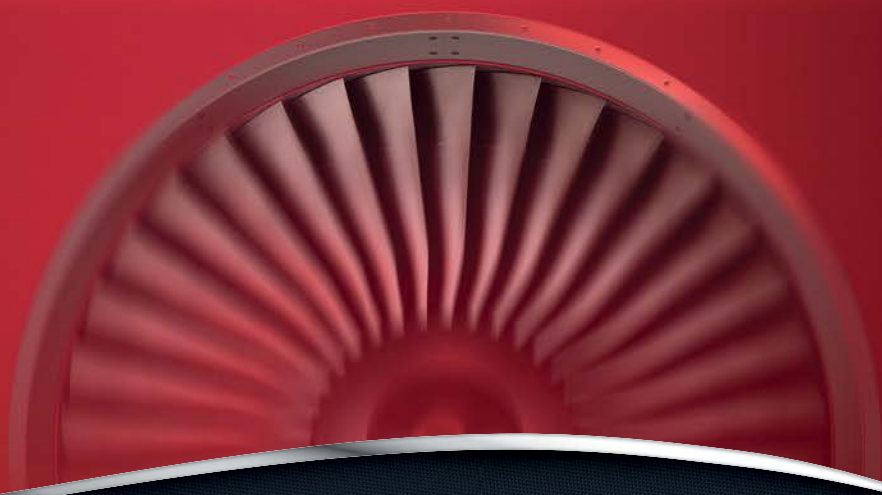

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ESA Gathers Record Multiyear Funding

- > CO_2 EMISSION MONITORING IS A MAJOR FOCUS
- > ESA BOLSTERS INVOLVEMENT IN NASA-LED MOON PROGRAM

Thierry Dubois Lyon, France

The resounding success of the European Space Agency (ESA) at its triennial ministerial council is further evidence of Europe's new emphasis on space, indicating that the industry's consistent plea for increased budgets has convinced politicians.

The ESA's 22 member states have agreed to fund the organization's activities for a record €14.4 billion ($16 billion) over five years, slightly higher than the initial proposal, thus securing current programs and paving the way for more.

The European Union (EU) is poised to increase its space budget and the European Commission (EC) now has a dedicated directorate-general for defense, industry and space. The sector is increasingly seen as critical. The EC is proposing a €16.2 billion ($18 billion) budget for 2021-27, up from €11 billion for 2014-20.

The Copernicus Earth-observation program will provide more accurate CO_2 emission monitoring.

ESA

Decisions for ESA (an organization independent from the EU) were made at a Nov. 27-28 council at the ministerial level in Seville, Spain. One of the winners was the Copernicus Earth-observation program. Oversubscribed at €1.9 billion instead of the proposed €1.4 billion over three years, the extra funding will facilitate improved performance. ESA runs the space segment of Copernicus, an EU program.

CO_2 emissions will be more accurately monitored, with a resolution target of 2 X 2-km (1.2 X 1.2-mi.) squares. Swath will be increased by 50%, to roughly 300 km, says Josef Aschbacher, director of Earth-observation programs.

One instrument, the multiangle polarimeter, will measure nitrogen dioxide (NO_2) emissions. "It is an indicator of human activities and therefore helps distinguish [at a given location] natural from anthropogenic CO_2 emissions," Aschbacher explains. The Sentinel-5B satellite currently measures NO_2 emissions, but its service life is expected to end in 2024.

A cloud imager will "mask out" the clouds, as CO_2 measurement works only in a cloud-free atmosphere.

The excess funds will also help bring forward the Copernicus Hyperspectral Imaging Mission for the Environment (CHIME). It was planned to fly in the early 2030s, but users would rather see it in service from 2027-28, says Aschbacher. CHIME is expected to provide a variety of data, from crop-yield assessment to estimating carbon storage in soils and mineral mapping.

Cooperation in exploration programs with NASA and other agencies received strong support. Funding for the International Space Station (ISS) has been confirmed until 2030.

ESA will contribute €300 million to the Lunar Gateway, starting with a communications system. It will complement other devices, thus enabling simultaneous data transmission between the Gateway and Earth as well as between the Gateway and the Moon's surface.

In return, Frank De Winne, ESA's ISS operations and astronaut group leader, expects scientific cooperation and ESA astronaut flights to the Moon's surface—as hinted recently by NASA Administrator Jim Bridenstine and ESA Director General Jan Woerner.

ESA intends to participate in a Mars sample-return mission. In 2026-28, an ESA-made "fetcher" vehicle, equipped with a robotic arm, is planned to be launched along with a NASA-made small launcher. The fetcher would collect samples NASA's Mars 2020 mission will have packed. The small launcher would carry the parcel into Mars' orbit and rendezvous with an ESA-made Earth-return orbiter. The samples would land on Earth in the early 2030s, says De Winne.

Overall, the "exploration" budget has increased by 30%, at €1.95 billion over three years.

In the "enabling and support" pillar, the Space Rider reusable spaceplane program was launched. The unmanned spacecraft's outlines include an 800-kg (1,800-lb.) payload and the ability to fly six times. ESA says it could be used for experiments in microgravity, in-orbit technology demonstration for applications such as exploration robotics, Earth observation, telecommunications and satellite inspections. Studies have been launched for future launchers: Ariane 6's upgrades and its successor.

A new pillar has appeared in ESA's activities—safety and security. At €541 million, it received less than the hoped-for €900 million. Nevertheless, Woerner expressed satisfaction at seeing issues such as space debris becoming part of the agenda (*AW&ST* Dec. 2-9, p. 22).

A €100 million mission—cofunded by private investors—is being devised. A startup company has been chosen, and its objective is to remove a 100-kg ESA object from low Earth orbit by 2025. ESA expects to sign a service procurement contract in 2020. The demonstration will aim to show regulators a technology is available.

Germany now ranks first as the main contributor to ESA's budget, followed by France, Italy and the UK.

U.S. Military Leaders Seek Open-Source Simulation

> SIMULATION STANDARDIZATION IS A GOAL

> CHINA SINGLED OUT AS GREATEST RIVAL

Bill Carey Orlando, Florida

Senior U.S. military leaders exhorted companies to develop integrated, standardized training and simulation systems to help them maintain fighting proficiency against other world powers—namely China—during the industry's largest annual conference.

With numerous companies among the 480 exhibitors at the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) displaying their own approaches to creating interactive, "immersive" training environments, military leaders called for technological unity.

"Closed and proprietary is not the way forward for us," said Maj. Gen. James Jacobson, U.S. Air Force director of training and readiness, during a senior leaders panel Dec. 3. "We need to see open and future-proof [systems] so that we can integrate the changing technologies."

Future training devices should function more like applications that work within a single synthetic environment created from common terrain, threat and weather databases, Jacobson said.

BILL CAREY/AW&ST

Visitors to I/ITSEC try out the CAE Trax Academy virtual reality cockpit trainer with headsets.

"It isn't one proprietary piece of equipment that stands alone and integrates part of the time; it's an application that integrates through a standard synthetic environment with standard data, with standard threat models that every application uses," said Jacobson.

Fred Drummond, deputy assistant secretary of defense for force education and training, said live, virtual and constructive training environments should draw from a "one-world geodatabase," enabling Marine Corps helicopters to navigate within an Army operation using the same geographic dataset, for example. He further called for a one-world threat database across ground, sea and subsea domains.

"My vision is we would see these databases as furnished equipment," Drummond said. "I don't care what equipment or company produces the stuff—I just need the folks in uniform who are using these simulators working on the same data."

In January, the Air Force will start the third class of its Pilot Training Next (PTN) experimental program without settling on standard training equipment, noted Jacobson. The service's Air Education and Training Command launched the initiative in February 2018 to explore ways to decrease the time and cost, but not the effectiveness, of pilot training by applying technologies including virtual and augmented reality, artificial intelligence and data analytics.

PTN also seeks to broaden the pool of pilot candidates by selecting participants from different learning backgrounds. The first class of 13 students included officers and enlisted airmen; the second class of 14 included students from the Navy and UK Royal Air Force. Jacobson said the effort to expand the candidate pool continues.

"We're not quite sure what scales for that yet, nor do we have necessarily a standard set of technology across all the bases," Jacobson said. "There is still a ways to go before we can reduce the training time and improve the quality of the product that gets to the next level of the U.S. Air Force."

Keeping true to the Pentagon's "change at the speed of relevance" credo means capabilities cannot take decades to be fielded, said Gen. Stephen Wilson, Air Force vice chief of staff, who delivered the military keynote address at I/ITSEC.

In a new era of great-power competition and with rapid advancements in technology, the U.S. can no longer assume technological superiority over rivals, warned Wilson, devoting the bulk of his remarks to the challenge presented by China.

Last year, China produced eight times the number of science, technology, engineering and mathematics (STEM) graduates as the U.S.; in five years, the STEM advantage will be 15:1, he said.

"They're mastering quantum computing in labs in Shanghai. They're making huge strides in artificial intelligence, machine vision, space and hypersonic [technology], just to name a few areas," Wilson said. "China is all in to win. It's an all-of-nation effort; it's industry, it's academia, it's national labs, it's military, it's what they call 'military-civil fusion.' It would be a mistake to underestimate China."

Training and simulation will play an integral role if the Air Force is to meet force connectedness, space dominance and other objectives identified in the National Defense Strategy, Wilson said. Announced by then-Defense Secretary James Mattis in January 2018, the joint services strategy aims to restore the U.S. competitive edge by countering Russia and China.

Simulators of the future need to be integrated and connected across weapons systems, should replicate combined-arms warfare in contested environments, and recreate operations in denied and contested environments including space, he said.

"Individual weapons systems simulators can help our men and women become proficient tacticians, but it's their ability to integrate and connect that will differentiate us against a peer threat," Wilson advised.

AEROSPACE & DEFENSE 2020

PRESSURE POINTS

AN EVENTFUL DECADE ENDS. ANOTHER BEGINS WITH THE PROMISE OF EVEN GREATER CHANGE.

Graham Warwick Washington

Watched year by year, aerospace does not appear to evolve that quickly. But looking back over a decade, the changes seem profound. What transformations lie ahead in the new decade?

Airbus launched the A320neo family in December 2010, ushering in the age of the reengined narrowbody airliner. A decade later it has booked 7,200 orders and delivered more than 1,000 aircraft, with the success of the larger A321neo coupled with the 737 MAX grounding putting Boeing under unprecedented pressure.

Ten years ago, civil aviation entered the new decade with a global commitment to mitigate its growing carbon emissions. But despite putting in place a CO_2 standard for aircraft and an international offsetting scheme for airlines, it ended the decade branded a villain of climate change.

Business plans and product strategies will be shaped by these pressures over the coming decade. Some airlines have already pledged to achieve net-zero CO_2 emissions by 2050, and there is a growing possibility that hybrid-electric regional aircraft will be flying short routes by the end of the decade.

For most of the past decade, the U.S. has relied on Russia to orbit its astronauts since retiring the space shuttle. That is set to change in 2020 when Boeing and SpaceX fly crew to the International Space Station, marking a new milestone for a commercial space industry that has blossomed over the last 10 years.

When SpaceX flew the first Falcon 9 launch vehicle in June 2010, it had only two successful Falcon 1 flights to its credit. Today, it has flown some 80 Falcon 9-family rockets, recovered almost 50 first stages and reflown them more than 20 times. And it is no longer alone in the commercial launch market.

When the FAA rushed in the requirement to register drones in December 2015, ahead of a Christmas sales bonanza, it had approved only a handful of commercial operations. By the end of decade, more than 1.5 million drones had been registered in the U.S., almost 420,000 of them for commercial use.

This growth has been achieved within a regulatory framework that strictly constrains drone operations. Those limits are set to be widened early in the 2020s, unlocking potential for operations such as medical transport, search-and-rescue

KEY INTEL

Data Web Galleries

DEFENSE Global military aircraft competitions and country-by-country analyses of national priorities, budgets and programs: *pages 28-56*

MILITARY AIRCRAFT Challenges developing new-generation fighters, transports and rotorcraft are presenting hard options: *pages 57-61*

WEAPON SYSTEMS The U.S. ramps up hypersonic strike-missile flight testing as attention shifts to countering the new threats: *pages 64-67*

COMMERCIAL AIRCRAFT Return of the 737 MAX, rise of the A321neo, wane of the widebody—and what comes next? *pages 82-86*

SAFETY Aircraft certification draws increased scrutiny because of the 737 MAX: *pages 88-89*

SUSTAINABILITY The aviation community responds to growing emissions criticism: *pages 90-92*

DATA CENTERS Five-year delivery forecasts and key specification tables for combat and transport aircraft: *pages 62-63*; commercial and business aircraft: *pages 98-99*

AIR TRANSPORT Reasons for concern lie behind an optimistic forecast for global airline profitability: *pages 78-80*; regional outlooks: *pages 100-109*

PROPULSION Commercial engines ramping up, the military market in flux and electric propulsion advances: *pages 70-73*

BUSINESS AIRCRAFT New models boost deliveries even as the long-term forecast continues to edge downward: *page 94*

UNMANNED AIRCRAFT The buzz around drone delivery, the Pentagon's shifting needs and emerging cargo UAVs: *pages 68-69*

VERTICAL FLIGHT Helicopter-makers focus on completing development programs while the eVTOL market advances: *pages 96-97*

SPACEFLIGHT The satellite industry transitions to volume production; the commercial launch market dominates and diversifies: *pages 74-77*

MRO Exploring the factors behind the forecast growth in maintenance, repair and overhaul as well as commercial and military demand: *pages 110-127*

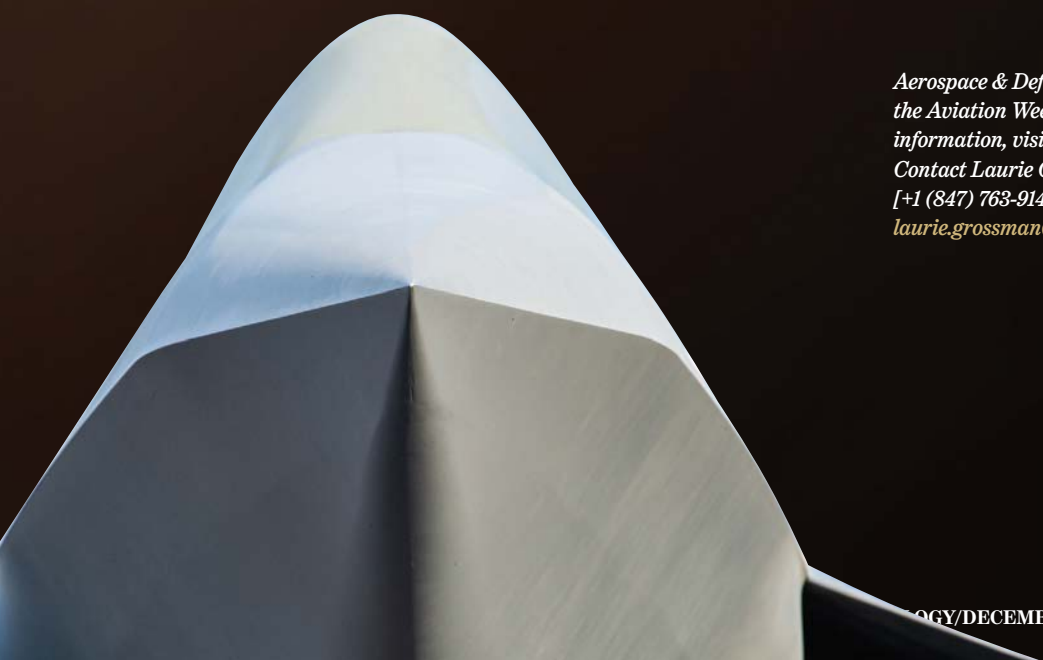
missions and package delivery that promise potential societal benefit and commercial return.

In 2011, the F-35 Joint Strike Fighter entered its second decade of development. Almost 10 years later, more than 400 aircraft have been delivered to 11 customers. The F-35 has seen combat with four operators, but it has yet to complete operational testing and enter full-rate production.

With no appetite for another decades-long program, the U.S. Air Force plans to leverage advances in digital design and manufacturing to reinvent how aircraft are created. It wants to develop a new design in five years, produce a limited fleet and move on to the next one. But Europe and the UK plan to follow a more traditional path in developing sixth-generation fighters for fielding in 2030-40.

A decade ago, disruption was not a word often uttered in the C-suites of aerospace companies. Now, thanks to SpaceX, it is a fact of life. Digitalization and digital twins, autonomy and artificial intelligence, electrified aircraft propulsion, urban air mobility—looking back from the vantage point of 2030, industry observers will llikely see the 2020s as yet another decade of dramatic change for aerospace.

Aerospace & Defense 2020 incorporates data from the Aviation Week Intelligence Network. For more information, visit awin.aviationweek.com
Contact Laurie Grossman at +1 (866) 857-0148 [+1 (847) 763-9147 outside North America] or laurie.grossman@aviationweek.com



ANTHONY PECCHI/H.GOUSSE/AIRBUS

WATCHPOINTS 2020

From urban air taxis to hypersonic strike missiles, here are some of the aerospace and defense **milestones to look forward to in 2020.**

Graham Warwick Washington

Urban Planning

Uber, under its Elevate aerial ride-sharing initiative, remains committed to conducting test flights with experimental eVTOL vehicles in 2020. The tests, set to take place in Dallas, Los Angeles and Melbourne, Australia, will be key to establishing the public acceptability of urban air taxis.

Future Fighters

After difficult negotiations, France and Germany expect to sign an aircraft-demonstrator contract for the Future Combat Air System in early 2020. Spain has already joined the program, but Italy and Sweden have sided with the UK's Team Tempest, dividing European fighter investment.

AIRBUS

Transforming Transportation

The viability of electric short-haul air transport will be put to the test in 2020 with flights of both retrofitted aircraft and new designs such as Eviation's 11-seat Alice. And planned testing of Boom's Mach 2.2 XB-1 demonstrator will advance the return of high-speed air travel.

HARBOUR AIR

Rebuilding Boeing

A critical year lies ahead for Boeing, one that includes returning the 737 MAX to service and delivering hundreds of stored aircraft, beginning delayed flight testing of the 777X and deciding whether to launch the new midmarket airplane in the face of growing orders for Airbus' A321XLR.

BOEING

VOLOCOPTER

BELL

Rotary Revival

In March 2020, the U.S. Army plans to select two competitors from a field of five to build prototypes of its Future Attack Reconnaissance Aircraft. The need is urgent, and the program is fast-paced, with the flyoff set for 2023 and deliveries of the armed scout helicopter to begin in 2028.

Accessible Space

If final tests by Boeing and SpaceX go as planned under NASA's Commercial Crew program, U.S. astronauts will be launched into orbit from U.S. soil for the first time in nine years. Meanwhile, Blue Origin and Virgin Galactic expect long-awaited suborbital tourist flights to begin in 2020.

NASA

RAYTHEON

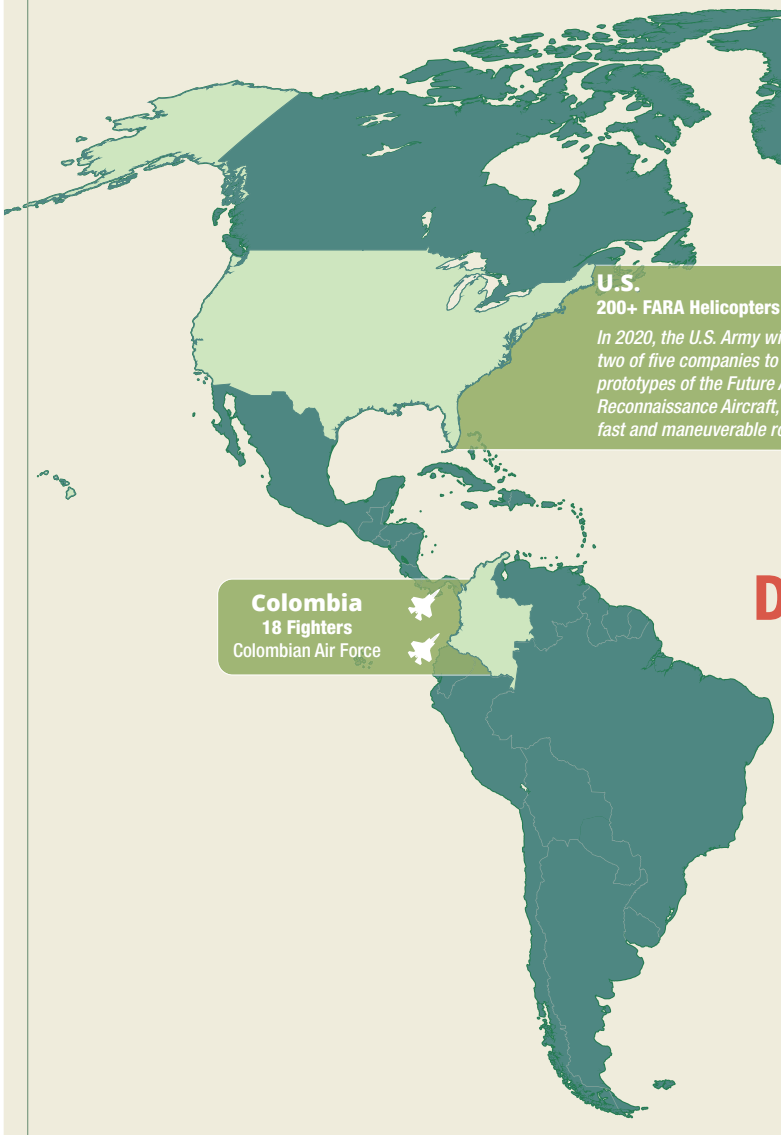
Rapid Response

U.S. hypersonic missile flight testing will begin to ramp up in 2020 as it races to catch up with the deployment of high-speed, maneuverable strike weapons developed by Russia and China. The tests will be crucial to fielding U.S. air-, land- and sea-launched boost-glide missiles beginning in late 2021.

Technology Trends

There are a bevy of technologies to watch in 2020 including: airliners flying in formation to save fuel and reduce emissions; helicopters equipped to fly with zero, one or two crewmembers; laser weapons defending air bases from drone attacks; and unmanned loyal wingmen teamed with manned combat aircraft.

BOEING

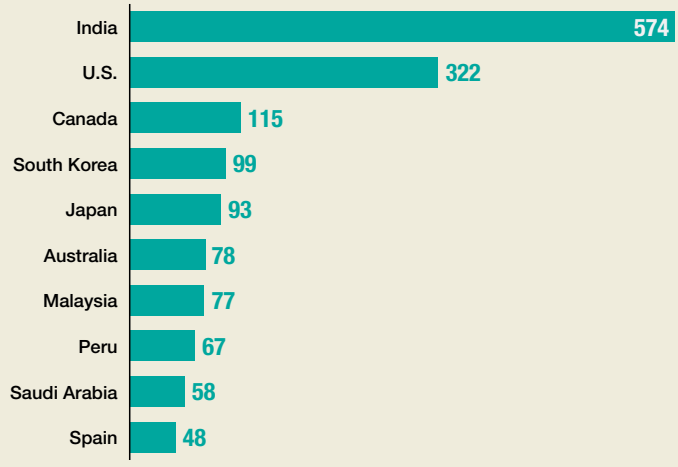


THE WORLD'S HOTTEST DEFENSE COMPETITIONS

Matt Jouppi and **Michael Tint** Washington

Over the next decade, the world is going to purchase 10,335 new aircraft. While armed forces have requirements for every type of aircraft, budgets and politics often intervene, slowing or altogether stopping plans to upgrade fleets and develop wholly new aircraft. Nonetheless, opportunities abound—from international competitions for new and used fighter aircraft to the U.S. effort to develop a Future Armed Reconnaissance Aircraft and head-to-head competitions for training aircraft. The Aviation Week Intelligence Network has examined the world's requirements for military aircraft and compiled these best guesses on which companies might win those competitions and how they may unfold.

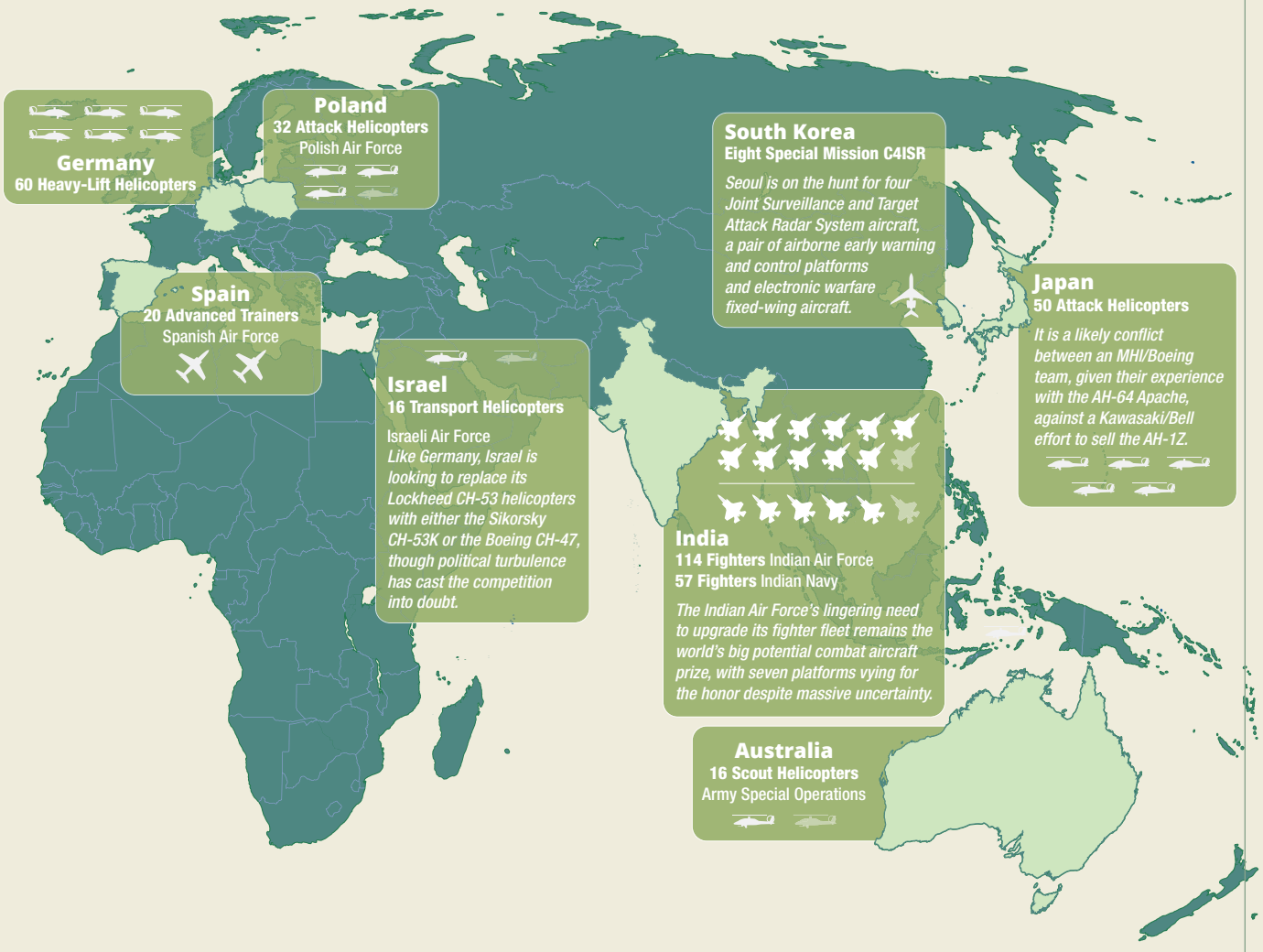
Aircraft in Open Competitions, 2020-29



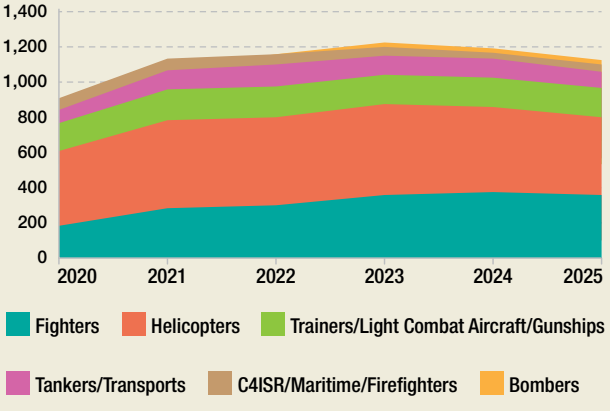
TOTAL NEW DELIVERIES
10,335

CURRENT COMPETITIONS
2,084

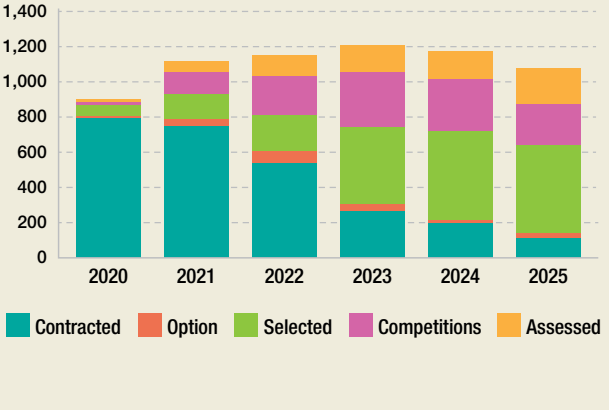
PERCENTAGE OF DELIVERIES IN COMPETITION
20.2%



Deliveries by Category, 2020-25



Likelihood of Deliveries, 2020-25



Source: 2020 Aviation Week Military Forecast

MILITARY AIRCRAFT COMPETITIONS

From fighters to helicopters, tankers and transporters to trainers and special-mission aircraft, here are more details about key contests likely to unfold over the next 10 years.

Matt Jouppi and **Michael Tint** Washington

FIGHTERS

Countries around the world have pending competitions for the purchase of up to 721 fighter aircraft over the coming years. Here is a look at the status of some of the most significant.

The **Indian Air Force**'s hunt for 114 aircraft to replace its aging Mikoyan MiG-21 and MiG-23/-27s, Sepecat Jaguar and Dassault Mirage fighters is a race among the Boeing F/A-18E/F, Dassault Rafale, Eurofighter Typhoon, Lockheed Martin F-21, Mikoyan MiG-35, Saab JAS 39E and Sukhoi S-35. The acquisition, which has been years in the making, could receive approval to move forward early in 2020. Likewise, the **Indian Navy** is expected to release a request for proposals for 57 fighters in 2020. To win, manufacturers are offering to manufacture aircraft in-country.

The **Canadian Air Force** issued a request for proposals (RFP) for its Future Fighter Capability Project in July and expects to award a contract in 2021-22 to buy 88 aircraft. It will choose from the F/A-18 E/F, F-35A or JAS 39E.

The **Japan Air Self Defense Force**, seeking 60-90 aircraft, will launch an F-2 replacement program in April 2020 but still is weighing whether to join a cooperative development program, partner with a foreign company to develop its own new fighter or go it alone.

The **Finnish Air Force** has received bids for a $10 billion competition to make 64 aircraft. The F-35 is favored over the Boeing Super Hornet and Growler, Rafale, Typhoon and Gripen.

To replace its Northrop F-5 and F/A-18 fleets, the **Swiss Air Force** hopes to award a $6.5 billion contract for the purchase of up to 40 fighters in 2020.

Germany's Luftwaffe has fallen out of love with the F-35 and will decide between the Typhoon and F/A-18 E/F/G in a competition driven by a requirement for a NATO nuclear delivery capability.

In 2018, the **Peruvian Air Force** started studying its next fighter requirement and wants to replace its Dassault Mirage 2000 and Mikoyan MiG-29 fleets with 24 aircraft. Options include the Rafale, Korea Aerospace Industries (KAI) FA-50, Lockheed Martin F-16 and MiG-35.

HELICOPTERS

When it comes to helicopters, two of the largest potential opportunities are again in India.

The **Indian Navy** is looking for 234 helicopters—123 of which have anti-submarine-warfare capabilities, and 111 of which are armed light utility rotorcraft. The competitors include the Airbus AS565, Kamov Ka-226T, NHIndustries NFH90 and Sikorsky MH-60R. But the contract award could become tangled in a court challenge.

Major helicopter competitions are also underway in the U.S. and Asia. The **U.S. Army**'s Future Attack Reconnaissance Aircraft competition, which could involve more than 200 long-range, fast scout aircraft. The contest is pushing the technological envelope, with new entries from four teams—AVX Aircraft/L3Harris, Bell, Boeing, Karem Aircraft/Northrop Grumman/Raytheon and Sikorsky.

By the first quarter of 2020, the **U.S. Navy** intends to award a contract for a TH-57 helicopter replacement, choosing between the Airbus H135 Bell 407 GXI and Leonardo TH-119 for a training helicopter to enter service in 2021. The Navy needs 130 aircraft and has budgeted for 109.

The **Japan Ground Self Defense Force** is seeking up to 50 attack helicopters to replace its AH-1S Cobras, with Bell likely to partner with Kawasaki Heavy Industries on its AH-1Z and Boeing likely to team with Mitsubishi Heavy Industries on its AH-64E.

The **South Korean Air Force** has delayed its TH-X competition, scheduled in 2017, to replace the MD500 fleet of training helicopters. The Airbus H145M, Bell 505X Jet Ranger and Leonardo SW-4 are in the running.

TRANSPORT

In the market for transport and training aircraft a few competitions stand out.

The **U.S. Army** canceled its Fixed-Wing Utility program in 2018, saying it received no acceptable offers, but that has not changed its need for about 76 replacements for the Beechcraft C-12 and Fairchild C-26. The service will probably give it another go, with the Beechcraft King Air 350ER and Pilatus PC-24 likely entrants.

What does India not need? In this case, it is seeking 100 aircraft to replace aging Antonov An-32 transporters. The **Indian Air Force** may expand on an existing purchase of Airbus C295s or buy the Ilyushin IL-214V.

Though **Saudi Arabia**'s joint venture with Antonov on the An-132 has stalled, the Persian Gulf powerhouse needs about 10 transporters. It was likely to opt for the Airbus A400M, but Germany's recent export ban has opened the door to the Ilyushin IL-76 or the Kawasaki C-2.

The **Peruvian Air Force** needs six "heavy-lift" aircraft, of which two would be tankers. Although the government green-lighted the purchase of Lockheed Martin C-130Js, the air force has reopened the selection process in order to consider the South American Embraer KC-390.

TONY OSBORNE/AW&ST

SPECIAL MISSION AIRCRAFT

When it comes to specialty aircraft for maritime patrol, electronic warfare or to aid battlefield communications, conflict in the Asia-Pacific region is driving interest.

The **Japan Maritime Self Defense Force** needs eight new signals intelligence aircraft to replace its Lockheed Martin OP-3 and UP-3 aircraft and is considering special mission business jets, UAVs, a modified Kawasaki P-1 or Mitsubishi MRJs.

The **Japan Air Self Defense Force** is likewise preparing to replace the YS-11 with six modern standoff jammers—perhaps a modified Kawasaki C-2 or aircraft from foreign and domestic prime contractors.

The **Philippines Air Force** needs a pair of maritime patrol aircraft (MPA) and may look to purchase secondhand Lockheed Martin P-3s or lower-end maritime surveillance aircraft.

Not all of the action is in Asia, though. The **Spanish Navy** needs eight maritime patrollers, perhaps the Airbus C295 MPA or, more likely, the ATR 72 MPA.

BOEING

LIGHT COMBAT AIRCRAFT/TRAINER

Over the next 10 years, training and light-combat aircraft will be a hot market, with requirements for some 372 aircraft. Here is a sampling of some of the top contests.

The **Indian Air Force** is looking at the FMA IA-63, Pampa III, Hindustan Aeronautics Ltd. (HAL) HJT-36 and Yakolev-130 to fill its need for 73 intermediate jet trainers. India also will consider the HAL HTT-40 and other basic flight trainers, and is looking to purchase 38.

The **Peruvian Air Force** is seeking 24 light combat aircraft to supplement its Cessna A-37 Dragonflies. The Aero Vodochody L-39NG and KAI FA-50 are in the running.

By the early to mid-2020s, the **Swedish Air Force** aims to replace its fleet of Saab 105 trainers with about 30 new advanced jet trainers—either the Boeing/Saab T-7A or Pilatus PC-21.

With budgets tight in **Malaysia**, its defense minister may trade palm oil for the 36 aircraft it needs—perhaps HAL Tejas Light Combat Aircraft, KAI FA-50s, Leonardo M-346s, Mikoyan MiG-35s, Pakistan Aeronautical Complex JF-17s or Saab JAS 39s. Russia has proposed buying back unserviceable MiG-29s and replacing them with MiG-35s.

To replace aging Chengdu FT-7s, the **Pakistani Air Force** wants a dedicated trainer squadron of 12. It may opt for the Hongdu L-15, KAI T-50 or Leonardo M-346.

BACKGROUND IMAGE: CHAINARONG PRASERTTHAI/ISTOCK

MC2 KENNETH RODRIGUEZ SANTIAGO/U.S. NAVY

Back to the Future

> COMPETING VISIONS EMERGE TO REPLACE E-8C ROLE

> U.S. ARMY AND AIR FORCE TAKE DIFFERENT PATHS TO FUTURE LONG-RANGE STRIKE

F-22s and B-2s rule the air now, but the focus is shifting to networks and long-range missiles.

Steve Trimble Washington

Three different visions of the future of U.S. air and space power from the air, land and maritime perspective will come to the fore in 2020.

The U.S. Air Force will propose a radical break from the status quo with a $30 billion, five-year plan to invest in the future, including combat power, advanced communications, offensive and defensive space and a more survivable logistics system. It is a break from the status quo because the Air Force will finance the plan by divesting multiple fleets of older aircraft by the end of 2024.

As the Air Force doubles down on the future, the U.S. Army is laying plans to assume more of the long-range surveillance and strike capabilities now performed by the Air Force. One of the most significant and somehow least heralded new initiatives unveiled in 2019 is the Army's Multi-Domain Sensing System (MDSS), which seeks to introduce by 2028 new fleets of surveillance aircraft, airships and satellites to identify targets hundreds or thousands of miles downrange. The targeting data collected by the MDSS will then queue strikes from a new arsenal of long-range, ground-launched missiles and projectiles—not unlike how the Air Force's satellites, E-8Cs and RC-135s currently pick out ground targets deep behind enemy lines for bombers and fighters to strike.

Finally, the Marine Corps and Navy are changing course. In another pivotal 2019 moment, Gen. David Berger, the newly confirmed Marine Corps commandant, published new planning guidance in July. The 26-page strategic blueprint concedes that China's long-range, anti-ship weapons make the Marines' traditional amphibious strategy unfeasible. In 2020, Berger and Chief of Naval Operations Adm. Mike Gilday will lay out a new strategic direction, emphasizing closer integration of each service's tactical air forces.

As the services scramble to fulfill a goal to be prepared to "dominate" a conflict with China and Russia by 2028, different visions of a future conventional conflict are starting to take shape. The Air Force is betting long on future capabilities, shifting investments into technologies that would redefine traditional notions of how to manage a battle in real time from the air and space. The Army is focusing on existing technologies, expanding the reach of artillery and regenerating certain capabilities such as the E-8C Joint Surveillance Target Attack Radar System (J-Stars), which the Air Force plans to abandon. The Navy and Marine Corps remain committed to an aircraft carrier-centric force structure but also to adapting it to operate in a new threat environment.

The trend began in 2018 with the Air Force's decision to cancel the E-8C J-Stars Recapitalization program. The J-Stars typified the type of capability that established the U.S. military's strength over the past three decades. It was conceived by DARPA's Assault

Breaker program, which was tasked with finding a cost-effective solution to neutralize the Soviet Union's armored might in Eastern Europe. Assault Breaker demonstrated that an aircraft with a sensor and onboard battle management suite could peer deep behind enemy lines, identify tanks on the move and pass the coordinates to the Army's Advanced Tactical Missile System (Atacms) or Air Force strike aircraft.

By 2018, however, the threat had changed. The E-8C's APY-7 radar can identify targets 155 km (96 mi.) away, but Russia's S-400 air defense system introduced the 40N6 interceptor in 2018. The 40N6 boasts a range of 400 km, and is designed to strike a radiating, slow-moving target like the E-8C. Such a capability creates a Catch-22: The S-400 radar and 40N6 launcher can be detected and targeted, but not if aircraft such as the E-8C must operate far beyond the range of its sensor to survive.

U.S.

2020 DEFENSE BUDGET
$750 billion (requested)

PERCENT OF GDP
3.2

PERSONNEL UNDER ARMS
1.4 million
active duty military

The Air Force also made other crucial decisions at the end of 2018. The Pentagon's spending plan for the 2020-24 period, which was released in March 2019, gutted the budget for Next-Generation Air Dominance (NGAD) by 50%, cutting funding over the five-year period to $6.6 billion from $13.2 billion. Air Force leaders stated unequivocally for the first time that a next-generation fighter program was no longer included in the five-year spending plan for NGAD. Instead, the Air Force decided to push back the launch of an F-22 replacement beyond 2024.

In the meantime, the service would focus on reinventing how such next-generation combat aircraft would be designed, built, operated and sustained, with an emphasis on what Will Roper—the assistant secretary of the Air Force for acquisition, technology and logistics—calls the "holy trinity": digital design tools, open architecture software standards and agile software development.

The Air Force's plan for replacing J-Stars is following themes similar to NGAD. The Advanced Battle Management System (ABMS), launched a year ago, proposes to disaggregate the function of battle management command and control (BMC2). The task of BMC2 is to close kill chains as quickly as possible. An aerial network aggregates data flowing off sensors. Software algorithms, not humans, identify the targets and pass the coordinates to platforms carrying weapons. A human operator, the final link in the chain, then decides whether to pull the trigger. Those trigger-pullers could be flying on a new fleet of combat aircraft designed to be built in small batches, with unique flight characteristics but sharing mission systems, software and as many common components as possible.

It is a grand, sweeping vision for the future of airpower after 2030, but in some ways it connects the Air Force

Ground-based command centers once defined the U.S. approach to military dominance.

TECH. SGT. JOSHUA STRANG/U.S. AIR FORCE

back to its roots. Before airborne BMC2 became institutionalized by the early 1990s, the Air Force trained pilots to the "centralized control, decentralized execution" standard, with an emphasis on granting crews at the forward edge of the battle as much autonomy to operate as possible. Moreover, the post-World War II aerospace industry churned out new aircraft designs in cycles that could be measured in months or years instead of decades. The industry's innovativeness in the early years of the Cold War inspired Roper's "Digital Century Series" title for the new NGAD initiative, referencing the six different fighters that entered the Air Force inventory between 1954 and 1959.

But achieving that goal probably will not come without a cost. It is possible that U.S. taxpayers will keep defense spending growth in line with or above inflation, but the Air Force leadership is not counting on it. The new five-year spending plan for fiscal 2021, which the Air Force submitted to the Defense Department in September, assumes flat or declining budget levels starting in fiscal 2022. In such an environment, paying for investments in new capabilities is a zero-sum game; the funding has to come from other programs.

The U.S. Army is hedging its bets on air power by investing in long-range, high-speed missiles.

U.S. ARMY

Last year, the Air Force redirected at least $11 billion to other capabilities, including $6.4 billion by canceling the J-Stars Recap and $6.6 billion by deferring the launch of a new fighter under NGAD. In 2021, the Air Force will dig even deeper. More than $30 billion will be diverted to next-generation capabilities by accelerating retirements of older aircraft. The rule used by Air

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Force leaders, according to Chief of Staff Gen. David Goldfein, was each fleet's relevance in a conflict with China or Russia between 2030 and 2038. If the aircraft fleet's cost cannot justify its assessed value during that period, the Air Force will propose early retirement within the next five years.

So far, the Air Force has openly discussed only one aircraft fleet as likely to face early retirement: the Rockwell B-1B Lancer. The fleet has performed nobly over the past 18 years as a close air support asset for ground troops in Afghanistan and the Middle East, an unlikely role for an aircraft originally designed to drop nuclear bombs on defended targets in the Soviet Union. Although it can still perform conventional missions against lightly defended targets and is the only Air Force fleet with a maritime strike capability, the service has to decide if that is worth the cost of sustaining the swing-wing bomber through its retirement date in 2040.

If Congress accepts the Air Force's funding transfers, the result could be a new approach to air power after 2030. With the advantages of stealth, precision and centralized BMC2 eroding, the Air Force's counter is to make decisions faster than an enemy can react by harnessing and exploiting a vast quantity of sensor data at lightning speed. If American fighters and bombers cannot rely on stealth to survive, they can still win by moving faster and more decisively.

But the Army seems to be hedging its bets. Its maneuver forces now rely on the Air Force's reconnaissance and strike aircraft to identify and attack such threats as long-range artillery, including surface-to-surface missiles. In the future, the Army's Long-Range Precision Fires (LRPF) program envisions attacking threats far beyond the horizon. The longest-range weapon in the Army's arsenal today is the 300-km Atacms.

By 2025, the Army hopes to deploy the Long-Range Hypersonic Weapon with a range beyond 3,000 km and the Precision Strike Missile with a range potentially over 700 km. Such weapons could be used to target an adversary's air defenses at the beginning of a war, allowing Air Force combat aircraft to more easily penetrate airspace that would otherwise be denied.

But the Army's ambitions do not stop there. As the Air Force pursues the ABMS mission, the Army appears to be taking over-the-horizon surveillance and targeting into its own hands. So far, the MDSS remains an internal Army concept. It calls for establishing an intelligence, surveillance and reconnaissance (ISR) architecture with multiple layers stretching from treetop level to space. Two new pillars of the architecture are the Airborne ISR (AISR) fleet of business jet-class aircraft with the E-8C's sensors and a constellation of small satellites in low Earth orbit. Such a capability would allow the Army to complete the sensor-to-shooter kill chain by itself in many cases, freeing the service from dependence on the Air Force and Navy for targeting support.

At some point in 2020, the Joint Staff may have to get involved. It is the Joint Staff's duty to adjudicate overlapping or redundant capabilities between the services. Each service is now taking different approaches to performing a mission defined by the E-8C: Detecting moving targets in any weather.

The Air Force plans to introduce the first two increments of the ABMS by 2025, with a third and more advanced version coming online after 2030. The Army has the AISR requirement. The Navy, meanwhile, already operates a fleet of medium-altitude aircraft equipped with powerful synthetic aperture radars (SAR). The subset of the Navy's Boeing P-8A is equipped to carry the Raytheon Advanced Airborne Sensor (AAS), which replicates the E-8C's SAR and ground-moving-target-indicator capabilities.

Over the last three decades, the Navy has adopted several missions after they were abandoned by the Air Force. The Navy's E-6B Tacamo fleet now performs the role once played by the Air Force's EC-135 Looking Glass. The service's fleet of EA-18Gs now provides medium-range electronic attack for the Air Force's tactical aircraft. The AAS-equipped P-8A fleet could find itself under similar pressure to replace the void created by the retirement of the E-8C, as long as the third increment of the ABMS and the Army's AISR programs are still in the development phase.

Canada's Defense Agenda Uncertain as Trudeau Enters Second Term

> BOEING AND SAAB LIKELY TO BID ON FUTURE FIGHTER CAPABILITY

> REQUEST FOR PROPOSALS EXPECTED AT MIDYEAR FOR REMOTELY PILOTED AIR SYSTEM

Steve Trimble Washington

Canadian Prime Minister Justin Trudeau won reelection in November, but his Liberal Party lost its four-year-old majority in Parliament—a subtle twist of fate that poses uncertainties for the national security agenda, which was largely absent from the political debate on the campaign trail.

Trudeau entered 24 Sussex, the prime minister's Ottawa residence, in 2015 riding partly on a firm to-do list of campaign promises focused on the Canadian armed forces, including launching a competition to replace the air force's CF-18s and completing the acquisition of a fixed-wing search-and-rescue aircraft fleet. Trudeau subsequently published a new white paper in 2017 that called for raising defense spending by 70% by 2028.

Trudeau largely fulfilled his commitments to the armed forces. Although he swore during the 2015 election campaign never to buy the Lockheed Martin F-35, the politics of Boeing's failed bid to disrupt what was then a Bombardier C Series sale to Delta Air Lines—by filing an anti-dumping complaint—forced Trudeau to cancel an interim purchase of Boeing F/A-18E/F Super Hornets. The F-35 reentered the CF-18 replacement competition, with Public Services and Procurement Canada (PSPC) agreeing last summer to remove a contractual requirement for guaranteed local maintenance support, opening the way for Lockheed to submit a bid. Boeing and Saab are expected to submit proposals for the F/A-18/E/F and Gripen E/F, respectively, by the deadline in January.

But the dearth of defense issues in the 2019 election campaign leaves Trudeau with broad latitude. The Liberal Party's platform made no specific promises about defense spending, other than a commitment to reform acquisition by creating a dedicated procurement agency for the armed forces.

Canada still has a long list of unfulfilled acquisition priorities coming due. In addition to entering a year-long source selection for the Future Fighter Capability, the PSPC is scheduled to release a request for proposals for the Remotely Piloted Air System by midyear, opening a competition between bids by L3 MAS/Israel Aerospace Systems and General Atomics Aeronautical Systems.

CANADA

2019 DEFENSE BUDGET
$22.5 billion

PERCENT OF GDP
1.3

PERSONNEL UNDER ARMS
71,500
active duty

CANADIAN DEPARTMENT OF NATIONAL DEFENSE

Canada's CF-18s are headed for retirement by the middle of the next decade, pending the outcome of the country's ongoing Future Fighter Capability tender process.

Additional tenders are in the pipeline for a turnkey pilot training system and a fleet of new tankers.

So far, the new government has been silent on those priorities, with Trudeau expressing only in the Speech to the Throne on Dec. 5 a promise to renew the country's "commitment to NATO and United Nations peacekeeping."

Accomplishing Brexit Will Challenge UK Defense

> ELECTION STRENGTHENED CALLS FOR SCOTTISH INDEPENDENCE

> UK COMMISSIONS SECOND QUEEN ELIZABETH-CLASS CARRIER

Tony Osborne London

Boris Johnson's election landslide on Dec. 12 makes Brexit on Jan. 31 a certainty.

But as the chants of "Get Brexit Done"—a slogan used by the Conservative party in their election messaging—fade away, Britain's place in the world appears infinitely more vulnerable.

Johnson's parliamentary majority means he can now sweep aside any opposition to pursue his vision of Brexit.

But he was not the only victor.

The Scottish National Party secured 48 of Scotland's 59 seats, which the party says is a mandate for a second independence vote. If it were to succeed, there would be far-reaching consequences to Britain's national defense capability. Scotland is home to strategically important air bases and, most significantly, the UK's Trident-based nuclear deterrent. Johnson is unlikely to approve such a referendum at least in the short-term, but the Scottish nationalists could make life difficult for his government, and preventing a referendum could be seen as undemocratic.

The complexities of having Northern Ireland as the only part of the UK to share a land border with an EU country, the Republic of Ireland, mean that after a Brexit there will be a border in the Irish Sea between Northern Ireland and the rest of the UK. This, too, could have security implications and lead to renewed violence from unionist groups, as they see their political influence being eroded. Nationalists see an opportunity for a united Ireland once again. There is also uncertainty about the futures of Gibraltar and Diego Garcia.

Exiting the EU means British security forces no longer will be linked to EU databases on criminals, organized crime and terror. Questions also have arisen about Russia's influence in the British democratic process, with Johnson suppressing publication of an intelligence report on Russian infiltration in British politics during the the election run-up.

And there is a fiscal aspect as well. Since the Brexit vote in 2016, Britain's GDP has begun to stagnate as economic output and investments fall away. National debt also is rising. The British Parliament's own analysis suggests GDP could be 7% lower over the next 15 years than without Brexit, and even with a free-trade agreement established with Europe. Questions then would arise about whether Britain could afford to maintain military spending. Currency fluctuations will affect big-budget programs such as the ongoing purchase of the Lockheed Martin F-35 Joint Strike Fighter (JSF).

Britain is one of a handful of NATO countries with defense spending at or above NATO's target of 2% of GDP. The Conservative manifesto published in the run-up to the election calls for this to increase by at least 0.5% above inflation every year. Britain's defense budget for 2019-20 was £39.5 billion ($52.7 billion), and this will rise to £41.3 billion for 2020-21. The government will maintain and renew the Trident nuclear deterrent but also support the defense industry with "ambitious global programs," including local construction of Type 31 frigates and local production of the Boxer armored vehicle.

UK

2020-21 DEFENSE BUDGET
£41.3 billion ($55.1 billion)

PERCENT OF GDP
2.0

PERSONNEL UNDER ARMS
192,660 (full-time and reservists as of October 2019)

In December, the Royal Navy commissioned the second new Queen Elizabeth-class aircraft carrier, HMS Prince of Wales, in a further step toward restoring the country's carrier capability. Following operational trials in the fall off the Eastern U.S., more are planned around the UK during 2020, paving the way for the first operational deployment in May 2021.

The UK plans to have 35 F-35s in service by the end of 2022, and the government has committed to buying all of the 138 F-35s it planned to purchase when it joined the JSF program in the early 2000s. Whether that commitment is met and if the UK will purchase additional variants could be determined in a strategic defense and security review planned for 2020.

LPHOTO DANIEL SHEPHERD/ROYAL NAVY

Operational testing of the F-35 onboard HMS Queen Elizabeth has paved the way for the first operational deployment to the Far East in 2021.

With the retirement of the Panavia Tornado last March, the Eurofighter Typhoon fleet has become the heavy-lifter of the UK's air defense mission and is continuing air strikes against Islamic State group sites in Iraq and Syria along with the UK's MQ-9 Reaper unmanned aircraft systems.

The UK now is stepping up development of a Typhoon replacement for the mid-2030s with the Tempest future combat air system, supported by Italy and Sweden. More nations could join in 2020, with Japan a key target. And with delivery of the first of nine Boeing P-8 maritime patrollers, the UK is back in the long-range antisubmarine-warfare business, with an initial operating capability expected in April.

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French Defense Budget Increase Is Part of Multiyear Plan

- FLEET RENEWAL CONTINUES
- AIRCRAFT AVAILABILITY IS STILL AN ISSUE

Thierry Dubois Lyon

France's defense budget remains on an upward curve as planned and with much less controversy than a year ago. The trend signals the government's determination to simultaneously renew its armaments, maintain its presence in conflict zones—such as the Sahel—and sustain troop morale.

The confirmation of the budget's growth comes at a time when French President Emmanuel Macron is questioning NATO's functionality. Nevertheless, the increase maintains France's defense expenditures on a trajectory to meet, in 2025, the NATO requirement of 2% of GDP. Next year, the proportion will stand at a calculated 1.86% (despite the reckoning by the national audit office in 2017 that France is complying with NATO's 2% standard, thanks to expenses in research and development and operations abroad).

It also takes place against a backdrop of gradual increase in the EU's defense posture. European Commission President-elect Ursula von der Leyen has dedicated a directorate-general position to defense, industry and space. Germany, France's main partner in the EU, is also increasing its defense budget (see page 43). And although the UK is to leave the EU after Brexit takes effect, it is expected to remain France's strongest military ally.

The 2020 budget attributed to the ministry of armed forces amounts to €37.5 billion ($41.5 billion). The 4.5% expansion is part of the 2019-25 programming law.

The French Air Force is expecting delivery of two Airbus A400M transports, one Lockheed Martin KC-130J tanker and one Airbus Multi Role Tanker Transport. It will also receive the first two upgraded Dassault Mirage 2000D fighters, and General Atomics will hand over three (one "system," under the French government's taxonomy) MQ-9 Reaper UAVs.

The French Navy will receive two NHIndustries NH90 helicopters and another two upgraded Atlantique 2 (ATL2) maritime patrol aircraft. The French Army will receive seven NH90s.

The air force is now in charge of France's military space segment, which will see the launch of a CSO Earth-observation satellite—the second in a planned constellation of three.

Few new orders are expected. One may be of importance, however: four medium-altitude, long-endurance EuroMALE UAVs. Airbus is the prime contractor, Dassault and Leonardo are major partners, and they are all struggling to reach a financial agreement with the government, according to French daily *La Tribune*. The aircraft is still at an early design stage. The French Air Force will also order four C-130H upgraded transports.

For the navy, the ministry is to order three new E-2D Hawkeye airborne radar aircraft from Northrop Grumman. Seven modified Dassault Falcon 2000s will be delivered under the Albatros maritime patrol program. For the army, 14 Tigre combat helicopters will be upgraded.

Although not a firm order yet, the November launch of the construction phase of the Archange program marks the country's determination to renew its capability in electromagnetic signals intelligence, notably the interception of voice radio communications and radar waves. From 2025, three modified Falcon 8Xs will gradually replace the existing two Transall C-160 Gabriels. The Thales-made payload will include multipolarization antennae and artificial intelligence software to improve automated data processing.

Meanwhile, Francois Cornut-Gentille, a deputy specializing in defense budgeting, is raising several issues. He notes that no credit has been allocated to the nascent "space supremacy" program. A three-satellite program for space-based electromagnetic intelligence has been postponed, and the 2020 launch of the second CSO will be three years late, he adds.

Aircraft availability is a widespread problem, according to Cornut-Gentille. The upgrade of the navy's E-2Cs should improve their poor availability—13%, as of Dec. 31, 2018. Cornut-Gentille also points at the A400M's "abnormally low" 27.5%. The air force expects to have 17 A400Ms by the end of 2020. That percentage should improve progressively, thanks to the aircraft's maturity and the support contract signed with Airbus in June 2019, the ministry notes.

To keep troop morale at a sound level, some investment will be made in housing and family care (especially for those who have one parent abroad for an extended period)—a combined €200 million in 2020, as part of the nine-year "military welfare program."

FRANCE

2020 DEFENSE BUDGET
€37.5 billion
($41.5 billion)

PERCENT OF GDP
1.86

PERSONNEL UNDER ARMS
268,000 (including civil servants)

French Military Aircraft Fleets

AIR FORCE	
Combat	219
Transport	75
Support	22
Liaison	27
Training	116
Air Display	21
Helicopters	74
UAVs	6
ARMY	
Helicopters	286
Liaison	13
NAVY	
Combat	42
Tactical Airborne Early Warning	3
Maritime Patrol	22
Maritime Surveillance	13
Combat and Rescue Helicopters	55
Support and Public Service Helicopters	24
Maritime Support	22

As of July 1, 2019. Source: French Ministry of Armed Forces.

NATO Programs Make Progress Despite Alliance Divisions

- NOT ALL MEMBERS WILL MEET THE 2% DEFENSE BUDGET GOAL
- NATO IS MOVING TO MODERNIZE AND RENEW ITS SHARED AIRCRAFT FLEETS

Tony Osborne London

NATO's London meeting in December exposed deep divisions among alliance members.

It was supposed to be a celebration of the alliance's 70th birthday, but instead NATO leaders expressed ongoing concerns about the relevance of Article 5, NATO's raison d'etre that declares an attack on one is an attack on all, and about Turkey's role in the alliance given its rekindled relationship with Russia and its blocking of renewed defense plans of the Baltic states and Poland.

And then there is the troubling fiscal question, one often posed by U.S. President Donald Trump, about why some of Europe's most successful economies are still struggling to devote 2% of their GDP to national defense.

NATO called upon member-states in 2014 to meet the 2% target within a decade. Nine of the 29 alliance members now meet or expect to meet the 2% target by the end of 2019, but some will not meet the target by 2024. Germany, with arguably one of NATO's biggest economies, is not expected to hit the target until 2031.

Nonetheless, across the alliance, spending is on the increase. Figures released by NATO in advance of the London meeting revealed that in most countries, defense cuts largely have ceased and, combined, the allies have invested $130 billion since 2016. This is expected to grow to $400 billion by the end of 2024. The additional funding is helping NATO to increase its readiness, and alliance members used the meeting to commit to a joint readiness of 30 battalions, 30 air squadrons and 30 combat ships for operations in 30 days.

The meeting also saw nations recognize space as a new warfighting domain, reflecting steps already taken in the U.S., France and the UK. Members took the first steps toward recognizing the potential challenge of China as a growing international power and the world's second-largest defense spender.

After the collapse of the Intermediate-Range Nuclear Forces Treaty (INF) between Russia and the U.S. in 2019, NATO hopes it can encourage China to join future arms control agreements.

NATO has yet to formally respond to Russia's deployment of the Novator 9M729 cruise missile, the weapon the U.S. said violated the INF treaty. Secretary General Jens Stoltenberg says the NATO response to the breach will be "defensive, measured and coordinated" and will be "an important part of our work for the months to come," but he would not say whether the alliance will respond with similar capabilities.

CHRISTIAN TIMMIG/HQ AIRCOM, RAMSTEIN

NATO's first Alliance Ground Surveillance derivative of the Global Hawk UAV was delivered in November.

NATO also is looking ahead to inducting what will be its latest—30th—member, North Macedonia.

In addition, the alliance is taking its first steps toward the modernization and, ultimately, renewal of its shared aircraft fleets. In November, NATO contracted with Boeing to use elements of the $1 billion Final Lifetime Extension Program (FLEP) on the Boeing E-3A Sentry airborne early warning (AEW) aircraft fleet based in Germany. Under the program, the aircraft will be upgraded with modernized data-linking and communications systems as well as new consoles for the operators. The program also is expected to help reduce obsolescence of the aircraft, ensuring it can operate to 2035. Upgrade work will be conducted in Germany and Italy, and is expected to be completed in 2026.

Beyond 2035, NATO plans to introduce the Alliance Future Surveillance and Control (AFSC) program, what is likely to be a distributed, networked and highly automated system of systems to perform multidomain surveillance. In December, the NATO Support and Procurement Agency (NSPA) awarded high-level concept contracts to Airbus, the Boeing-led Abiliti consortium, General Atomics, an L3 Harris-led consortium, Lockheed Martin and MDA of Canada to develop potential options and solutions for the AFSC system, and to understand how the system will be interoperable with capabilities being introduced by member states.

NATO also finally received the first Alliance Ground Surveillance (AGS) derivative of the high-flying Northrop Grumman RQ-4D Global Hawk Block 40 in November, after a two-year delay. The alliance is buying five of the aircraft equipped with Northrop's Multi-Platform Radar Technology Insertion Program, allowing it to perform a similar role to the E-8 Joint Stars aircraft. The aircraft will be based at Sigonella, Sicily, from which U.S. Air Force Global Hawks are operating. Next steps include a verification process for each of the aircraft on arrival in Sicily, and NATO hopes to achieve an initial operating capability in the first half of 2020. Although the AGS program is being funded and acquired by 15 member states, access to the data acquired by the aircraft will available to all NATO countries.

Russian Defense Modernization Slows but Will Not Stop

- MORE SU-34 FIGHTER-BOMBER ORDERS ARE LIKELY, ANALYST SAYS
- DELIVERY OF THE FIRST PRE-PRODUCTION SU-57 DUE BY YEAR-END

Maxim Pyadushkin Moscow

Russia is finishing its armed forces' first massive post-Soviet rearmament. The renewal, which started in the early 2010s, will not stop but is likely to continue at a slower pace. Most of the new weapons have been combat-tested in Syria, where Russia for the first time has conducted limited force-projection operations.

According to the federal budget approved in November, Russia's defense spending will drop to 2.4% of GDP in 2020, the lowest rate since 2015, when it reached 4.2%. The budget share of defense spending also will decrease, to 15.7% in 2020 from 16.8% in 2019, reports the defense committee of Russia's State Duma. That rate is likely to remain low through 2022.

Nevertheless, Russian defense expenditures are expected to grow slightly. The budget for 2020 allocates 3,059 billion rubles (about $48 billion) for national defense. This sum is expected to grow to 3,285 billion rubles in 2022.

SUKHOI

Russia's military placed an order for 76 Su-57 aircraft during the summer.

During the past decade, Russia prioritized air force rearmament, receiving about 460 new fixed-wing aircraft in 2011-20, says Konstantin Makienko, deputy head of the Moscow-based think tank Center for Analysis of Strategies and Technologies (CAST). Deliveries peaked in 2014, when the air force received 101 combat and training jets. By 2018, that number had dropped to 50 aircraft.

The military clearly has opted for modification of the heavy Sukhoi Flanker family. Major purchase contracts included single-seat Su-35 and double-seat Su-30SM multirole fighters and Su-34 fighter bombers, as well as Yakovlev Yak-130 jet trainers.

Now, the rearmament is fixed and will continue at a slower pace, the CAST expert says. According to Makienko, the air force is likely to order another Su-34 fighters after deliveries under the current order for 92 aircraft are completed. Prospects for the Su-35 and Su-30SM are not so clear, but production can continue because of export demand.

The Russian military is expected to take a serious leap with the introduction of the Su-57 fifth-generation fighter. Delivery of the first aircraft from the preproduction batch was expected by the end of 2019. The military already placed a new order for 76 Su-57s last summer. Three regiments are expected to receive the new fighters by 2028.

"We have to start working out the government rearmament program through 2033 next year," Russian President Vladimir Putin announced in November. The program should focus on precision weapons, aerospace defense, reconnaissance and strike unmanned aircraft, laser and hypersonic systems, weapons based on new physical principles and robotic vehicles, he said.

Russian forces gained some experience operating these types of weapons during operations in Syria, where Russia has been supporting local government forces in the civil war raging since 2015. More than 300 types of "major weapons and military hardware" have been tested in this operational zone, Defense Minister Sergei Shoigu said in November.

RUSSIA

2019 DEFENSE BUDGET
3,059 billion rubles
($48 billion)

PERCENT OF GDP
2.4

PERSONNEL UNDER ARMS
1,013,628

According to Makienko, Russian forces in Syria now number 6,000-7,000. They mostly provide air support for ground operations by the Syrian government forces and protect their bases in Khmeimim and Tartus.

"The Russian military got a taste of high-precision weapons in Syria," he points out. Another new experience is a wide use of unmanned vehicles for air reconnaissance and target detection. This enabled the air force to cut the reaction time from target acquisition to engagement from 1 hr. to a few minutes, he notes.

Russia now uses relatively small UAV models such as the Forpost, a licensed copy of the Israel Aerospace Industries Searcher, and the indigenous Orlan. However, the military already has financed development of larger unmanned vehicles. Sukhoi flight-tested the S-70 jet-powered, stealth-shaped UAV in 2019. The Russian military plans to use it for target detection and strike missions.

Another important program is the Kronstadt Orion medium-altitude, long-endurance aircraft designed for aerial patrol and reconnaissance. The first deliveries also were planned for the end of 2019.

Makienko agrees that the experience in Syria has proved Russian armed forces can conduct limited force projection, so the new rearmament program can shift to naval and strategic missile forces operations. "This is a mistake, as the resources should be invested in [the rearmament] of the ground forces," he says.

2020 Brings Decisions for Berlin's Military Modernization

> MORE EUROFIGHTERS ARE EXPECTED TO BE ORDERED IN 2020

> GERMANY WANTS ARMED FORCES TO PLAY MORE PROACTIVE ROLE

Tony Osborne London

Germany may have made big commitments to increase defense spending, but it is struggling to deliver the modernization its armed forces badly need.

As the richest European country, it appears to be finally awakening to allied calls to play a more proactive role in international security.

Berlin added more than €5 billion ($5.5 billion) to the defense budget in 2019, and although ministers admit it is unlikely to meet NATO's goal of spending 2% of GDP by 2024—instead targeting 1.5% then and 2% for 2031—1.5% is a significant hike from today's 1.35%.

Her fellow ministers remain cautious. Defense spending at 2% of GDP would make Germany one of the biggest defense spenders in the world. Foreign Minister Heiko Maas has suggested developing a more assertive German military should be pursued only with support from European allies.

There is light on the horizon, though. Several key programs are being funded, boosting a long-criticized shortfall of combat aircraft, helicopters and naval vessels.

GERMANY

2019 DEFENSE BUDGET
€45 billion ($50 million)

PERCENT OF GDP
1.35

PERSONNEL UNDER ARMS
182,649
(as of October 2019)

JOHANNES HEYR/BUNDESWEHR

Defense Minister Annegret Kramp-Karrenbauer (center) has secured billions in additional funding for Germany's armed forces; but without procurement reform, the country may struggle to spend it to improve capability.

The biggest challenge is in spending it.

Germany lacks political expediency. Chancellor Angela Merkel's shaky governing coalition is slowly pushing through modernization, and the years of slicing the defense budget have left the procurement agencies in disarray and short-staffed, in urgent need of reform.

"A country of our size, with our economic and technological power, our geostrategic position and global interests, cannot just stand on the sidelines and watch," said German Defense Minister Annegret Kramp-Karrenbauer in a November speech to military officers.

Among the most important purchase decisions will be on replacing its aging fleet of Panavia Tornado fighter bombers. Germany wants a platform that can handle all 12 missions performed by the Tornado, including the nuclear strike mission with the dual-key B61 free-fall weapons. Berlin has narrowed the choice to the Eurofighter or Boeing F/A-18E/F Super Hornet, knocking back Lockheed Martin's F-35. This is despite neither being equipped to perform the nuclear mission. A renewed request for information could revive the F-35's chances but would also push a decision to the right.

Berlin is, however, expected to approve in early 2020 the purchase of additional Eurofighters to replace the Tranche 1 aircraft.

The Quadriga requirement calls for up to 38 additional Eurofighters. The government is also expected to approve the long-awaited fitting of an active, electronically scanned array radar onto existing Tranche 2 and 3 Eurofighters; the Quadriga aircraft will be delivered with the sensor.

In 2017, Berlin signed up for the Netherlands-led Multinational Multi-Role Tanker Transport fleet, which will enable replacement of Germany's aging Airbus A310 tanker-transport aircraft. Germany also became the first Airbus A400M operating nation to begin using it in an operational environment, sending one to Jordan to support the ongoing reconnaissance mission against the Islamic State group. Also coming is a long-awaited selection to replace Germany's Sikorsky CH-53G Stallion heavy transport (STH) helicopter fleet.

The STH program is considering the Boeing CH-47 Chinook or Sikorsky CH-53K King Stallion. The decision has faced numerous delays, but industry is now expecting a contract to be signed in 2021, suggesting a selection in 2020.

Meanwhile the German Navy has opted to simplify its helicopter fleet by adopting the European NH90 to replace its Westland Lynx shipboard anti-submarine helicopters. The service had selected the NH90 as its replacement for the Sikorsky Sea King and has now opted to buy 31 NH90s to replace 24 Lynxes, to equip 15 of Germany's surface combatants with two helicopters each.

Other programs have been less fortunate. The plan to modernize ground-based air defenses with the MBDA and Lockheed Martin Medium Extended Air Defense System (TLVS in German) has yet to achieve contract signature, despite its 2015 selection. Having submitted their final offer in the summer, MBDA and Lockheed Martin are hopeful the multibillion-euro deal will finally get the green light in 2020.

Turkey's International Defense Relations Challenge NATO Solidarity

> PROCUREMENT OF RUSSIAN-MADE S-400 ROILS U.S., KILLS F-35 DEAL

> RAPID DEVELOPMENT OF LOCAL DEFENSE INDUSTRY CONTINUES

Tony Osborne London

Turkey's international standing among its NATO allies took a beating in 2019, and there is little sign of relations improving during 2020.

President Recep Tayyip Erdogan's decision to invade Northern Syria to create a so-called safe zone for Syrian refugees, while also attacking Kurdish groups that allegedly support the Kurdish Workers Party (PKK) militant group, prompted an international outcry, initiated embargoes and sent ripple effects through the alliance. Concerns remain that Turkey's actions may have enabled thousands of Islamic State group prisoners to escape and allowed foreign fighters to find their way home. Some fear that this could create a new terrorist threat, essentially nullifying the six-year campaign to defeat the group, which has seen its caliphate collapse thanks to the efforts Kurdish and Iraqi ground forces as well as those of the international coalition's air and ground campaign.

Although a ceasefire is in place, brokered between Ankara and Moscow, and embargoes have been lifted, consternation remains about Turkey's activities elsewhere.

Ankara remains frustrated at the alliance's reluctance to recognize Kurdish groups such as the YPG and YPD as terrorists. This frustration became public when it emerged that Turkey had blocked defense plans for the Baltic States and Poland, although the issue appears to have been resolved at the recent NATO meeting in London. The country also remains angry at Washington over its unwillingness to hand over the exiled cleric Fetullah Gulen, whom Turkey asserts was behind the failed coup against Erdogan in July 2016.

The delivery of the first battery of the Russian-made S-400 air and missile defense system means Turkey's industrial and military participation in the F-35 Joint Strike Fighter will be terminated. Turkish F-35s that have already been produced will not be delivered. Turkey's industrial participation in the program is expected to end by March 2020 and will be redistributed to other program partners. The U.S. has yet to impose sanctions against Turkey using the Countering America's Adversaries Through Sanctions Act (Caatsa) but has until the end of January 2020 to do so.

In Ankara, ministers are still hopeful they can find some common ground that will enable the country to receive the F-35s, but the U.S. remains insistent that Turkey cannot have both. In October, reports that Turkey would initiate a buy of Sukhoi Su-35 fighters from Russia were revealed to be false by Defense Minister Hulusi Akar, and confusion remains around the circumstances for the S-400's procurement. Ankara is still looking to develop its own air and missile defense system potentially using the Franco-Italian SAMP/T system as a baseline, although little progress has been made on this.

Meanwhile, Turkey appears to have stepped up its activities in the Aegean, antagonizing Greece with incursions into Greek airspace and waters with UAVs and naval vessels and by drilling illegal—according to the European Union—exploratory oil wells off the coastline of Cyprus.

Turkey's push to become a major exporter of arms continues, with a growing presence at international exhibitions and demonstrations of Turkish-made platforms.

Development of a Turkish combat aircraft, the TF-X, appears to be gaining government support as Turkey's involvement in the F-35 slips away. At the Paris Air Show, Turkish Aerospace CEO Temel Kotil said the aircraft could fly in 2025. Ankara has also assigned $1 billion in funding to support the program for the next four years, out to its preliminary design review. Testing continues on the T625 Gokbey twin-engine dual-role helicopter after first flight of a complete prototype in 2020.

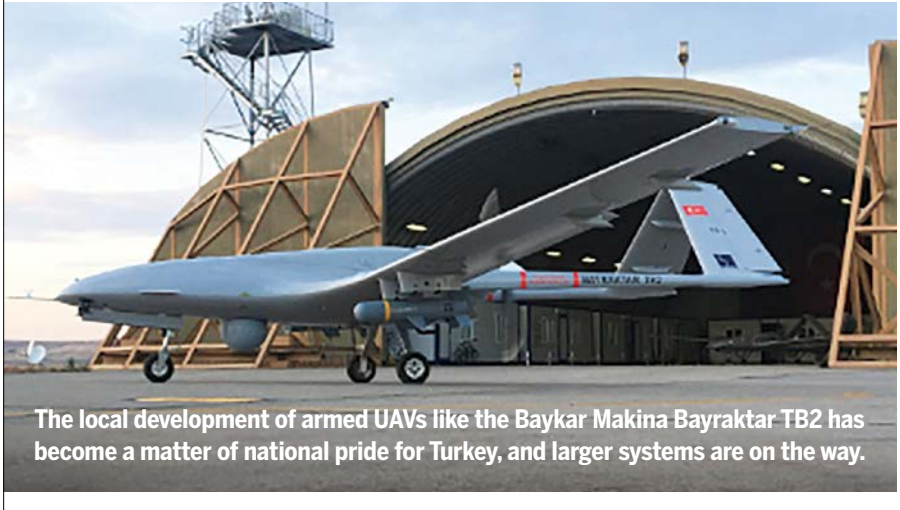
Turkish UAV development continues, with dozens of armed systems now in service with Turkish forces and exported to Qatar and Ukraine. The most recent milestone was the first flight of Baykar Makina's twin-engine medium-altitude, long-endurance 5.5-metric-ton Akinci in early December. Turkish Aerospace's own twin-engine Aksungur development of the Anka flew for the first time in March. Turkey is also investing in a stand-off jammer capability using the Bombardier Global Express and developing upgrade packages for the F-16 Fighting Falcon, including a locally developed active, electronically scanned array radar.

TURKEY

2019 DEFENSE BUDGET
79,356 billion Turkish lira
($13.6 billion)

PERCENT OF GDP
1.89

PERSONNEL UNDER ARMS
Approximately 360,000



BAYKAR MAKINA

The local development of armed UAVs like the Baykar Makina Bayraktar TB2 has become a matter of national pride for Turkey, and larger systems are on the way.

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Ongoing Political Crisis Holds Up Israel's Largest Defense Deals

> ECONOMIC PRESSURES ARE INCREASING ON DEFENSE SPENDING

> LOCAL CAPABILITY FOR OFFENSIVE, DEFENSIVE MISSILES GROWS

Steve Trimble Washington

Major decisions for Israel's defense industry and military acquisition system remain on hold entering the new year as a monthslong political crisis continues to paralyze plans for further consolidation, structural reform and contract signings.

Two inconclusive elections in 2019 set the stage for unprecedented political dysfunction in Israel, with the Knesset dissolved since May and Prime Minister Benjamin Netanyahu—the leader of a caretaker government—clinging to power while indicted on charges of fraud, bribery and breach of public trust. Since no political party was able to claim a Knesset majority by the Dec. 11 deadline, a third round of elections scheduled for March sets the stage for a constitutional crisis—with one of the leading candidates at the center of a criminal prosecution.

The political crisis comes at an inopportune time for a domestic industry and military awaiting critical decisions.

As public listings for both Israel Aerospace Industries (IAI) and Rafael loom, IAI is jockeying to win support for a merger between the state-owned defense companies—albeit with a reluctant Rafael. Meanwhile, the defense ministry is anxious to sign contracts using the 10-year, $38 billion military aid package authorized by the U.S. government in 2018. Acquisitions of fighters, tankers, helicopters and possibly tiltrotors are hanging in the balance.

Political turmoil in Israel does not change the country's strategic environment. The ministry is investing in advanced fighters, standoff weapons, and increasingly sophisticated missile defenses in response to the existential threat posed by Iran and rocket attacks from paramilitary organizations and terrorists in the Gaza Strip.

Internally, domestic economic pressures are growing. In November, the Organization for Economic Cooperation and Development slashed the growth forecast for Israel's gross domestic product (GDP) in 2020 from 3.3% to 2.9%, with potentially lower tax revenues raising pressure on the finance ministry's goal of achieving a budget deficit lower than 3% of GDP.

Meanwhile, plans for defense spending are in flux because of the political uncertainty. In October, Netanyahu, who is also the country's defense minister, called for fixing the budget of the Israel Defense Forces (IDF) at 7% of GDP. It is not clear whether a new Knesset would approve such a proposal.

In the near term, the IDF wants to move forward on several deals that could be a boon for Boeing. Israel has ordered 50 Lockheed Martin F-35As in three batches since 2010, but its air force is considering a deal for a fleet of McDonnell Douglas F-15 Israel Advanced fighters derived from the U.S. Air Force's F-15EX. A possible deal for eight Boeing KC-46A tankers has been discussed for months. Meanwhile, a competition to replace the CH-53D continues between the Sikorsky CH-53K and Boeing CH-47F. If the less expensive CH-47F is selected, Israel also could acquire Bell Boeing V-22 tiltrotors.

As the air force looks to recapitalize, Israel has strengthened its defenses against long-range missile attacks from Iran. In July, the Arrow 3 interceptor was tested successfully against a threat representing the Iranian Shahab-3 medium-range ballistic missile. During the test, conducted in Alaska, the IDF used a U.S. TPY-2 radar to track the target. As the system becomes operational, Israel will rely on the homegrown Oren radar for tracking and a local supply chain to build up a stockpile of missiles to defend against a salvo attack.

A capability for early warning against such attacks is also under development. IAI has been commissioned to deliver a group of optical nanonsatellites that would supplement coverage provided by the Offeq constellation. Israel also continues to improve its capacity for offensive, long-range missile strikes. On Dec. 6, the defense ministry released a cryptic statement saying the country's defense establishment conducted a preplanned test of a rocket propulsion system. Local media sources pointed to the possibility of a test of the Jericho intercontinental ballistic missile, with the Center for Strategic and International Studies noting that plans for a Jericho IIIA ICBM include a new rocket motor.

Israel's defense industry relies on the export market, but new challenges have appeared as China and Russia have stepped up efforts to win arms deals abroad.

ISRAEL

2019 DEFENSE BUDGET
76 billion shekels (proposed)
($21.7 billion)

PERCENT OF GDP
5.8

PERSONNEL UNDER ARMS
178,000 active duty

The Arrow 3 interceptor, tested successfully on July 28, gives Israel a defensive counter to Iran's long-range ballistic missiles.

U.S. MISSILE DEFENSE AGENCY


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Moves by Iran Prompt Defense Equipment Buildup in the Middle East

- ATTACKS BY IRAN SPUR GULF NEIGHBORS TO BOLSTER DEFENSES
- MANY NATIONS IN THE MIDDLE EAST WORK TO ADD CAPABILITIES AND INVEST TO STRENGTHEN LOCAL DEFENSE INDUSTRIAL BASE

The UAE ordered two more Saab GlobalEye airborne sensor platforms at the Dubai Airshow, bringing its planned fleet to five.

SAAB

Tony Osborne London

While military operations are tapering off as the Saudi-led coalition and Houthis seek an end to the bloody five-year conflict in Yemen, Riyadh remains subject to several arms embargoes, notably from Germany and more recently South Africa, over its conduct and the humanitarian crisis that followed.

As fervent allies of Riyadh, both the UK and U.S. have been prevented from making transfers of arms. A court appeal by anti-war campaigners in June prompted the British government to halt the issuing of new export licenses to Saudi Arabia, while in Washington lawmakers questioned ongoing arms transfers to the Saudis, effectively blocking them before the resolutions were vetoed by President Donald Trump.

But as always in the Middle East, as one fire is dowsed, a match is lit elsewhere.

On top of the decision by President Recep Tayyip Erdogan of Turkey to invade Northern Syria, prompting concerns about the specter of new life being breathed into the Islamic State group, the Gulf states are again having to nervously look north. There they see their old foe Iran ratcheting up tensions by seizing oil tankers in the Gulf and then being accused by Riyadh of masterminding an attack on a Saudi oil refinery with drones and cruise missiles, impacting global oil production.

Iran's actions prompted the U.S. to strengthen its presence in the region, deploying to Saudi air bases bombers and fighters, including F-22 Raptors and F-35 Joint Strike Fighters.

Adding to the regional tensions, Saudi Arabia, Egypt, Bahrain and the United Arab Emirates are continuing their blockade of Qatar, having accused Doha of supporting regional terrorism in 2017.

The response in many of these countries has been to strengthen their defense postures as well as invest in their own national defense industrial capabilities. In Saudi Arabia, this task is being taken on by Saudi Arabia Military Industries (SAMI) with requirements driven by the country's General Authority for Military Industries (GAMI). SAMI has acquired much of the kingdom's defense industry, bringing under a management umbrella international joint ventures for shipbuilding, sensor production and aircraft and helicopter assembly.

More advanced is the UAE, where the government recently placed an order for the locally developed—albeit with a Brazilian partner—Calidus B-250 light attack aircraft, to be armed with locally developed small munitions. Qatar is taking a similar approach, creating Barzan Holdings to set up a local defense industry and manage joint ventures with major defense companies.

With many Middle Eastern countries having secured their big budget fighter purchases, they are now either in the process of taking delivery of new combat aircraft or preparing to do so.

Qatar's ambitions remain the most eye-opening, with plans to purchase no fewer than three fleets of fourth-generation fighters, growing its fighter fleet eight-fold from its current 12 Dassault Mirage 2000s. Qatar has already taken delivery of its first Dassault Rafales and begun building a new airbase on the west coast of Qatar to house them. Following closely behind will be Boeing F-15QA Advanced Eagles and Eurofighter Typhoons purchased through the UK government.

In the UAE, Abu Dhabi is intently focused on ordering the Lockheed Martin F-35 but is unlikely to be able to do so until the early 2020s. As a result, it has begun upgrades for both its Dassault Mirage 2000-9 and Lockheed Martin F-16 Block 60 fleets and is making investments in its support fleets, announcing plans to double its Airbus A330 Multi-Role Tanker Transport fleet. It will also increase its fleet of Saab GlobalEye Swing-Role Surveillance System aircraft (based on the Bombardier Global 6000 business jet) from three to five. First deliveries of the airborne early warning platform are planned for Spring 2020.

Kuwait is also gearing up for the delivery of its first Eurofighter Typhoons in late 2020. The Kuwaiti examples will be the first Eurofighters equipped with the Captor-E active, electronically scanned array radar. These will be joined in short order by Boeing F/A-18 Super Hornets equipped with conformal fuel tanks.

Along with ongoing deliveries of Boeing F-15SA and refurbished F-15SRs, Saudi Arabia is also taking delivery of locally assembled BAE Systems Hawk jet trainers and gearing up for enhancements to its naval aviation capabilities with the purchase of Sikorsky MH-60R anti-submarine warfare helicopters. Ongoing deliveries of Russian-supplied MiG-29M2 "Fulcrums" to Egypt and reported planned purchase of the Sukhoi Su-35 "Flankers" are causing consternation in the U.S. and could trigger sanctions against Cairo.

H-20 Should Be Close as Avic Hints at Next Fighter

> PENTAGON SUGGESTS JH-XX IS NOT FAR BEHIND LONG-RANGE BOMBER

> THE H-6 HAS A HIGHLY SUPERSONIC AIR-TO-SURFACE MISSILE

Bradley Perrett Beijing

If there was a disappointment for observers of Chinese military technology in 2019, it was the non-appearance of the Avic Xian H-20. Official statements in 2018 gave good reason to think China would show the long-range bomber in 2019—but it did not. Yet that probably makes revelation of the critical new weapon even more likely in 2020.

The JH-XX strike aircraft, probably a high-performance medium bomber, may not be far behind the H-20. But immediate new Chinese fighter developments should be limited to current production types such as the Avic Chengdu J-20, while the J-31 from Avic Shenyang, first shown as a technology demonstrator in 2012, is made ready for service. Work has begun on the next Chinese fighter, which an industry official says, probably conservatively, will appear no later than 2035.

China first acknowledged a long-range bomber program in 2016 and referred to the new type as the H-20 in August 2018. Such an announcement normally would precede unavoidable public observation of a prototype. Two months later a military expert, no doubt authorized and well-informed, told state media flight-testing would begin soon. All that prompted expectations for the H-20 appearance in 2019 but that did not happen.

Why the H-20 is still hidden must be a matter for speculation. Conceivably, it could have been flown secretly. But since the Avic installation presumed to be handling the project is the one at Xian, which also has nationally important but publicly visible test-flight facilities, the aircraft easily would have been observed if it had flown.

Anther possibility is that development hit some unexpected difficulty in the second half of 2018, perhaps in propulsion. China has struggled to develop satisfactory aero engines.

The H-20 is expected to have an all-wing or blended-wing-body configuration. Its stealthy design will help it pass undetected between widely spaced naval radars on islands and ships in the Pacific, providing a leap in capability from the current Chinese bomber, the easily detected Avic Xian H-6. It should also fly farther.

In January 2019, the Pentagon estimated 2025 as the earliest likely operational point for both the H-20 and a type variously called a medium-range bomber, a tactical bomber and a fighter-bomber; this is the aircraft that has also been reported as the JH-XX. By referring to the timing of this aircraft and the H-20 together, the Pentagon implied their development schedules might not be far apart. If so, the JH-XX also should appear in the next few years.

Several factors taken together suggest the JH-XX will be conceptually similar to but larger than the U.S. F-111 of the 1960s: the thrust of likely engines, the "JH" and "fighter-bomber" categories and the Pentagon's mention that the type will carry air-to-air missiles and have medium range.

Both new bomber types will contribute to the strategy of warding off support for U.S. friends and allies that China could conceivably attack, most notably Taiwan. Joining anti-ship ballistic missiles in the role, the H-6 has been the initial bomber element in the strategy. Subsonic and hardly survivable, it must be kept well clear of fighters and surface-to-air systems as it flies to a position for launching cruise missiles—but its weapons are increasingly threatening.

The latest is the DF-100, which was purportedly paraded in canisters in China's Oct. 1 National Day parade and revealed in the flesh in a grainy video posted by China's rocket force a few days before. An official magazine, *Naval & Merchant Ships*, also described it. (The weapon's name is sometimes given as CJ-100.)

A new bomber version, the H-6N, appeared at the same time as the missile, with a belly recess that Hong Kong's *South China Morning Post* said was intended for carrying the DF-100 or a supersonic rocket reconnaissance drone called DF-8 or WZ-8. In the video, the DF-100 appeared to be designed for highly supersonic flight; according to *Naval & Merchant Ships,* it cruises at Mach 4 and can sprint at Mach 4.5.

Unevenness of the taper at the nose suggests the DF-100 has an inlet there like that of the Boeing HyFly hypersonic missile demonstrator tested a decade ago. The HyFly inlet fed a ramjet that pushed the missile to scramjet takeover speeds in the range of Mach 3.5–4.0. Toward the rear of the DF-100 main body (that is, ahead of the booster) are shapes that could be auxiliary ramjets. Conceivably, their role would be to accelerate the weapon between

CHINA

2018 DEFENSE BUDGET
1.654 trillion yuan
($236.8 billion)

PERCENT OF GDP
1.9

PERSONNEL UNDER ARMS
2 million

CASIC

Avic is keen to exploit the size of the J-20 for multiple roles.

booster burnout speed and a velocity at which the main, cruise ramjet, fed by the nose inlet, could take over.

Such externally mounted ramjet engines are increasingly common. In such a configuration, the first stage would be an indispensable part of the weapon however it was deployed, in contrast to missiles that have rocket boosters for launch from the surface but not from aircraft.

The proportions of the launcher vehicles and missile canisters in the parade suggested a large size. Whereas four-axle launch trucks each carry three DF-10 subsonic cruise missiles, which are larger than Raytheon Tomahawks, the DF-100 trucks each have five axles and only two missile canisters. The implication is that two DF-100s weigh more than three DF-10s.

Almost relentless developments in Chinese bomber aviation suggest to Australian analyst Malcolm Davis of the Australian Strategic Policy Institute that this is an area where more news can be confidently expected in 2020. The H-20, however, is the only new aircraft type of any category that is likely to appear in 2020, adds Davis.

In the years after the J-20 first appeared in 2011, its primary intended role generally was seen as air-to-air combat and especially penetrating an enemy fighter barrier to destroy vulnerable but indispensable support systems, such as tankers and surveillance aircraft. But Avic is keen to exploit the type's large size for other functions, an industry source says.

Avic's brochure for the J-20 indicates that multirole potential: It calls the type a heavy, stealthy fifth-generation fighter renowned for dominance in medium- and long-range air combat and excellent capability in ground and marine precision strike. "Major operational missions include seizing and maintaining air superiority, medium- and long-range fast interception, escort and deep strike," Avic says.

The DF-100 is designed for highly supersonic flight.

CHINESE ROCKET FORCE

After the Chengdu works beat Avic Shenyang for this program, the latter created the J-31 technology demonstrator, which at first was not wanted by the military. It is now being developed for naval and air force service. Prototypes of the operational version have not appeared but should not be far away.

Then there is the question of the fighter that comes next. This was mentioned by Avic Chief Technical Expert Wang Haifeng in an interview that China's *Aeronautical Manufacturing Technology* magazine published online in early 2019.

"We have chosen technology development directions according to a war [concept] we have designed," Wang told the magazine in reference to fighter design, but without setting out the specific research. "Considering the characteristics and maturity of those technological directions, we have adopted various organizational models for pre-research and research. I believe that no later than 2035 our current efforts will turn into a weapon for protecting the seas and skies."

The J-20 was declared operational in 2017, so passing the same milestone for the next fighter in 2035 would imply an 18-year interval between types. It is most unlikely that China, striving to catch up with the U.S., is intending to wait so long. Indeed, Wang repeatedly stresses in the interview that programs must progress faster. "The new situation requires us to significantly shorten type-development cycles, reduce research and development costs and still provide capabilities that can compete with those of strong enemies," he says in one such reference. He does not say what that "new situation" is, but pressure from the armed forces for quicker results would not be a bad guess.

As to the method of development, Wang says Chinese engineers must pay attention to what is going on elsewhere. "While achieving independent capacity for research, we must understand the direction of foreign development, he says. "Core technology cannot be bought but, in certain areas, ideas can be borrowed." But, while absorbing foreign ideas, China needs to innovate: "This will promote the modernity of products and shorten technology research cycles," he notes.

And technological missteps are hard to avoid, he adds, signaling a willingness to take developmental risks. Wang is based at a research institute at Chengdu.

Funds for these and other programs are coming from a defense budget that is growing much more slowly than in the last decade—for example, 17.8% in 2007, before adjustment for inflation. The official budget and unofficial estimates of total defense pending tend to track economic growth, so Chinese military spending slows with GDP, more or less. The total allocation is generally close to 1.9% of GDP, according to annual estimates by the Stockholm International Peace Research Institute (SIPRI).

China's GDP in 2019 will be up by 6.1% on 2018, according to the Economist Intelligence Unit. The official budget for 2020 can be expected to rise by roughly that much plus an allowance for inflation and will be announced in the first quarter of the year. It will not include all military spending, however.

Spending on developing and producing equipment has been given a rising share of the budget: 41.3% in 2016, up from 33.2% in 2010. The figure dropped a little in 2017, so China may have finished that rebalancing.

YAN SIMING/INTERNATIONAL AVIATION

Launchers for DF-100s took part in China's Oct. 1, 2019, National Day parade. The missile can also be carried by the H-6N.

Japan Funds Future Fighter Concept Design

> THE FUTURE FIGHTER DEVELOPMENT IS IN THE BUDGET

> BUT THE WORK DOES NOT LOOK LIKE PROGRAM LAUNCH

Asia-Pacific Staff

Japan will proceed with concept design of its Future Fighter in the coming fiscal year following finance ministry agreement to spend ¥11.1 billion ($110 million) on the work. The funding is part of a defense budget that will be 1.2% higher than for fiscal 2019.

The amount of spending on the Future Fighter suggests a greater effort than was put into concept designs earlier in this decade. The aircraft is intended to enter service in the 2030s and replace the Mitsubishi Heavy Industries (MHI) F-2.

Creating a concept design, however well-funded, does not normally count as the launch of a program, which is what the defense ministry has called for in the fiscal year beginning April 1, 2020. Nonetheless, Defense Minister Kono Taro stressed that fiscal 2020 would be the first year in which development of the Future Fighter would be specifically funded.

Japan is considering some level of partnership with British and U.S. companies for the Future Fighter. Candidates are BAE Systems, Lockheed Martin, Northrop Grumman and probably Boeing. BAE's offer involves participation in the British Tempest fighter program, not necessarily using the same airframe.

Kono Taro and Finance Minister Aso Taro agreed to the ¥11.1 billion allocation in a meeting on Dec. 17. In August, the defense ministry inserted a line in its budget request for "launch" of the Future Fighter program but included no suggested funding level. It wanted a program office established.

The money that the finance ministry has agreed to allocate will be added to ¥17.7 billion already in the defense ministry's budget request for research on integrating missiles, sensors, artificial intelligence and a drone that would accompany the Future Fighter. Another ¥1.9 billion is for research on formation flying, remote control and the human-machine interface for the drone.

"Because the finance minister agreed to the budget, concept design will start next year," Kono Taro said, suggesting a name change for the program. "It has been called the Future Fighter until now, but since we are going to start development I want to call it the Next-Generation Fighter from now on." Parliament has not yet approved the budget, but the ruling Liberal Democratic Party controls the legislature.

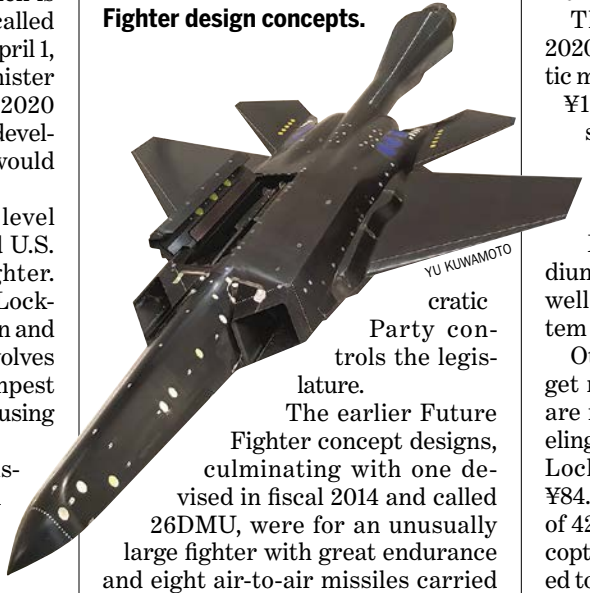
JAPAN

2020 DEFENSE BUDGET
¥5.32 trillion
($49.0 billion)

PERCENT OF GDP
0.97

PERSONNEL UNDER ARMS
247,154

This wind-tunnel model depicts the underside of one of several Future Fighter design concepts.



YU KUWAMOTO

The earlier Future Fighter concept designs, culminating with one devised in fiscal 2014 and called 26DMU, were for an unusually large fighter with great endurance and eight air-to-air missiles carried internally, including six of long range. MHI is a likely prime contractor.

The rise in the overall fiscal 2020 defense budget will be the eighth in succession, following the accession of Prime Minister Shinzo Abe in 2012. The budget may end up close to ¥6 trillion if a supplementary budget to cover increased annual payments to the U.S. is added to it later. In November 2019, President Donald Trump asked Japan to quadruple annual payments for U.S. forces stationed there to around $8 billion. No agreement has been reached between the two governments.

The Joint New Air-to-Air Missile (JNAAM), an effort of Japan and Britain to put a Japanese seeker with an active, electronically scanned array on an MBDA Meteor ramjet missile, will enter its third year of development in 2020. The first test shot is planned for 2023.

On the other hand, the finance ministry is demanding private companies such as MHI (airframe) and IHI (engine) invest their own money in the Future Fighter to ensure contractors are fully incentivized to prevent failure. Also, the finance ministry is trying to reduce the profit margin of contractors, arguing that the current method of pricing by multiplying an agreed profit margin to manufacturing costs makes contractors profit from increased costs.

The most expensive item in the 2020 defense budget request is ballistic missile defense. The ministry seeks ¥116.3 billion for vertical launch systems for missiles on ships and at two Aegis Ashore sites. The money also is intended to pay for SM-3 Block IIA and PAC-3 MSE and upgraded Type 3 medium-range surface-to-air missiles as well as a command-and-control system upgrade.

Other major items in the 2020 budget request and their total amounts are four Boeing KC-46A aerial-refueling tankers for ¥112.1 billion and six Lockheed Martin F-35B fighters at ¥84.6 billion. Japan plans to buy a total of 42 F-35Bs for two Izumo-class helicopter carriers, which will be converted to light aircraft carriers. ¥3.1 billion is being sought to convert the Izumo.

The 2020 budget also includes three Lockheed Martin F-35A conventional-takeoff fighters for a total of ¥31.0 billion. Other aircraft to be procured are three Kawasaki P-1 maritime patrollers for ¥63.7 billion, seven Mitsubishi SH-60K naval shipborne helicopters for ¥50.6 billion, eight Mitsubishi UH-60J air force search-and--rescue helicopters at ¥39.0 billion and three Kawasaki CH-47JA army transport helicopters for ¥23.7 billion.

KF-X Funding Surges In South Korea's 2020 Budget

> PARLIAMENT FULLY APPROVES REQUESTED BUDGET LEVEL

> FIGHTER PROGRAM IS RISING TOWARD PEAK DEVELOPMENT SPENDING

Kim Minseok Seoul and **Bradley Perrett** Beijing

Funding for the Korea Aerospace Industries (KAI) KF-X fighter program will surge in 2020 as part of a 7.4% rise in the South Korean defense budget. The parliament has fully approved the defense ministry's request for the coming year.

The budget provides 1.40 trillion won ($1.19 billion) for KF-X development and 1.79 trillion won for the acquisition of Lockheed Martin F-35 Lightnings in 2020. There were few cuts from the defense ministry's request, and the released funds were reallocated to preserve the total.

SOUTH KOREA

2020 DEFENSE BUDGET
51.15 trillion won ($44 billion)

PERCENT OF GDP
2.6

PERSONNEL UNDER ARMS
580,000

BRADLEY PERRETT/AW&ST

KAI presented this KF-X mockup at an air show in Seoul in 2019.

Authorized spending totals 50.15 trillion won. The 7.4% rise comes well ahead of likely growth in nominal GDP, so military spending should increase as a fraction of the economy.

The KF-X allocation is more than double the 664 billion won budgeted for the fighter program in 2019. The dramatically higher funding will be spent in the fifth year of the development program for the twin-engine aircraft.

KAI began building the first KF-X prototype in 2019; that aircraft is due to be rolled out in June 2021 and to fly in May 2022. It is one of four single-seat prototypes that KAI will build, an industry source says, adding that there also will be two twin-seaters.

Powered by General Electric F414-GE-400K engines, the KF-X is due for first delivery in late 2026 following completion of flight testing in the middle of that year. Accordingly, the program is due to last 11 years. Because it was launched with a budget of 8.82 trillion won, the average should be 800 billion won a year. That includes an average of about 160 billion won a year from development partner Indonesia.

The high 2020 budget is consistent with the common pattern in which an aircraft's development costs rise to a peak just before the beginning of flight testing, as the program employs its full complement of engineers and builds prototypes. A shortfall in Indonesian funding also could be a factor in the surge of money flowing from South Korean taxpayers.

"Indonesia has requested a reduction in its development costs and an increase in the technology transferred to it," Wang Chunghong, director of the ministry's Defense Acquisition Program Administration (DAPA), told the parliament's national defense commission on Dec. 4. There has been no indication since then that an agreement has been reached.

Indonesia did not contribute to KF-X development from early 2017 until January 2019, when KAI said the Southeast Asian country made a contribution of 132 billion won. Whether Indonesia has paid since then is unclear. In July, the *Chosun Ilbo* newspaper said Indonesia had contributed a total of 220 billion won so far of the 520 billion won it had been due to pay.

South Korea intends to buy 120 KF-Xs to replace Lockheed Martin F-16s. Indonesia has a reported requirement for 50 aircraft.

KAI contracted with MBDA in November to integrate the Meteor long-range air-to-air missile on the KF-X. This followed a 2017 statement by the ministry that the fighter would use the Meteor and the Diehl IRIS-T short-range weapon. The ministry intends to use U.S. missiles in the future.

Elsewhere in the budget, a request for 364 billion won to buy training helicopters under the TH-X program was wholly rejected. But sources say DAPA, the ministry's purchasing office, was not in a position to proceed with the acquisition next year. Proposed spending of 17.4 billion won on air combat-maneuvering instrumentation pods was halved for unknown reasons.

The F-35 funding (1.79 trillion won) will pay for deliveries of aircraft to follow the 13 F-35s reportedly received in 2018 and 2019. South Korea is due to take delivery of 27 more aircraft by the end of 2021, completing its current planned acquisition of 40 under program F-X 3.

That acquisition was originally supposed to include 60 fighters, so the air force wants the defense ministry to buy 20 more F-35As in what would become F-X 4—but that procurement probably would not occur before the middle of the 2020s. The navy is pushing for some of those aircraft to be F-35Bs for operation from a future aircraft carrier or flattop assault ship. If naval operation is not needed, the Boeing F-15 also may be a candidate for F-X 4. Before then, the current force of 40 F-15Ks should enter an upgrade program.

In 2020, the air force is likely to be continuing to integrate the operations of its four new Airbus A330 MRTT tankers.

FAST FIVE WITH HONEYWELL

MIKE STEWART

Vice President Advanced Technologies
Honeywell Aerospace

Mike Stewart, previously a corporate fellow within Honeywell Aerospace, today leads the organization's Advanced Technology organization across general aviation, commercial, defense and space.

What is the mission of Honeywell Aerospace Advanced Technology?

A. Technology initiatives below technology readiness level 6 are under the purview of the Advanced Technology organization, from atomic clocks to propulsion engines to vapor cycle systems to avionics. We work to tie these together for our commercial customers, but also DARPA and to support the U.S. Air Force Research Lab, the Navy, Army and the space markets. The differentiator for us is our breadth—we fully understand every type of part on an aircraft, and even how they can be used in other vehicles. We have been a part of every manned space mission. We have 110 Fellows—subject matter experts who have created the industry standards for key technologies used throughout aerospace and defense.

What do you see as the biggest challenges as the industry moves forward?

A. Technology is moving at such a lightening pace. The urban air mobility challenge has forced things to happen at a speed that simply would not have happened otherwise. It is pushing all markets forward, from electrification of the aircraft to automation. Our job is to take the very complex possibilities and simplify them so that they are usable and can affect the customer's desired outcome. At the same time, we have to be able to certify the use of technologies such as machine learning and artificial intelligence. We have to be able to prove that out, and Honeywell is working to make that possible. Most important, we have to simplify the interface so that the technologies can be used to improve safety and efficiency of flight.

Artificial intelligence is at the forefront of so much technology development—how is this affecting Honeywell?

A. We are applying AI and autonomy in a progressive way, beginning with low-criticality applications of AI and machine learning, to prove it out. Longer term, we are looking at AI as an enabler to help identify conditions and address situations that have not been anticipated by a pilot or user, and then offering recommendations on how to deal with a situation. AI and machine learning are a big help in integrating this broader picture across all levels of aviation that we serve, particularly as things become more connected and more integrated. In the end, AI is a tool, and we want to be able to qualify it to a higher standard of safety.

You also mentioned autonomy as a major factor in aerospace. What is Honeywell's focus in this area?

A. Autonomy and urban air mobility play together. UAM is a small segment but represents signifi cant change—a different kind of pilot whose training may not be as in-depth, who may be backed up on the ground. We want to be able to put that backup in place when it's needed, regardless of how many pilots are in the cockpit. We also know that wind tunnels and other situations will affect air vehicles traveling among buildings. Sensors, weight, the ability to cool electronics on the vehicle—all these technologies are evolving quickly and we're well positioned to work with UAM OEMs from technology to certification. We are also working on solutions for helping pilots on long flights, to allow a single pilot in the flightdeck for longer periods of time.

What are the strengths of the Honeywell Aerospace Advanced Technology organization today?

A. Our investment in technology is as high as I've seen in my quarter century with Honeywell. The pace is so much faster, and we have to keep up with that pace. We look across the world for where that investment should be made. We are invested here in the U.S. but also the broader global environment, whether that means bringing technologies to bear on small satellite development or addressing CleanSky initiatives in Europe. This is our tradition—we were the first to develop a digital map, the first flight management system, the first auto pilot. We intend to play a similarly broad role in this new and much accelerated technology environment.

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From Bogota to the Beagle Strait, South American Countries Look Inward

> EMBRAER R-99M, AV-TM 300 MISSILE AND KC-390s SET FOR DELIVERY

> COLOMBIA AND CHILE TEAM UP ON T-35 REPLACEMENT

BRAZIL AIR FORCE

Steve Trimble

South America's appetite for financing development of military aircraft and missiles continues on a steady growth trajectory, with several key milestones scheduled to occur in 2020.

On a continent that has seen only scattered and brief armed conflicts between nations on the mainland for more than a century, military expenditures tend to be focused on defeating internal threats to law and order such as criminal gangs and drug smugglers, and acquisition programs usually rely on the expertise of aerospace and defense industries from the U.S. to Israel to China.

But homegrown technologies are becoming more popular throughout the continent, as national industries are set in 2020 to deliver upgraded surveillance aircraft, new airlifters, cruise missiles and advanced jet trainers, as well as to partner with foreign companies to design and assemble fighters and medium-altitude, long-endurance (MALE) unmanned aircraft systems (UAS).

The first new capability scheduled to enter the South American fleet in 2020 is the R-99M, an upgraded version of the Embraer ERJ-145 jet equipped with a Saab Erieye radar for the Brazilian Air Force. The R-99M is the latest example of Brazil's reemergence over the last decade as a global military aerospace export power, a status it last held in the mid-1980s. It joins a delivery stream to the air force next year that includes more KC-390 Millennium airlifters and the Avibras AV-TM 300 ground- and air-launched cruise missile. Meanwhile, Brazilian machinists are preparing to open a final assembly line near Sao Paulo for Brazil's version of the Saab F-39 Gripen, which entered flight testing in 2019.

Brazil's sophistication and industrial depth for aerospace technology remains the outlier in South America, but other countries are taking steps in that direction.

Colombia, in particular, is relying on military-funded projects to develop an aircraft design and assembly capability within an industry sustained mainly by maintenance, repair and overhaul work. Bogota-based CIAC is set in 2020 to enter a codevelopment phase with Airbus on the Atlante 2, a 750-kg (1,650-lb.) surveillance version of the MALE UAS initially funded by the Spanish government. A prototype of the Atlante 2 could enter flight testing in 2020 or 2021, preceding a planned eight-year production program in Colombia.

The Atlante 2 project builds on CIAC's capabilities using a steady, step-by-step approach. CIAC previously developed the hand-launched Equites UAS and the 75-kg Quimbaya tactical UAS. More recently, the company received a military airworthiness certificate for the T-90 Calima, a piston-engine-powered basic trainer designed by composite-material specialist Lancair and assembled by CIAC for the Colombian Air Force.

That experience with the T-90 Calima encouraged Chile's state-owned aerospace company ENAER to seek a partnership with Colombia's burgeoning aerospace industry. In July, ENAER and CIAC signed an agreement to collaborate on future projects. In the 1980s, ENAER delivered the Piper-designed T-35 Pillan trainer aircraft, and the Chilean Air Force now wants a replacement. The collaboration with CIAC could allow ENAER access to the Colombian company's recent experience on the composite T-90.

The scheduled delivery of the first R-99M in early 2020 kicks off several efforts to deliver homegrown capabilities to air forces throughout South America.

The T-35's successor would not be the first attempt to develop a multinational basic trainer on the continent. A decade ago, the Union of South American Nations (Unasur) launched the IA-73 project at the Latin American Aerospace and Defense exhibition in Rio de Janeiro. The intent was to develop a joint successor for the T-35 and Embraer E-312 Tucano trainers, but the project was canceled as support for the Unasur organization itself evaporated.

Argentina's FADEA attempted to revive the concept as a national program. The composite IA-100 demonstrator achieved first flight in August 2017. A successful demonstration phase was supposed to be followed by series production of the IA-74 aircraft, but the project disappeared from FADEA's books within months of the IA-100 first flight.

Instead, FADEA has focused its limited resources on a revived production line of the IA-63 Pampa. The third generation of the jet-powered lead-in trainer entered development in 2013, achieved first flight in 2016 and completed first delivery to the Argentine Air Force in February 2019. In July, it appeared that FADEA had scored a breakthrough on the export market, with the announcement by the government of Guatemala of a signed contact for two IA-63 Pampa 3 aircraft. But the contract was subsequently canceled after questions were raised about the transparency of the process.

After Kashmir Spat, Indian Defense Budget Lags Security Needs

> BUDGETS SQUEEZED BY PERSONNEL PRESSURE AND CURRENCY RATES

> DEFENSE ACQUISITION COUNCIL REDUCES PLANNED P-8 PURCHASE

Saurabh Joshi New Delhi

India faced major security challenges in 2019, after a terrorist attack on a police convoy in Jammu and Kashmir in February killed 40 personnel, leading to Indian airstrikes in Pakistan-occupied Kashmir and an air defense battle in which an Indian MiG-21 crashed (*AW&ST* March 11-24, p. 9).

In August, the change in constitutional status of the state of Jammu and Kashmir, and its bifurcation for direct rule from New Delhi, has kept tensions with Pakistan simmering.

But the $61 billion military budget announced in July did not increase as a result of these ongoing tensions. India's defense accounts continue to face pressure from within and without. The military continues to struggle with the perennial problem of buying defense equipment and even may reduce planned purchases of key equipment.

One internal pressure is the burden of paying salaries to 1.8 million civilian and military personnel and pensions for 3.1 million retirees, 60% of India's total defense budget this year. The budget is squeezed from the outside as well. Although the defense budget accounts for 15.5% of all government spending, it is only 2% of projected GDP. That is because tax collection is low in proportion to the value of economic activity in India.

And although modernization accounts are up nearly 10% across the board, according to the Institute for Defense Studies and Analyses (IDSA) in New Delhi, those increases are struggling to keep pace with inflation and global exchange rates. In 2018, the annual average exchange rate for $1 was 68.383 Indian rupees; in late 2019, $1 is worth 70.361 rupees.

Will next year be better? Not likely.

"There will be some growth—maybe 7% or 8%," says Laxman Kumar Behera at the IDSA. "The important thing is money for capital expenditure, but the economy is simply not generating enough resources."

Signs of an economic slowdown began surfacing in the second quarter of 2019, and GDP growth slowed to its lowest rate in six years in the third quarter. With consumption crashing and tax collections falling short, the budget is already tightening, and the difficulties are affecting military procurement programs.

The Defense Acquisition Council truncated a naval order for Boeing P-8I Long-Range Maritime Reconnaissance aircraft from 10 to six. And the army slashed its order for sniper rifles. The three services have requested an urgent infusion of more than $450 million to pay for critical requirements.

"There should still be enough of a budget to pay for committed liabilities like the [Dassault] Rafale and [Almaz] S-400 orders," says Behera. "But anything more would be overoptimistic. It looks like it will take one or two years for things to turn around and start climbing again."

INDIA

2019 DEFENSE BUDGET
4.3 trillion rupees ($61 billion)

PERCENT OF GDP
2.04

PERSONNEL UNDER ARMS
1.4 million active duty

It is just as well that none of the larger acquisition programs for fighters, helicopters and submarines are anywhere close to fruition. At this point, maintaining current levels of spending alone might be a real accomplishment.

"There are no large acquisition programs that are close to completion of their process right now, so there's no question of having to find a budget for them anyway," says Behera. "The only other way would be to try and find additional resources in case a critical requirement emerges—maybe additional taxes."

Some force accretion is expected in 2020 and 2021. The first four Rafale fighters are anticipated to arrive in India by May 2020, with the order for 36 to be completed in fiscal 2021-22.

India is also looking forward to delivery of the first of five S-400 squadrons from Russia. Though it anticipates delivery by October 2020, with the order expected to be completed by April 2023, Russian industry officials have said the delivery will begin in September 2021 and wrap up by the first half of 2025.

India plans to float tenders for 110 air force fighter aircraft as well as six new conventional submarines, expected to be sent out next year. An invitation to vendors to submit their "expression of interest" to supply 111 Naval utility helicopters was issued in 2019, but progress is only expected next year. All three tenders will follow a new "Strategic Partnership" process, which requires an Indian partner company to be the prime and has added a layer of complexity.

India had planned to buy 10 P-8 Long-Range Maritime Reconnaissance aircraft but has cut back to six.

BOEING

Russia Threat Prompts Airpower Uplift in Scandinavia

> COUNTRIES LOOK TO AIRCRAFT FLEET UPDATES

> REGIONAL JOINT PROCUREMENTS ARE CONSIDERED

Tony Osborne London

The defense capabilities of the Nordic nations look likely to be boosted in the 2020s as governments in the region react to the threat posed by Russia.

During 2019, both the Norwegian and Swedish military commanders handed their governments reports outlining the need to strengthen their national defenses and bolster personnel numbers, materiel and supplies.

MARCUS WANDT/SAAB

Saab flew the first production JAS 39E for the Swedish Air Force in December, but the first front-line unit will not form for another three years.

In both cases, the plans call for a strengthening of air defenses and support for aircraft fleets. In Sweden, where defense spending will be expanded by 5 billion krona ($500 million) a year starting in 2022, through a banking tax, part of the increase is planned to allow the air force to grow its front-line fighter force by keeping part of the Saab JAS 39C/D fleet alongside the JAS 39E Gripens that were intended to replace it. This will grow the Swedish fighter force to around 120 aircraft, up from the current 100 Gripen C/Ds.

In Norway, where delivery of 52 Lockheed Martin F-35 Joint Strike Fighters is underway, proposals call for the procurement of a long-range air defense capability able to deal with short-range ballistic missiles, additional maritime and land-based tactical helicopters, Boeing P-8 Poseidon maritime patrol aircraft and Lockheed C-130J Hercules airlifters.

Both nations accept that the biggest challenge will be recruiting and retaining personnel to crew, support and protect these additional capabilities.

Russia today can "act fast and without warning," Norway's chief of defense, Adm. Haakon Bruun-Hanssen, said in October, noting that his country's forces in particular need to be able to react much more quickly to aggression, at least until NATO reinforcements arrive. Proposals to increase the military capabilities of both countries are set to be discussed in their parliaments during 2020.

Despite being largely unaligned to NATO, in the case of Finland and Sweden, or with the EU, in the case of Norway, the Scandinavian countries are becoming increasingly aligned defensively through pacts such as Nordefco, under which Denmark, Finland, Iceland, Norway and Sweden are moving toward joint procurements.

The first steps are relatively minor, with testing underway of a common-standard Nordic uniform—only differing in national camouflage—but the nations already have agreed to work together on military exercises, basing and cooperation on operations overseas. The countries also are taking steps to boost cooperation on air surveillance to produce a common Nordic air picture, to work on counter-UAS technologies and cyberdefenses and to develop anti-access area-denial systems for ground troops.

Most Nordic nations have settled on a choice of future combat aircraft. Norway declared an initial operating capacity (IOC) with the F-35A in early November and is planning to perform a NATO air-policing mission to Iceland during 2020.

Denmark's procurement of the F-35A is behind schedule. Copenhagen is buying 27 of the aircraft, although only 22 will be based in-country, with first deliveries expected in 2022 and an IOC expected in 2024.

Sweden took delivery of the first production JAS 39E Gripen in December, although the type is a long way from operational service, with the first front-line unit not expected to form until 2023. Stockholm already is thinking toward the 2040s and beyond, having signed with Saab, its national aerospace champion, to look at supporting the UK's Tempest future combat air system development. Under agreements signed in the summer, the UK and Sweden will lead joint studies that will firm up mutual requirements and establish an outline for the industrial base by the end of 2020.

Only Finland has not decided on a future combat aircraft, but a contest is well in hand and expected to pit the West's most potent combat aircraft against the Finnish winter climate beginning in January with the Eurofighter Typhoon.

Helsinki wants 64 fighters to replace its F/A-18 Hornet fleet, but a government decision to cap the contest budget at €10 billion ($10.9 billion) could mean fewer aircraft are procured. Finland wants the platform to be operational into the 2060s and will judge the bids on aircraft military capability, security of supply, industrial cooperation, procurement and life-cycle costs, and security and defense policy implications. A request for the best and final offer will be sent in 2020, and a selection is expected in 2021.

In the meantime, two of the Baltic states also are modernizing their armed forces, with Latvia and Lithuania purchasing Sikorsky UH-60M Black Hawks. The latter is also buying two batteries of the Kongsberg Norwegian Advanced Surface-to-Air Missile System, deliveries of which are set for 2021.

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ACES HIGH

- FIGHTER MARKET SET FOR 41.5% GROWTH
- BOEING'S MARKET SHARE RISES AS F-35 GROWTH SLOWS
- FUTURE FIGHTER CONCEPTS HIT DEFINITION STAGE

As Kuwait readies to receive the first Eurofighter Typhoon equipped with AESA radar, Airbus is proposing to expand the type's capability with a full airborne electronic attack suite.

EUROFIGHTER

Steve Trimble Washington

The world's fighter market will thrive in 2020. A long-repressed call to replace aging fighter fleets around the globe is finally gaining momentum, as overall defense spending levels continue to rise. A sharp growth spurt in fighter output in 2020 will revive decades-old production models that not long ago either seemed to be winding down or dormant, and will fuel investments in new long-range weapons, offensive electronic warfare, seamless connectivity, improved sensors and other new capabilities.

The world's fighter community also will seek to clarify and define a new generation of tactical combat aircraft systems after 2030. As these programs come into sharper focus, the pressure will grow on industry, particularly in the U.S. and UK, to break from the traditional business model. As military officials become impatient with development schedules measured in decades, support is growing for acquisition policies that foster greater levels of competition by transferring ownership of the underlying technology to the government and away from the original equipment manufacturers.

Alternative approaches to air-combat technology also will be tested. An experimental combination of artificial-intelligence-enabled computing and resilient aerial networks will attempt to create new manned-unmanned teams of fixed-wing combat aircraft, as well as seek to improve the flight performance of even the U.S. Air Force's most advanced fleets, including the developmental Northrop Grumman B-21 bomber. At the same time, militaries will adopt more cost-effective ways to achieve airpower, with attritable unmanned systems gaining favor and the acquisition of a manned, light attack aircraft in the U.S. set for perhaps a final debate.

For the first time in nearly three decades, it is a good time to be in the fighter business. The market for new deliveries shrank dramatically after the Cold War and never regained momentum as production ramp-ups were prolonged and in some cases strangled. The tide has turned since 2017 especially as the market's most dominant player, the Lockheed Martin F-35, finally began a steep climb to full-rate production in 2023.

U.S. and European manufacturers are set for an unusually steep, two-year growth spurt. The Aviation Week Intelligence Network's Military Fleet Discovery database forecast 212 fighter deliveries in 2020, but that is only the beginning. The fighter industry outside Russia and China is estimated to deliver 300 aircraft in 2021, a 41.5%, one-year jump.

More impressively, the growth spurt in 2021 is expected even as the growth rate for the F-35 program begins to

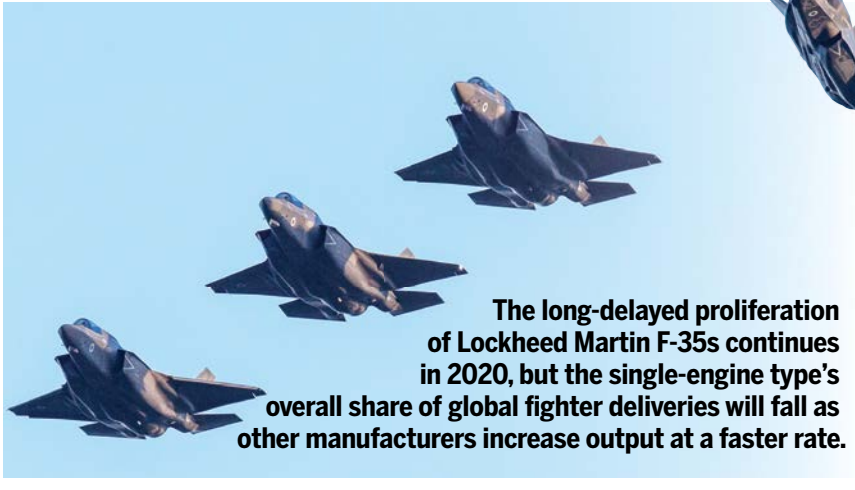
slow down, with the single-engine fighter family's share of the Western fighter market falling to 57% in 2021 from 65% in 2020. The slack will be picked up mainly by another U.S. company. Boeing's share of the overall fighter market will rise to 19% in 2021 from 12% in 2020, as the U.S. Air Force revives F-15EX deliveries and the Navy receives the first F/A-18E/F Block III.

The popularity of fighters is not limited to the West. In August 2019, Russia formally launched the Sukhoi Su-57E for the export market, joining the Su-35 as both types gain interest in formerly safe U.S. fighter markets, such as Turkey and Egypt. Since declaring the stealth aircraft operational in February 2018, China has been displaying its capabilities, including a flyby at the Zhuhai Airshow nine months later with ultra-long-range PL-15 missiles and a formation flight of seven Chengdu J-20s on China's National Day on Oct. 1.

The response from the U.S. and Europe has been to increase quantity and quality of the current options as quickly as possible. Lockheed's aeronautics division is expected to deliver more than 300 F-35s over the next two years and incorporate the first element of the Block 4 follow-on modernization program. The F-35's dominance in the U.S. military's tactical fleet, however, is ending. The F/A-18E/F Block 3s ordered by the Navy in 2017 will be delivered in 2021. If Congress passes a fiscal 2020 budget, Boeing can start delivering the F-15EXs on the Air Force's pending order.

The French Air Force could deploy for the first time in 2020 with Dassault Rafale F3-R jets, which reached initial operational capability in late 2019. Meanwhile, Kuwait will receive the first Eurofighter Typhoon equipped with the Captor-E, an active, electronically scanned array (AESA) radar. Brazilian Air Force pilots will arrive in Sweden in early 2020 to begin training to fly the Saab JAS 39E/F Gripen, of which a single-seat version achieved first flight with a Saab test pilot in August 2019. Hindustan Aeronautics Ltd. plans to deliver the first Tejas Mk. 1A Light Combat Aircraft in the final operational configuration by March 2020.

The capabilities of each model are growing. A focus in 2020 will be on electronic-warfare upgrades. As Boeing starts developing the EA-18G Block 2, Airbus will seek to win funding support for a "Euro-Growler" version of the Typhoon, with Hensoldt scheduled to flight-test a new standoff jammer on a Pilatus PC-12 in 2020.



LOCKHEED MARTIN

The long-delayed proliferation of Lockheed Martin F-35s continues in 2020, but the single-engine type's overall share of global fighter deliveries will fall as other manufacturers increase output at a faster rate.

Lockheed has revived production of the F-16 in Greenville, South Carolina, but the Air Force continues to upgrade the current fleet. L3Harris Technologies and Northrop Grumman are competing to equip a subset of the Air National Guard fleet with an integrated electronic warfare system, which will complement the 73 aircraft receiving Northrop APG-83 scalable agile beam radars.

The kinetic capabilities of fighters also continue to expand in 2020. As Lockheed nears flight-testing in 2021 of the long-range AIM-260 Joint Advanced Tactical Missile for the F-22 and F/A-18E/F, a competition is brewing between the Lockheed Cuda and Raytheon Peregrine concepts for a new medium-range air-intercept missile. Meanwhile, the Air Force Research Laboratory in 2020 will enter the second phase of a project to develop a Miniature Self-Defense Munition, hoping to counter adversaries with missiles guided by chaff-evading dual-band sensors. In Europe, MBDA has proposed a similar hard-kill, 10-kg (22-lb.) mini-missile for intercepting incoming munitions.

Adding such capabilities should help the current fleet, but it is not expected to be enough. Some countries—India, Japan, South Korea and Turkey—are developing new aircraft that approximate or exceed the capabilities of fifth-generation fighters, such as the J-20 and the F-35. South Korea started building the front fuselage section of the first KAI F-X prototype in 2019, as Indonesia resumed payments to the joint project after a two-year hiatus.

The schedule for the TF-X project has been unstable. The original schedule called for first flight of the TF-X prototype in 2026, but Turkish officials moved that up to 2025 in June, and then moved it back to 2027 in December. India is not due to attempt a first flight of the Advanced Medium Combat Aircraft (AMCA) until 2032 but is working toward the rollout of the Tejas Mk. 2 in 2021 or 2022.

Along with the AMCA, perhaps the most intriguing concept among this club is Japan's Future Fighter program, the F-3. Both the Indian and Japanese programs have at least a decade to deliver an operational fighter, so they can consider technologies beyond the state of the art. Although Japan wants to lead the Future Fighter program, it is open to international collaboration. Lockheed has suggested a new version of the F-22, modified with software and electronics from the F-35. Another option is the Tempest model promoted by the UK, Sweden and Italy, which allows Japan to modularize with, say, a bespoke airframe, but share a common set of sensors and weapons with the international partners.

The Tempest model hints at the extent militaries are willing to go now to reinvent the fighter after 2030. Franco/German/Spanish Future Combat Air System officials plan to move forward in 2020 to secure funding for a flying demonstrator of a new fighter by 2025, but that approach seems the outlier. The U.S. Air Force, by contrast, has reshaped the Next-Generation Air Dominance program. Details are sketchy, but a "next-generation fighter" program launch is not scheduled before 2025.

Gallery *See a review in photographs of key events in the combat aircraft sector in 2019:* **AviationWeek.com/Defense2019**

Tanker Turmoil

> THE PRICE OF THE BOEING KC-46 DESIGN FIXES IS UNKNOWN

> U.S. CONGRESS BLOCKS KC-10 RETIREMENT

Lee Hudson Washington

After a two-year delay, the U.S. Air Force is receiving Boeing KC-46 aerial refueling tankers at a regular rate. But with ongoing deficiencies and a likely gap in tanking capacity, the military may conduct a competition for refueling services in 2020.

The Remote Vision System (RVS) is one of several lingering shortcomings on the KC-46. The two sides hope to agree on a design fix for the RVS in 2020, but the service's acquisition executive Will Roper says he will worry about the tanker program daily until a design is validated.

BOEING

On the KC-46, the RVS—a technology akin to virtual or augmented reality—experiences what the Air Force calls a "rubber sheeting" effect that distorts the image on the visual display used by the boom operator during refueling operations, Roper says.

The RVS technical deficiencies are acute enough that they preclude safe and effective boom-and-receptacle aerial refueling, the service says. Missions with the current RVS may increase the risk of midair collisions, boom strikes, probe loss and damage. The defect could be particularly costly for stealth aircraft such as the Northrop Grumman B-2 bomber and Lockheed Martin F-22 or F-35 fighters if the boom scrapes low-observable stealth coatings.

Roper says he is "very pleased" Boeing is looking to install a laser range finder for the boom so that the RVS operator has an indication of how far the boom is from the receptacle. The Air Force and Boeing will not know how much any of the KC-46 fixes will cost until a design is validated, but the company has agreed to pick up the tab.

"One thing I'm very happy about is we've got some of the best visual experts at the Air Force Research Lab, and they're creating a model simulator of the RVS so that we can work through design iterations with Boeing," Roper says, before Boeing invests engineering time.

The RVS recently completed a system-requirements review and is scheduled for a preliminary design review in the early second quarter of 2020, Jamie Burgess, vice president and KC-46 program manager at Boeing, tells Aviation Week.

The primary supplier for the RVS is Collins Aerospace, and Boeing has opted to continue partnering with Collins on the fix. "We're forecasting several years for the design development process," Burgess says.

A flaw to the boom telescope actuator is another pending KC-46 Category 1 Deficiency, and its fix is on a similar timeline. Boeing is maintaining a pace of delivering about three aircraft per month and anticipates that cadence will continue in 2020.

Despite the issues, Boeing still sees the potential to sell the new tanker to the United Arab Emirates (UAE), even though the UAE revealed at the Dubai Airshow its intention to purchase three additional Airbus A330 Multi-Role Tanker Transport (MRTT) aircraft, adding to its fleet of three.

"The timeline on that is difficult to estimate, but we still believe there is a potential market there," Burgess says.

Slow KC-46 deliveries may have opened up the possibility of future competition even within the U.S., as the Air Force and U.S. Transportation Command (Transcom) need tanking services.

Air Mobility Command issued a request for information in 2018 for a commercial refueling service that can handle 7,000 hr. annually. Airbus and Lockheed Martin joined forces to respond as the service determines the way ahead. In 2019, Omega Air Refueling took delivery of the first of two former Royal Netherlands Air Force KDC-10 aircraft that they could potentially use to provide a tanking service to the U.S. Air Force.

The KC-46A Remote Vision System that enables the boom operator to perform their duties is going through a redesign at the expense of the manufacturer.

The KDC-10 joins the company as its first boom-equipped tanker. Omega currently owns and operates a small fleet of tanker aircraft, with four different configurations approved to support U.S. Navy and Marine Corps aircraft.

Transcom is also concerned about aircraft refueling capacity and is looking to delay retirement of the Boeing KC-135 because of delays in the Air Force receiving the KC-46 from Boeing.

"Obviously, it's going to cost money, and when the money is put into the program, that's when we'll know; but the intent is to retain 29 [KC-135] weapon systems beyond their currently scheduled retirement,"

HERVE GOUSSE/AIRBUS

In 2020, the first of eight Airbus A330 MRTTs will enter service with the Dutch-led Multinational MRTT fleet.

Army Gen. Stephen Lyons, head of Transcom, told the Senate Armed Services Committee in March.

The Air Force plans to divest the KC-10 fleet while retaining a portion of its KC-135 aircraft into the 2050s, but delays in KC-46 delivery are causing a substantive tanking gap for the military.

"During KC-46 unit conversions, we are working closely with the U.S. Air Force to retain sufficient [aerial refueling] capacity and potentially delay the requirement of KC-135 aircraft in order to maintain [a] sufficient number of aircraft to meet operational requirements," states Lyons' written testimony submitted to the committee.

Citing concerns about the tanker gap, Congress in its agreement on a fiscal 2020 defense policy bill, says it will block the military from retiring primary inventory KC-10 aircraft in that fiscal year.

Issues with tankers and airlift extend beyond the U.S. Ten years after the Airbus A400M's first flight, the airlifter has yet to secure export orders beyond Malaysia. Although sales to Indonesia and Saudi Arabia are in the offing, a contract from the latter is hindered by Germany's ongoing arms embargo.

Despite ongoing issues with the engines, which recently prompted Germany to refuse to take delivery of two machines, Airbus has made progress in delivering the platform's tactical capabilities, including the airdropping of loads and paratroopers from the side doors. Work is also continuing with the helicopter aerial refueling capability following successful trials with extended aerial refueling hoses trailing 120 ft. rather than 90 ft., as before. Airbus hopes it can certify helicopter aerial refueling in 2021. Tanking of fixed-wing aircraft including fighters is currently being used operationally by the German Luftwaffe in Jordan.

Meanwhile the company is also continuing to push for sales of the MRTT. During 2020, the first one will enter service with the Dutch-led Multinational Multi-Role Tanker Transport Fleet (MMF). The MMF has eight MRTTs on order and options for an additional three if more nations join.

In addition to the UAE's follow-on order, Australia is reportedly looking to purchase an additional pair of the aircraft. Despite a recent drought of orders, Airbus is also continuing development of the C295 twin-turboprop airlifter.

The work on Canada's Fixed-Wing Search-and-Rescue requirement has resulted in a modernized version of the aircraft, equipped with a Collins Pro Line Fusion avionics suite and new aerodynamic features to improve fuel efficiency, although these will be added on a case-by-case basis.

Burkina Faso is the latest country to order the type. Italy's Leonardo continues to develop the C-27J Spartan. The aircraft has enjoyed significant success in Africa in recent years, with sales to Chad, Kenya, Morocco and Zambia. Leonardo is also looking to develop the C-27J as an aerial firefighting platform.

In September, Embraer delivered the first production KC-390 airlifter to the Brazilian Air Force. Brazil has ordered 28 KC-390s to perform a wide range of missions, including cargo resupply and air refueling. Portugal has also signed an order for six.

In November, Embraer and Boeing launched a rebranded version of the airlifter for the commercial market—the C-390 Millennium, which will compete head-to-head with Lockheed Martin's C-130J derivative—the LM-100J. That platform recently was granted FAA type certification, allowing it to deliver the first two LM-100Js to launch customer Pallas Aviation in the first quarter of 2020. And Lockheed officials say they are close to signing a new multiyear contract with the U.S. for 50 C-130J airlifters for the Air Force, Marine Corps and Coast Guard. The company had 512 of the aircraft on order as of the end of September.

In Russia, an aerospace laboratory revealed a possible new option in the government's search for a domestic alternative to the Ukrainian-made Antonov An-124 heavy lifter. The Central Aerohydrodynamic Institute (TsAGI) announced a wind tunnel campaign for a new heavy transport aircraft intended to replace the An-124 Ruslan.

TsAGI names the four-engine, high-wing design concept "Elephant." A picture of the wind tunnel model shows it bears a striking likeness to the An-124, which itself appears to be inspired by the external design of the Lockheed C-5A.

—With Tony Osborne in London

Gallery *See a review in photographs of key events in the tanker/transport sector in 2019:* **AviationWeek.com/Tankers2019**

OEMs Enjoying Boom in Military Helicopter Orders

ERIC RAZ/AIRBUS HELICOPTER

> U.S. AIR FORCE BEGAN MH-139 TESTING IN DECEMBER

> INDIA COULD BE ONE OF BIGGEST MARKETS FOR NEW ROTORCRAFT

Tony Osborne London

With the commercial helicopter industry still struggling after the oil and gas price slump, military sales are keeping some of the major rotary-wing OEMs in the black.

The uptick in international defense spending—particularly in Europe—has given even flagging programs a new lease on life and spurred new export opportunities.

Among the biggest beneficiaries is Airbus' Super Puma-family. Once a mainstay of oil and gas operations, the helicopter has in the last two years won major contracts in Kuwait, Singapore and Hungary, which ordered 16 aircraft, while the smaller H215 has been snapped up by Serbia and Uzbekistan. Demand is such that governments and militaries are now looking to repurpose commercial H225s for the military mission. Ukraine's machines used by Kyiv's interior ministry have been modified from an oil and gas configuration, and the French military is also looking to expand its H225 fleet the same way.

The Airbus H145M twin-engine light helicopter has also found favor with international militaries, securing orders from Germany, Hungary, Serbia and Thailand. Germany ordered the H145 commercial version for the search-and-rescue mission, and Ecuador ordered six for the same mission. Work is continuing to enhance that platform's manned-unmanned teaming capabilities and weapons options.

Also during 2019, the French government accelerated and expanded plans to develop a military version of Airbus' new H160 twin-engine medium helicopter. Formal development of the H160M Guepard will begin in 2021, with first deliveries planned for 2026.

Few details have been revealed about the AW249's development timeline, although four need to have flown by 2025. Leonardo is building the MH-139 utility helicopter for the U.S. Air Force to replace UH-1 Huey helicopters flown in VIP and ballistic-missile security missions. The Air Force testing began in December, and first deliveries are expected in fiscal 2021.

A series of major Foreign Military Sales contracts are in the offing for Boeing's AH-64 Apache and CH-47 Chinook. Among them are a request for 36 Apaches for Morocco, a new customer for the platform, and a request from Bangladesh for an unspecified number.

Boeing is also waiting for signatures on Chinook follow-on orders from the United Arab Emirates and the UK. Britain, with its fleet of 60 Chinooks, wants to begin replacing some of its 1970s-era models, which, despite regular upgrades, are increasingly costly to maintain.

Eastern Europe proved to be a lucrative market for U.S.-made rotorcraft in 2019: Sikorsky's Black Hawk picked up selections and orders from Croatia, Lithuania and Poland. The latter is still looking to replace its Soviet-era Mil Mi-8/17s and SW-4 Sokol transport helicopters in the coming years. Having selected Leonardo's AW101 to take over the antisubmarine-warfare mission of its Mil Mi-14s, Poland is also hoping to replace its Hind assault helicopters with a new-generation attack helicopter. A decision could come during 2020; the AH-64 Apache is considered the favorite.

The Czech Republic's decision to purchase the Bell AH-1Z Viper and the UH-1Y Venom as a pair marks the first success for the utility platform. Bell had previously secured sales of the AH-1Z to only Bahrain and Pakistan.

Airbus' H225 has enjoyed a renaissance as some customers look to repurpose stored commercial versions.

Other major program selections expected during 2020 include the face-off between two U.S.-made heavy-lifters—Boeing's Chinook and Sikorsky's CH-53K King Stallion—to replace Germany's CH-53G Sea Stallions. Industry is also eagerly awaiting the U.S. Navy's decision on the TH-73 Advanced Helicopter Training System, for which the Airbus twin-engine H135, Bell single-engine Model 407GXi and Leonardo TH-119 derivative of the AW119 Koala are competing. The Navy plans to buy about 130 airframes to replace its tired TH-57 SeaRangers.

Australia is looking for a fleet of 16 rapidly deployable twin-engine light helicopters it can fit into a C-17 for its Land 2097 Phase 4 requirement. Airbus, Bell, Leonardo and MD Helicopters have entered bids, although a decision may not come until 2021.

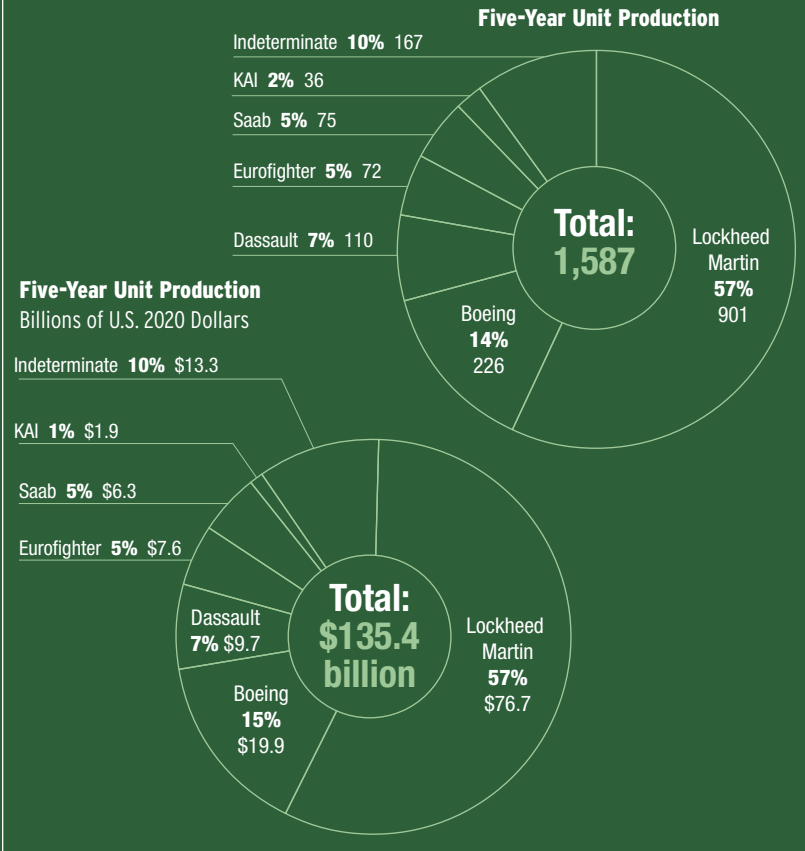
India looks like one of the biggest military markets in the coming years, with requirements for 111 naval utility, 197 reconnaissance and surveillance, and more than 120 naval multirole helicopters.

Meanwhile, across the Atlantic, the U.S. Army's Future Vertical Lift plans are beginning to tease international militaries into thinking about their future fleet mix. Next-generation rotorcraft promise next-generation speed and range, but questions remain about through-life costs and high price tags. So far, one of the Army's Joint Multi-Role flight test demonstrators, Bell's V-280 Valor has achieved performance requirements, while the Sikorsky/Boeing SB-1 coaxial rigid-rotor compound helicopter is yet to get beyond hovering, following its first hop in March. With Bell planning to fly the V-280 autonomously, the Sikorsky-Boeing team have considerable work to do.

Gallery *See a review in photographs of key events in the rotorcraft sector in 2019:* **AviationWeek.com/Rotor2019**

DATA CENTER

Fighter/Attack Aircraft Costs, 2020-24



Snapshot

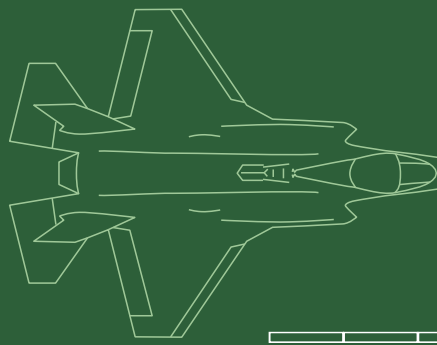
The Lockheed Martin F-35 fighter and Airbus A400M airlifter are among the most complex and challenging military programs underway in the U.S. and Europe. Here is Aviation Week's progress assessment as of the end of 2019.

A400M Atlas

Delivered: **86 aircraft to five operators**

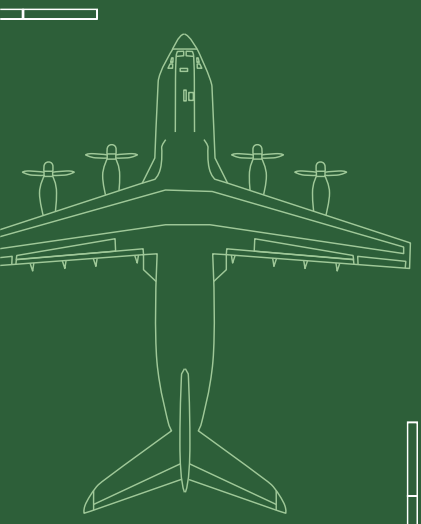
Ordered: **77 for delivery in 2020-29**

Forecast: **81 deliveries in 2020-29**



COMBAT AIRCRAFT TO WATCH

MODEL/ DESIGNATION	WING SPAN (FT.)	MAX. LENGTH (FT.)	MAX. HEIGHT (FT.)	WING AREA ($FT.^2$)	EMPTY WEIGHT (LB.)	GROSS WEIGHT (LB.)	ENGINES (NO./TYPE)	THRUST (AFTERBURNING)	PERFORMANCE	LOADING
BOEING										
F/A-18E/F Super Hornet	44.9	60.3	16	500	E: 32,100	66,000	2 X GE F414-400	22,000 lb. ea.	M 1.8+	17,750 lb. external
DASSAULT AVIATION										
Rafale C	35.8	50.2	17.4	492	22,000	54,000	2 X Safran M88-4E	16,860 lb. ea.	M 1.8	21,000 lb. external
EUROFIGHTER										
Typhoon	35.1	52.4	17.4	538	24,250	51,600	2 X Eurojet EJ200	20,000 lb. ea.	M 2	16,535 lb. external
KOREA AEROSPACE INDUSTRIES										
KF-X	36.8	55.5	15.5	501	26,015	37,920	2 X GE F414-K1	22,000 lb. ea.	M 1.81	—
LOCKHEED MARTIN										
F-35A Lightning II	35	51.4	14.4	460	29,300	70,000	1 X P&W F135-100	43,000 lb.	M 1.6	18,000 lb. internal/external
SAAB										
JAS 39E Gripen	32.4	49.9	14.8	323	17,640	36,300	1 X GE F414G	22,000 lb.	M 2	13,200 lb. external
SUKHOI										
Su-35S	48.2	71.9	19.4	667	—	76,059	2 X NPO Saturn 117S	31,970 lb. ea.	M 2.25	17,640 lb. external



F-35 Lightning II

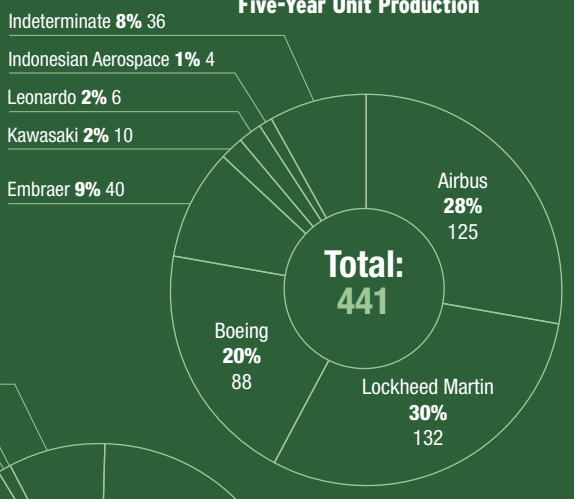
Delivered: **478 aircraft to 12 operators**

Ordered: **318 for delivery in 2020-29**

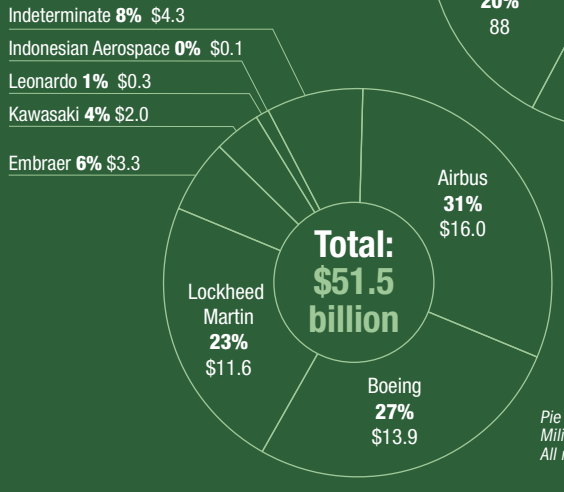
Forecast: **1,684 deliveries in 2020-29**

Military Transport Aircraft Costs, 2020-24

Five-Year Unit Production



Five-Year Unit Production
Billions of U.S. 2020 Dollars



Pie Chart Source: Aviation Week Military Fleet & MRO Forecast 2019. All numbers and percentages rounded.

MILITARY TRANSPORTS TO WATCH

MODEL/ DESIGNATION	CREW	WING SPAN (FT.)	MAX. LENGTH (FT.)	MAX. HEIGHT (FT.)	WING AREA ($FT.^2$)	EMPTY WEIGHT (LB.)	GROSS WEIGHT (LB.)	POWERPLANT (NO./TYPE)	POWER (SHP) OR THRUST (LB.)	SPEED	PAYLOAD/ RANGE
AIRBUS DEFENSE AND SPACE											
A400M Atlas	**2+1**	**139.1**	**148**	**48.3**	**2,384**	**169,000**	**310,850**	**4 X EPI TP400-D6**	**11,000 shp ea.**	**M 0.7**	**66,140 lb./ 2,450 nm**
ANTONOV											
An-178	2	100.3	108.1	33.3	—	—	—	4 X Progress D-436-148FM	—	405 kt.	22,046 lb./ 2,160 nm
BOEING											
KC-46A Pegasus	3-15	157.8	165.5	52.8	3,050	—	415,000	2 X P&W PW4062	62,000 lb. ea.	M 0.86	207,670 lb. (fuel transfer)
EMBRAER											
C-390 Millennium	2	115	115.4	38.8	1,513	—	178,570	2 X IAE V2500-E5	31,330 lb. ea.	M 0.80	50,700 lb./ 1,520 nm
ILYUSHIN											
IL-112V	—	90.6	79.2	29.2	700	—	46,300	2 X Klimov TV7-117CT	3,500 shp	245-270 kt.	7,720 lb./ 1,300 nm
LEONARDO											
C-27J Spartan	2+1	94.2	74.5	31.6	882.6	38,581	70,107	2 X R-R AE2100D2	4,637 shp ea.	325 kt.	22,046 lb./ 1,000 nm
LOCKHEED MARTIN											
C-130J-30 Super Hercules	3	132.6	112.8	38.8	1,745	87,667	164,000	4 X R-R AE2100D3	4,637 shp ea.	355 kt.	36,000 lb./ 1,700 nm

U.S. Hypersonic Hype Will Hit Testing Hurdles in 2020

> ARRW AND HCSW ARE SET FOR 2020 FLIGHT TESTS

> "RANGE REAPERS" AND "RANGE HAWKS" JOIN TEST FLEET

Steve Trimble Washington

Hypersonic missiles became a household word in 2019. The U.S. taxpayer is now about to find out whether the maneuvering Mach 5+ weapons are worth all the hype—or the cost.

The focus on testing of U.S. hypersonic weapons comes none too soon, as strategic rivals forge ahead. Russian Strategic Missile Forces expect to activate the first battery of Avangard intercontinental ballistic missiles tipped with a nuclear hypersonic glide vehicle (HGV) by the end of December, fulfilling a patient, 15-year development program.

Previewing a likely deployment by the People's Liberation Army Rocket Force next year, China rolled out at least 16 DF-17 missiles with conventional HGVs during the National Day Parade on Oct. 1.

If everything goes according to the current plan, the first U.S. HGV will enter service in about 2-3 years, starting with the Air Force's Hypersonic Conventional Strike Weapon (HCSW) and Air-Launched Rapid Response Weapon (ARRW) in 2022, followed by the Army's Long-Range Hypersonic Weapon (LRHW) and the Navy's Intermediate-Range Conventional Prompt Strike (IR CPS) a year later. Air-launched scramjet-powered weapons—the Hypersonic Air-breathing Weapon Concept (HAWC) could enter service at some point between the fielding dates for the HCSW and ARRW, but the precise timing has not been released.

In 2020, the focus of the Pentagon's $10 billion bet on HGVs, scramjets and hypersonic defensive systems will enter a new phase. Over the next four years, the three armed services plan to conduct a total of 40 hypersonic weapon flight tests, with the first two in 2020.

That is the plan anyway. It has been over two years since the Pentagon completed the last flight test of a hypersonic weapon—a Navy evaluation of the forerunner of the IR CPS and LRHW configuration for the HGV and two-stage missile stack. Despite the recent international interest, designing a successful maneuvering hypersonic weapon remains one of the most challenging assignments for aerodynamics and propulsion engineers.

Not surprisingly, U.S. test schedules have continued to slip. The original schedule for DARPA's Tactical Boost Glide (TBG) program called for a first flight test by the end of June 2019, but unspecified technical difficulties caused a delay to the end of the year.

The Pentagon's overlapping hypersonic programs are also prone to creating confusion. TBG shares a similar profile to ARRW. In fact, the TBG is itself testing two HGVs: one designed by Lockheed Martin, the other by Raytheon. The follow-on ARRW prototyping program also is split between Lockheed and Raytheon HGVs, although the only hypersonic weapon with an official designation so far—AGM-183A—belongs to the Lockheed version of ARRW.

Whether launched from air, ground or sea, the next round of testing is about to begin. If the first TBG flight test is completed by the end of 2019, the first AGM-183A ARRW and HCSW tests should occur by the end of 2020. Then the Pentagon plans to ramp up flight testing to unprecedented levels, even surpassing Russia and China.

"The hypersonics flight-test rhythm has increased to two events per year starting in fiscal 2020 and will continue to accelerate up to 20 events a year," the Army said in a Nov. 27 acquisition notice.

Such an unprecedented plan demands a new test infrastructure. The Army has defined the details of a planned, three-tiered hypersonic test range. The Portable Range Operations and Test Network will provide the communications backbone for the vast telemetry relay system for a hypersonic flight test.

The network will be used by assets on the ocean and in the air. The Broad Ocean Area Terminal Sensing System is being developed to install the acoustic radar and optical sensors on ocean platforms, including buoys, barges and ships. Finally, a new Sky Range composed of UAVs including RQ-4 "Range Hawks" and MQ-9 "Range Reapers" will help relay telemetry data from the HGVs and hypersonic cruise missiles at high altitude.

Other, future challenges still await the operational hypersonic weapon development effort in the U.S. A supply chain capable of producing hundreds, if not thousands, of missiles must be created. A defensive system, which remains in an early concept- definition stage, must be invented. The multiple, overlapping weapon capabilities pursued by all three services may need to be reconciled.

But 2020 will be the year the Pentagon will begin to find out how well these new weapons really work.

A B-52 carried an instrumented test version of the AGM-183A last June.

CHRISTOPHER OKULA/U.S. AIR FORCE

Moving Target

Europe's Twister concept suggests MBDA is developing an air-breathing interceptor as the U.S. considers adapting existing interceptor boosters for hypersonic threat.

> U.S. AND EUROPE SET TO DEFINE HYPERSONIC DEFENSES

> NEXT-GENERATION INTERCEPTOR REQUIREMENTS ARE WIDE OPEN

MBDA

Steve Trimble Washington

A year of change is in store for the military organizations tasked with intercepting missiles launched from another continent.

In the U.S., the $160 billion spent by the Missile Defense Agency (MDA) since its formation in 2002 has mainly been focused on intercepting ballistic missiles of medium to intercontental range by standing up a layered architecture, including the Ground-Based Interceptor (GBI), the sea-based Aegis Ballistic Missile Defense (BMD) system and the Army's Terminal High-Altitude Area Defense (THAAD) batteries, among others.

However, the recognition of an emerging threat—a new kind of missile that maneuvers within the atmosphere at hypersonic speeds up to Mach 20—and the collapse of the Redesigned Kill Vehicle upgrade program for the GBI appear to be driving fundamental changes in the future of the MDA's defensive architecture.

At the same time, governments from Europe to the Middle East to Asia are also building up defenses against attacks by a broad range of new air and missile threats, including a new program by the European Union to develop a counter to Russia's growing arsenal of hypersonic weapons.

Despite the billions invested in ballistic missile defenses, the imminent deployment of Russia's Avangard and China's DF-17 pose unique challenges. The MDA and U.S. Defense Department officials acknowledge the Ballistic Missile Defense System (BMDS) assembled over the past two decades is poorly designed to counter weapons that cruise at high speeds within the atmosphere and do not follow a predictable flightpath during the midcourse phase of flight.

In 2019, the U.S. and European governments finally responded, just as Russia was poised to clear the Avangard ICBM as operational by the end of December. The MDA selected five interceptor concepts for further refinement by mid-2020 and four companies to demonstrate prototypes for a future Hypersonic and Ballistic Tracking Sensor System (HBTSS). At the same time, DARPA is continuing to work on the secretive Glide Breaker program, although little about the project has been released.

Meanwhile, the European Union launched the Timely Warning and Interception with Space-based Theater Surveillance (Twister), a counter-hypersonic satellite constellation and ground-based interceptor under the framework of the multinational Permanent Structured Cooperation (PESCO).

Although public information on both projects is still limited, the MDA and PESCO appear to be taking different approaches with the interceptor. In September, the MDA selected one directed-energy concept and four interceptor missile concepts for further refinement, but the agency emphasized that each of the kinetic options is based on an existing booster; most likely, new, extended-range versions of THAAD and SM-3.

By contrast, MBDA showed a concept for a Twister interceptor that suggests the design is based on an air-breathing propulsion system, such as a subsonic or supersonic combustion ramjet.

The surveillance strategies for both the American and European efforts are more opaque. Pentagon officials have emphasized a need for a "tracking layer" of satellites in low Earth orbit, which could see hypersonic glide vehicles at relatively low altitude with on average 15 times dimmer heat signatures than ICBMs during the midcourse phase. The options that the MDA selected for the HBTSS concept definition stage have not yet been released, however. PESCO also has not provided details of plans for the "space-based theater surveillance" phrase embedded in the Twister acronym.

The MDA's defensive shield against ICBMs is established but may face major changes in the year ahead. The agency declared the GBI operational in 2004, but upgrades have come slowly and painfully. In August 2019, the MDA canceled the troubled Redesigned Kill Vehicle (RKV), a long-awaited replacement for the prototype kill vehicle designed for the GBI in the late 1990s.

Its cancellation opens several possibilities as the MDA enters a new budget request cycle for fiscal 2021. The RKV proposed to replace the GBI's existing payload on a one-for-one basis. The replacement—the Next-Generation Interceptor (NGI)—could follow that approach or revisit the MDA's previous attempts to develop multiple payloads for each GBI. The booster for the GBI interceptor itself could be modified or replaced by the NGI, an option first disclosed in October by Loren Thompson, a *Forbes* columnist and chief operating officer of the Lexington Institute.

Even as the missile threat has evolved, the pillars of the MDA's layered architecture have remained largely intact over the last 20 years. The agency will continue to leverage the investment in the current system as much as possible, but new threats and countertechnologies could lead to significant changes in 2020.

Air Defense Redefined

> MSDM AND SHIELD DEMONSTRATORS ENTER PHASE 2

> U.S. AIR FORCE, ARMY AND NAVY FIELD GROUND-BASED LASERS

Steve Trimble Washington

On March 4, 1961, an R-12 Dvina intercontinental ballistic missile was launched from Kapustin Yar in southwest Russia and flew east. About 1,300 nm to the west, a V-1000 anti-ballistic missile ascended from the Saryshagan launch complex on an intercept path. At about 80,000 ft. over Kazakhstan, the two rockets, as their Soviet designers intended, collided, and the missile defense era began.

Nearly 60 years after that first successful, non-nuclear missile defense test, ground-launched interceptors have become increasingly sophisticated, although each new advance has been countered to some degree by ballistic missiles with improved decoys and more complicated flightpath trajectories. In six decades of missile defense moves and countermoves, the constant has been the domain. With the exception of a few failed experimental projects, missile interceptors are launched from the ground.

The U.S. Air Force wants to change that paradigm over the next five years. In addition to ground-based missile defense, the Air Force Research Laboratory (AFRL) wants to introduce the capability to intercept missiles fired at aerial targets such as fighters, bombers and transports from the targeted aircraft. The age of relying on passive defense such as maneuvering to avert incoming missiles or dispensing chaff or flares to confuse their guidance systems may be supplanted.

Two very different approaches to aerial intercept completed a successful first phase in 2019. In 2020, the AFRL will launch the second phase of development work on the Miniature Self-Defense Munition (MSDM) and the Self-Protect High-Energy Laser Demonstrator (Shield).

As the guidance systems of missile threats become too sophisticated for decoys, chaff and flares, the U.S. Air Force plans to respond with hard-kill interceptors and defensive lasers to shoot them down.

AIR FORCE RESEARCH LABORATORY

The feasibility of aerial intercept weapons has not yet been proven. No equivalent to the breakthrough 1961 test in Kazakhstan exists for air platforms.

But there have been small steps toward proving the concept can work. A graduation event for Phase 1 of the

Shooting down unmanned aircraft systems and small cruise missiles from the ground will become an operational capability for the first time in 2020, but the U.S. Air Force hopes to repackage the technology for an aircraft pod.

Shield program last April shot down multiple missiles over White Sands Missile Range, New Mexico, but with a ground-based system adapted from a powerful U.S. Army laser weapon demonstrator far too large to be carried by a tactical aircraft. A few months later, the AFRL also completed a three-year study phase for the powered MSDM hard-kill interceptor, which evaluated proposals from Boeing, Lockheed Martin and Raytheon. In Phase 2, both programs face critical feasibility tests.

The Shield pod, which includes a Boeing container, Northrop Grumman beam director and a 50-kW-class, electrically powered solid-state laser supplied by Lockheed, is scheduled for a Phase 2 airborne demonstration in 2021. A potential Phase 3 could follow to attempt in 2021-25 an airborne shutdown by a pod carrying a scaled-up 150-kW-class laser. If successful, the defensive laser pod could transition into operational service.

Meanwhile, the MSDM competitors are required to submit by Jan. 31 bids for Phase 2 task orders worth up to $100 million each. The goal of Phase 2 is to push the roughly 3-ft.-long interceptors beyond a conceptual framework, setting the stage for a competition for an operational transition Shield program by the middle of the decade.

Although each concept presents unique technical hurdles, the Air Force is preparing for success. Last July, the AFRL's Munitions Directorate published a request for in-

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U.S. AIR FORCE

formation for a podded self-defense system. The pod ideas solicited by AFRL must be able to accommodate either about 10 MSDM interceptors, a high-energy laser or high-powered microwave system.

Hard- and soft-kill weapons could change the components of the formula for aircraft survivability. In addition to static features such as camouflage, structural shaping and radar absorbent materials, even the most stealthy tactical aircraft, such as the F-35, also carry a full suite of defensive aids, including self-protection jammers, towed fiber-optic decoys, chaff and flares. Although increasingly powerful, such aids at best can only fool or blind an incoming missile, not destroy it. If aerial interception becomes possible, tactical aircraft could add another layer of self-protection capability, and one that leaves no doubts for the crew about whether the countermeasure succeeded. Such a capability is sought as the threats to tactical aircraft multiply, exacerbated by fears of new missiles guided by dual-band seekers entering service.

The AFRL is not alone in the pursuit of active countermeasures. In June, MBDA unveiled a concept for a 10-kg (22-lb.) hard-kill anti-missile interceptor.

The technology for hard-kill and laser countermeasures is not new, but the airborne application envisioned for both systems is unique. In order to function on a fighter, a podded or integrated laser has to be able to propagate a high-power beam through a transonic or supersonic airflow. The goal of the Shield demonstration under Phase 2 is to fire the laser at such speeds, proving that the results of the AFRL's digital simulations and static live-firings on the ground will translate into a real-world scenario. Likewise, the MSDM demonstrators must prove that the guidance and propulsion systems of the interceptors can respond quickly enough to an incoming, potentially supersonic missile threat.

Ultimately, the point of the demonstrations is to introduce the technology on the next generation of fighter aircraft. In 2018, the Air Force decided to defer the launch of the Penetrating Counter Air capability under the Next-Generation Air Dominance to beyond 2025. The new schedule aligns with the timing for completing the technology readiness phase of both the defensive hard-kill and laser weapons. It is a prospect the Air Force has discussed publicly in the past.

"The same advantages that we talked about with magazine depth, with being able to fire quickly and to recharge, would give us some capability for our older airplanes to maneuver in places that they cannot now, by being able to defend themselves against integrated air defenses," Gen. James Holmes, commander of Air Combat Command, told an audience at the Directed Energy Summit in 2017. "It would help the new airplanes we are looking at, like the Penetrating Counter Air aircraft, operate in that environment."

Bold predictions about the future of laser weapons, in particular, provoke skepticism. A reliably relevant joke over the last five decades has been that an operational laser weapon is only 5-10 years away—and always will be.

But times have changed. The U.S. military touts 2020 as the year that operational laser weapons will be deployed, but in fact they are already in service. The Russian military has introduced the Peresvet combat laser system, which has been integrated into the defensive systems that protect the launch sites of intercontinental ballistic missiles. Ground- and ship-based air defense is also the initial mission for defensive laser weapons by the U.S. military. In 2020, the Air Force will deploy Raytheon's 10-kW-class High-Energy Laser Weapon System (HEL-WS) to two different bases overseas for an extended operational validation. Raytheon also is on contract by the Army to integrate a 50-kW version of the same electrically powered laser on a Stryker vehicle for a field assessment in 2021.

Some of the old challenges remain. A general rule in high-energy lasers is that for every watt of laser output, 3 watts of power is generated. That leaves 2 watts of power lost as thermal energy, which then has to be managed with either a cooling cycle or a mechanism to divert the heat away from the machinery of the weapon system. In the case of HEL-WS, there appears to be some improvement. Raytheon says the off-the-shelf laser amplifiers are closer to 40% efficient than 33%, resulting in three-fifths of wasted power instead of two-thirds.

To transfer the technology to an airborne application, however, the companies involved in Shield must repackage a ground system weighing thousands of kilograms into a padded system weighing no more than tens or low hundreds of kilograms. Even if the companies can find a way to scale up the power of amplifiers and not the weight, more solutions must be found to manage the same feat with the power generators, beam directors and thermal management systems.

On the other hand, program supporters no longer have to point to a merely theoretical threat. The startlingly successful attacks by unmanned aircraft systems and cruise missiles on defended oil processing facilities in Saudi Arabia on Sept. 14 prove the threat against ground bases is real. It may only be a matter of time before such capabilities are equally effective against defensive aids aboard fighters.

In April, the Air Force demonstrated that a ground-based laser can shoot down fast missiles during a demonstration at White Sands Missile Range, New Mexico.

INFLECTION POINT

- DELAYS TO THE FAA'S REMOTE ID RULE HAVE FRUSTRATED COMMERCIAL INDUSTRY
- PIVOT TO PEER THREATS CHALLENGES RELEVANCE OF MILITARY UAV FLEETS

Graham Warwick

Despite the rapid growth of the market since the middle of the past decade, drones have yet to make any real impact on the everyday lives of most people. That could change in the next decade as regulations catch up with technology and enable truly transformative operations.

The growth has been achieved despite tight constraints on the use of commercial drones and is expected to accelerate through the early 2020s as limits are widened to allow routine flights over people, at night and beyond visual line of sight (BVLOS). This will unlock the economic potential of drones for missions such as medical transport, search and rescue, and cargo delivery.

Since it began requiring registration in December 2015, some 1.5 million drones have been logged with the FAA. While the pace of recreational drone registration has slowed, the growth in the commercial market has far outpaced the agency's forecasts. With 416,210 commercial drones registered by Nov. 19, 2019, the FAA expects its forecast for 2022—452,000 units—will be reached in early 2020.

An increasing proportion of commercial drones are professional grade in terms of capability and safety, positioning the industry to further expand once regulations allow. In its 2019 forecast, the FAA says the commercial market is at an inflection point, with the professional grade sector, in particular, poised to expand rapidly.

The U.S. is weighing retiring most of its Global Hawks just as it begins export deliveries.

But much depends on the FAA itself, and the much-delayed regulations for remote identification of drones—a precondition for routine BVLOS operations. Proposed rulemaking has edged toward 2020, and a final rule could take another two years, to the frustration of industry and lawmakers.

Much attention is focused on drone delivery. This is already a reality outside the U.S., with Zipline operating drone networks delivering blood and vaccines to remote clinics in Rwanda

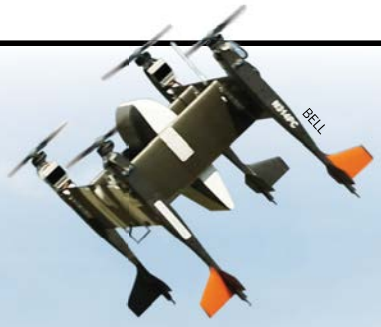
NORTHROP GRUMMAN

UNMANNED CARGO AIRCRAFT TO WATCH

Interest and activity in developing heavy-payload unmanned cargo aircraft is growing, aimed at creating a responsive logistics capability for commercial and military markets. Potential applications include long-haul point-to-point cargo service and delivery of goods to remote areas.

Such uses are outside the limits of current regulations allowing drone operations in national airspace, so developers face regulatory as well as technical challenges. But military and commercial interest is such that developers—startups and established OEMs—are undeterred.

Several developers of electric vertical-take-off-and-landing (eVTOL) vehicles believe they could be used first for cargo operations, helping pave the way for acceptance of air taxis for urban air mobility. Pipsitrel and Volocopter are among the eVTOL startups also developing cargo UAVs.



Bell APT 70
Flown: December 2018
Configuration: Tailsitter electric VTOL
Weight: 300 lb.
Payload: 70 lb.
Speed: 126 mph
Range: 35 mi.

Flown: October 2019
Configuration: Multirotor eVTOL
Weight: 1,760 lb.
Payload: 440 lb.
Speed: 50-70 mph
Range: 25 mi.

and Ghana. Wing is making deliveries direct to consumers in Australia, and other services are operating in China, Iceland and elsewhere.

The FAA's Integration Pilot Program (IPP) is paving the way for drone deliveries in the U.S. Part 135 air carrier certificates have been awarded to Wing and UPS, with seven more in the works. Both made their first U.S. commercial BVLOS delivery flights to hospitals and homes late in 2019.

In the military arena, U.S. manufacturers are responding to the Pentagon's pivot to address near-peer rivals and away from the counterinsurgency operations that have dominated the past two decades. The U.S. Air Force has floated the idea of retiring most of its Northrop Grumman RQ-4 Global Hawks, arguing the high-altitude, long-endurance unmanned aircraft are unsurvivable in contested airspace.

Congress will oppose the move, which has been tried before and blocked, but it has put manufacturers on notice that they must find new ways for their products to be relevant in peer conflicts. General Atomics plans to demonstrate new capabilities for its Predator medium-altitude, long-endurance family, including maritime patrol for the MQ-9 Reaper and multidomain operations for the MQ-1C Gray Eagle.

Teaming between manned and unmanned aircraft is taking on new importance as the U.S. and its allies strive to add combat mass to their shrinking fleets of highly capable but expensive platforms. Boeing Australia will fly its jet-powered Airpower Teaming System UAV in 2020, advancing the "loyal wingman" concept of augmenting the capability and survivability of manned combat and surveillance aircraft with teams of less expensive, more disposable autonomous sensor, jammer or weapon carriers.

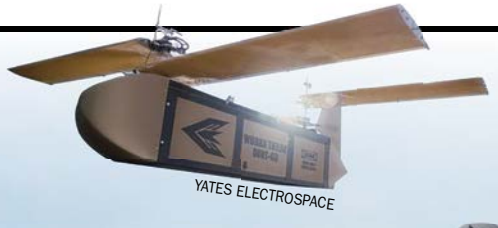
The U.S. Air Force is flight-testing the Kratos XQ-58A low-cost unmanned combat aircraft demonstrator, while research has been launched into "remote carriers" that will be integral components—along with sixth-generation manned fighters—of planned French/German- and UK-led future combat air systems.

And they are not alone. In Russia, Sukhoi is flight-testing the S-70 Okhotnik, a large jet-powered unmanned combat aircraft designed to operate alongside the Su-57 stealth fighter now entering production. MiG Corp. has confirmed it is developing a high-speed UAV to partner with the MiG-35. And China in October 2019 showcased the latest version of its stealthy flying-wing GJ-11 Sharp Sword.

The U.S. Army is taking manned/unmanned teaming to a new level by specifying that UAVs—which it calls air-launched effects (ALE)—be an integral part of its next-generation rotorcraft: the Future Attack Reconnaissance Aircraft armed scout and utility Future Long-Range Assault Aircraft. ALEs are intended to be launched at a low altitude to extend the sensor and weapon reach of rotorcraft and improve their survivability in contested airspace.

The Army and U.S. Marine Corps are also driving a trend toward more expeditionary, runway-independent unmanned aircraft systems. The Army is field-testing four vertical-takeoff-and-landing (VTOL) designs to inform requirements for a future tactical UAV to replace its workhorse Textron RQ-7 Shadow, but the Marines are reviewing their MUX requirement for a large multimission ship-based VTOL UAV.

Gallery *See a review in photographs of key events in the unmanned sector in 2019:* **AviationWeek.com/Unmanned2019**



Yates Electrospace Silent Arrow GD-2000

Flown: 2018
Configuration: Air-launched disposable glider (electric reusable option)
Weight: 2,000 lb.
Payload: 1,631 lb.
Standoff range: 40 mi.

Sabrewing Rhaegal RG-1

Flight (planned): 2020
Configuration: Ducted-tiltfan turbo-eVTOL.
Weight: 3,000 lb.
Payload: 1,000 lb.
Speed: 270 mph
Range: 1,150 mi.

Elroy Air Chaparral V1

Flown: August 2019
Configuration: Winged hybrid-eVTOL
Weight: 1,215 lb.
Payload: 300 lb.
Speed: 120 mph
Range: 300 mi.

Volocopter VoloDrone

Boeing CAV

Flown: January 2018
Propulsion: Multirotor eVTOL
Weight: 1,100 lb.
Payload: 500 lb.

Stand and Deliver

> GE9X, THE MOST POWERFUL TURBOFAN, IS SET TO POWER THE BOEING 777X

> GTF DELIVERIES ARE SET TO CLIMB

> ADAPTIVE COMBAT ENGINES FACE BUDGET CRUNCH

CFM is optimistic that Leap 1B-powered Boeing 737 MAX deliveries will resume in the first half of 2020.

MARK WAGNER/AVIATION IMAGES.COM

Guy Norris

After battling through more than two years of production, development and reliability challenges, the major civil engine manufacturers are hoping for smoother sailing in 2020 and possibly even the emergence of new applications.

General Electric is banking on brighter prospects in the first part of the year through turnarounds for two key stalled Boeing programs—the 777X and 737 MAX. As the sole engine provider for the 777X (with the GE9X) and for the MAX (with the CFM Leap 1B coproduced with joint venture partner Safran), GE Aviation has been affected by setbacks to both programs as well as added costs to fix durability issues with the 777X engine.

Retrofitted flight-compliant GE9X engines for the first two 777-9 test aircraft were delivered and installed by early December, clearing the way for flight tests to begin early in 2020. Deliveries of the stalwart GE90-115B and GEnx-1B/2B, meanwhile, continue for the 777-200F/300ER, 787 and 747-8, although production of both big twins is scheduled to slow later in 2020 in response to softening of the twin-aisle market.

Although GE90-115B production continues for 777F models as deliveries of passenger types transition to the GE9X-powered 777-9 through the early 2020s, GE Aviation's reliance on the GEnx will increase. The 2,000th GEnx, a -1B for a 787, was delivered to Boeing in late 2019 and, according to GE, is now roughly a third of the way through the engine's expected production life, based mostly on forecast sales of the 787. In competition with Rolls-Royce, GE currently claims 65-70% of the year-over-year 787 market based on 2019 orders.

Of the 2,000 GEnx deliveries, around 725 are GEnx-2Bs for the 747-8I/8F. Although -2B production continues to support Boeing's assembly rate of just six per year, the company is looking at potential alternative applications for the engine including the 767-XF, a notional freighter based on the 767-400ER. GE is also proposing a version of the GEnx-1B to Craic, the consortium of United Aircraft Corp. (UAC) of Russia and Comac of China developing the CR929 widebody twin, and hopes for a decision in late 2020. Further off, GE is also keen to restore links with Airbus and is studying potential hybrid derivatives based on the GEnx with GE9X technology for possible applications in the 2020s.

Although CFM caught up with 737 MAX production in 2019 after the rate slowed in the wake of the global grounding of the aircraft in March, the company is slowing Leap 1B production in response to Boeing's decision to temporarily halt the line starting in January. This will further impact CFM's free cash flow, which through late 2019 was already reduced by around $110 million per month. At the same time, the production system has continued to improve, with almost 1,320 Leap 1A and 1B engines made over the first three quarters of 2019, almost double the number in 2018.

CFM competes with Pratt & Whitney for the Airbus A320neo and, with around 520 Leap 1A-powered aircraft in service, claims a 63% market share against the rival PW1100G geared turbofan (GTF). Pratt continues to fight back with the GTF which, despite a nagging series of repair and maintenance issues, is performing in some cases better than advertised in key areas of fuel burn, emissions and noise.

Pratt delivered 779 large commercial engines in 2018 and, as of the end of September 2019, was on track for a similar tally, having delivered almost 530 by the start of the fourth quarter. While the bulk of these went to Airbus for the A320neo family, a growing volume of PW1500Gs are for the A220 program, which marked delivery of the 100th engine in December. The first production-standard PW1900G engine variants were also shipped to Brazil for the Embraer 195-E2 at the start of 2019, while a handful of PW1400Gs and PW1700Gs are powering flight tests of the United Aircraft Corp. MC-21 and Mitsubishi M90/100, respectively.

Besides steadying production through 2020, Pratt will focus on introducing durability and service improvements to the family, which has been developed as drop-in retrofits, as well as a new-build PW1100G standard, which has been flight-tested on the

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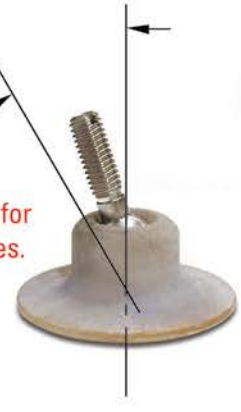

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prototype A320neo. Changes increase robustness in adverse operating conditions and include an already certified low-pressure turbine upgrade. Similar hardware and software improvements are underway to address low-pressure compressor issues on the PW1500G.

Rolls-Royce also continues to tackle long-running durability issues, on the Trent 1000, and hopes to deal with the last of these with the completion of a high-pressure turbine-blade redesign for the TEN variant in early 2021. The work, which by 2023 will have cost the company £2.4 billion ($3.2 billion) plus an additional £1.4 billion incurred in 2019 from customer and remediation shop visits, covers a total of nine problems found in the Trent 1000 Package B, C and TEN models. Of these, eight fixes have so far been designed; seven have been certified and are being incorporated into the fleet.

Despite softening widebody markets and Boeing's decision to pare back 787 production, Rolls-Royce is targeting around 500 large civil engine deliveries per year into the early 2020s. The bulk of these will be made up of Trent XWBs for the A350 augmented by Trent 7000s for A330neos, Trent 900s for the final batch of A380s, and Trent 1000 TENs for the 787.

For the company's future product lineup, 2020 will also be a key year of tests for its geared UltraFan next-generation engine. Following its decision earlier in 2019 to withdraw the concept from Boeing's new midmarket airplane (NMA) engine competition, Rolls is now targeting a notional entry-into-service date of around 2027. Although no other specific application has yet been identified, the development timetable would suit potential reengined upgrades of the A350 and 787 later in the decade.

The near-term focus remains on an accelerating series of demonstrator and rig tests that will pave the way for ground tests of the initial UltraFan in 2021. These include the Advance3, which has been used to evaluate the new high- and intermediate-pressure core architecture, a series of high-power gearboxes and several advanced fan and combustor tests.

MILITARY HIGHLIGHTS

The next major advance in military propulsion, the development of adaptive—or three-airstream—engines, will take big a step forward in 2020 with the start of ground tests of technology demonstrators in the U.S. and of design work on similar variable-cycle engines for next-generation combat aircraft in Europe.

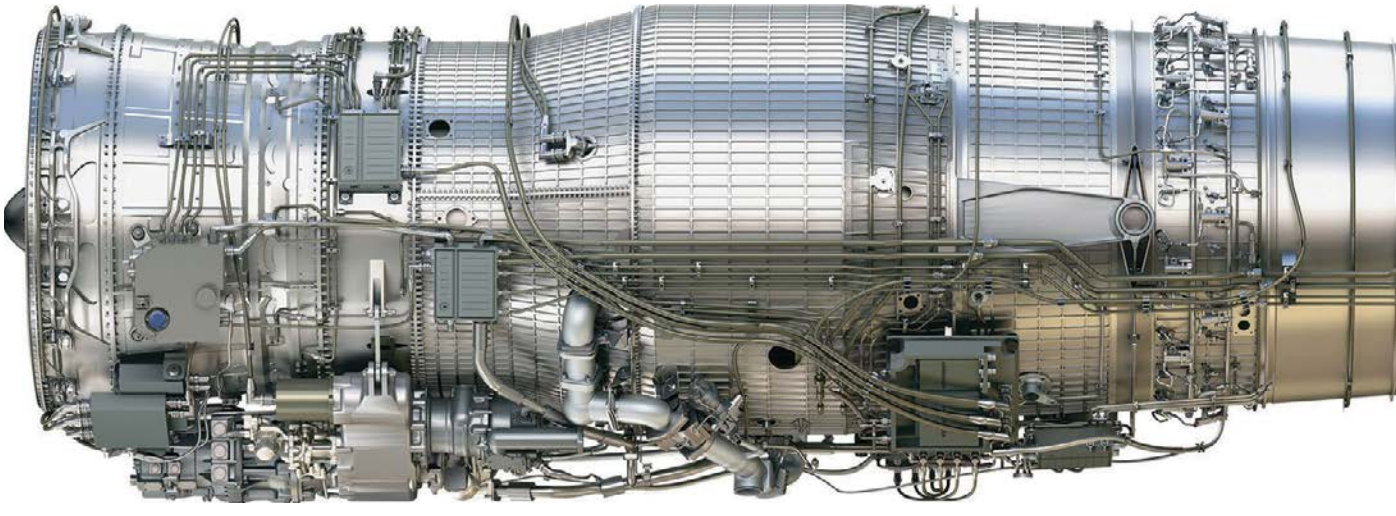
However, even though GE Aviation's XA100 and Pratt & Whitney's XA101 are primed to run under the U.S. Air Force Research Laboratory's Adaptive Engine Transition Program, funding for follow-on phases remains uncertain. Rated for 45,000 lb. thrust, the adaptive demonstrators are sized to provide a potential future engine for the Lockheed Martin F-35A and C models as well as provide the basis for possible sixth-generation U.S. Air Force and Navy air-superiority aircraft. But a next-generation fighter has been deferred while the Air Force lays the groundwork for a new production system inspired by the Century Series example of fielding six fighters within five years.

Ironically, while U.S. efforts to pioneer adaptive technology appear to be losing direction, work on variable-cycle programs in Europe has been galvanized by the launch of the Franco-German-Spanish Future Combat Air System (FCAS) and the UK's Tempest sixth-generation fighter. Germany's MTU and Safran plan to develop an adaptive 30,000-lb.-thrust engine for the program and will spend 2020 working on initial research and technology work for the FCAS demonstrators, which may fly with a modified off-the-shelf engine as early as 2026.

Rolls-Royce is leading development of the three-stream engine for the Tempest, based on an all-new core from its secretive Advance1 technology program. The Tempest engine will feature advanced thermal management technologies and a core-mounted electrical generator.

Eager to protect its sole-source position on the F-35 with its F135 engine, Pratt & Whitney is meanwhile continuing to cut unit costs as it works toward an eventual output of 16 per month. In late 2019 the company received a $5.7 billion contract to deliver 332 engines during low-rate initial production lots 12-14 and expects to enter full-rate production in 2020.

The Air Force's long-running search for a new engine for the Boeing B-52H fleet is also expected to reach the next stage in 2020, when it firms up a draft request for proposals issued in 2019. Bidding for the 650 20,000-lb.-thrust engine deal are GE Aviation with the CF34-10 and Passport, Pratt & Whitney with the PW800 and Rolls-Royce with the F130, a variant of the BR725.



AVIATION'S THIRD AGE

From a few fledgling concepts over recent years, the proliferation of nonconventional hybrid and electric propulsion developments continues to accelerate, with a slew of new projects entering ground tests in 2020 ahead of planned flight tests from 2021 onward.

The traditional large engine companies—GE Aviation, Honeywell, Pratt & Whitney parent company United Technologies Corp., Rolls-Royce and Safran—are all now engaged but have been joined by startups such as MagniX and Wright Electric. On Dec. 10, a De Havilland Canada DHC-2 Beaver modified with a MagniX motor by Vancouver-based Harbour Air achieved what the seaplane operator called the maiden flight of the world's first all-electric commercial aircraft.

GE Aviation is developing megawatt-class power electronics and eyeing potential flight-test opportunities with NASA. The company has already been selected by XTI Aircraft to supply a 1-megawatt turbogenerator, based on its Catalyst turboprop, for the hybrid-electric propulsion system it is developing to power the TriFan 600 ducted-fan vertical-takeoff-and-landing business aircraft.

Honeywell, one of the first engine-makers to enter the alternative power market, is pursuing both a hybrid and an all-electric approach, starting with first runs in 2020 of a hybrid propulsion demonstrator based on its HTS900 turboshaft.

Adaptive engines such as GE's XA100 will run in 2020, but they face some uncertainty.

GE AVIATION

The Cranfield-led hybrid-electric Islander reengining has the UK government's backing.

CRANFIELD AEROSPACE SOLUTIONS

However, based on market feedback, Honeywell has also partnered with Japanese automotive electric drivetrain producer Denso to fast-track the development of all-electric power concepts for electric vertical-takeoff-and-landing vehicles.

Another venture to watch in 2020 will be United Technologies Advanced Projects' (UTAP) ongoing modification of a De Havilland Canada Dash 8-100 regional airliner with a 2-megawatt parallel-hybrid propulsion system. Dubbed Project 804, the system replaces one of the aircraft's regular turboprops with a 1-megawatt thermal engine developed by Pratt & Whitney Canada and a battery-powered 1-megawatt electric motor developed by Collins Aerospace. UTAP hopes to demonstrate a 30% fuel saving when the aircraft flies in 2022.

Rolls-Royce is aggressively developing its hybrid and electric power strategy, most notably through the surprise acquisition of Siemens' eAircraft unit in 2019. Together with Airbus, Rolls is modifying an Avro RJ100 under the E-Fan X project to demonstrate a 2-megawatt-series hybrid propulsion system for a regional airliner. Rolls is supplying the 2.5-megawatt turbogenerator based on its AE2100 turboprop engine as well as the 2-megawatt electric motor that will drive the fan from a Rolls AE3007—replacing the Honeywell LF507 turbofan in one of the inboard nacelles.

Rolls is supplying most of the hybrid drivetrain while Airbus is providing the 2-megawatt battery system and 3-kilovolt electrical distribution system for the E-Fan X, which is scheduled to fly in 2021. In the near term, Rolls also plans an attempt to break the electric-aircraft speed record in 2020 with the battery-powered ACCEL project underway in the UK. It is part of Project Fresson as well, an effort led by Cranfield Aerospace Solutions to convert the nine-passenger Britten-Norman Islander to hybrid-electric propulsion for short-range flights such as interisland routes.

Safran is also making a concerted push into electric propulsion and continues development of a suite of smart batteries, generators, power management systems and motors for hybrid and all-electric applications such as VoltAero's Cassio 1 testbed, for which it is providing two 45-kW motors.

Sizing Up the Competition

> SIX POSSIBLE OPTIONS FOR U.S. MILITARY SPACE LAUNCH

> AWARDS EXPECTED MID-2020

BLUE ORIGIN

The methane-burning BE-4 engine, being used for both Blue Origin's New Glenn and ULA's Vulcan rockets, underwent a hot-fire test in July.

Irene Klotz Cape Canaveral

It is a testament to the ongoing transformation of the U.S. launch industry that not only does the Air Force have a record four companies vying for its space launch business but also the only operational rockets proffered in the competition belong to plucky SpaceX, whose raison d'etre is the human settlement of Mars.

Having the sole flight-ready rockets does not necessarily give SpaceX a leg up on the competition, which includes United Launch Alliance (ULA), a partnership of Lockheed Martin and Boeing, and Northrop Grumman, which aims to parlay its solid rocket motor expertise into a family of national security—and potentially commercial—launchers called Omega. A fourth contender is startup Blue Origin, bankrolled by tech billionaire Jeff Bezos, which is developing the reusable New Glenn launch system.

The Air Force plans to award two five-year National Security Space Launch Phase 2 Launch Service Procurement (LSP) contracts in mid-2020 for missions procured in fiscal 2020-24 and launching through 2027. The work would be split 60-40% between the two companies selected.

SpaceX was beginning to chip away at ULA's monopoly on national security space launches when forces outside the industry sent next-generation military launch service procurements off in a new direction. Trade sanctions imposed by Congress after Russia annexed Ukraine's Crimean peninsula in 2014 hit incumbent contractor ULA squarely due to the Russian-made RD-180 rocket engines that power its workhorse Atlas V rockets. Legislators stipulated that the U.S. military cannot buy launches using the Russian engines after 2022.

SPACEX

SpaceX flew a communications satellite for Arabsat during its second Falcon Heavy mission on April 11.

To break its dependence on the RD-180s while addressing pricing challenges from SpaceX and others, ULA is developing a new launch system called the Vulcan. The new booster, which is expected to debut in 2021, is intended to eventually replace both ULA's Atlas and Delta rocket lines, vehicles that trace their heritage to 1950s- and 1960s-era ballistic missile programs.

Of the four companies vying to become Air Force LSP contractors, ULA, whose core business is launching U.S. military and NASA payloads, would be most affected should it not be selected. Northrop says it can close its business case with as few as 3-4 flights a year of the Omega, a two-stage, solid-fuel booster based on space shuttle and Space Launch System motors, paired with a liquid-fueled Aerojet Rocketdyne RL10-powered third stage.

"What's unique about us is that we don't sell just rockets," Charles Precourt, Northrop vice president and general manager for propulsion systems, tells Aviation Week. "We provide systems to a broader base of missiles and launch systems such as flight computers, structures, engines and facilities management. So rather than stand up one rocket or even a small family of rockets, we leverage existing parts of our business so that we didn't have to invest in the facilities. We largely didn't have to bring on a new workforce. We are adding to existing lines of business in a way that is able to control overhead costs, which a single-product business couldn't.

"That gets us in the ballpark, where we can show the Air Force we can survive downturns in the economy," Precourt adds. "We can, in fact, survive in this business on very few flights.

For SpaceX and Blue Origin, winning national security space launch business is way to shore up their immediate and near-term finances and gain experience as the companies work toward their founders' aspirational goals to significantly broaden humanity's presence beyond Earth. SpaceX's Elon Musk eyes human missions to Mars, while Bezos' Blue Origin is looking to move Earth's heavy industry off the planet.

Winning the Air Force business is important enough to SpaceX and Blue

Origin that both companies filed protests over the LSP program. A SpaceX lawsuit, currently with the U.S. District Court for the Central District of California, is challenging $2.2 billion in LSP development contracts awarded in 2018 to rivals ULA, Northrop and Blue Origin.

Blue Origin took a preemptive strike at the upcoming LSA Phase 2 awards with a protest, partly upheld by the Government Accountability Office (GAO), over launch contract rules. The Air Force solicitation, which is in the process of being modified, stipulated that the agency could select a pair of companies that complemented each others' strengths and weaknesses to provide the best overall value to the government in terms of reliability, price and technical considerations.

The contract rules could have allowed the Air Force, for example, to avoid pairing companies that use the same key components—both ULA's Vulcan and Blue Origin's New Glenn are powered by Blue's BE-4 engine—or that share a common weakness. The GAO, however, ruled in favor of Blue Origin, which argued that to assess independent bids as pairs was not reasonable and was inconsistent with procurement laws. "In the wording they had before, the Air Force had a very straightforward way of saying 'This pairing is better than that pairing, independent of the structured scoring.' If they remove that piece that the GAO felt was objectionable, they don't have that option anymore," ULA CEO Tory Bruno tells Aviation Week.

"The bidder has to be judged entirely on their own proposal so that they can be in control of putting their best foot forward, that this combination thing isn't something the bidders can do because they don't get to see the other bidders' proposals," Bruno notes.

"The Air Force will have to be very careful in how they score all of the strengths and weaknesses and then run that through whatever algorithm they use to make sure they get the right outcome," he adds.

Beyond requiring U.S.-made rocket engines, the Air Force wants to ensure access to space by having two independent launch systems, each of which must be able to handle a range of orbits, mission designs and payloads. The military also is looking for flexibility, with the ability to switch out a launcher's payload within 12 months of flight. Currently, SpaceX and ULA handle the military's intermediate and heavy-lift space launch needs.

"Based on the GAO ruling and based on what we've responded to, I don't necessarily think that we will make any changes to our proposal, but I've got to see what they write," says SpaceX President and Chief Operating Office Gwynne Shotwell.

SpaceX is sticking with Falcon 9, which racked up its 77th mission on Dec. 16, and Falcon Heavy, which has flown three times, for the LSA Phase 2 work. It is the only contender with a proven launch vehicle in the offering. For the 2018 LSA development procurement, which it did not win, SpaceX also offered its superheavy-lift, reusable Mars-class Starship, which is in development. "We did change our strategy," notes Shotwell.

The Air Force does not anticipate that modifying the solicitation language, as recommended by the GAO, will delay contract awards. Among the four bidders, six possible pairings exist: ULA and SpaceX, ULA and Blue Origin, ULA and Northrop, SpaceX and Blue Origin, SpaceX and Northrop and Blue Origin and Northrop.

The military launch business comprises a shrinking but still important share of the overall U.S. launch industry, with 20-30% of recent missions for national security space, compared with 40-60% in 2010-15, according to Phil Smith, senior space analyst with Bryce Space and Technology, a Washington-area consultancy. "The share has dropped because the number of commercial launches has increased substantially, with most of these launches conducted by SpaceX and Rocket Lab," Smith says.

Overall, the number of orbital launches (both successful and failed) in 2019 stood at 95 in mid-December, with 7-8 more missions possible before year-end. China retained its title as the world's launch leader with 32 flights, followed by 20 for the U.S. and 19 for Russia, according to *Jonathan's Space Report*, a catalog of launches and satellites compiled by Harvard University astrophysicist Jonathan McDowell.

Gallery *See a review in photographs of key events in the space launch sector in 2019:* **AviationWeek.com/Launch 2019**

Northrop Grumman conducted a full-scale static test-firing of its Omega rocket first stage on May 30, in Utah.

NORTHROP GRUMMAN

High Throughput

- AIRBUS AND ONEWEB PIONEER HIGH PRODUCTION RATES FOR MINI-SATELLITES
- CLOSED-LOOP DIGITALIZATION MAY HELP REFINE PROCESSES

Thierry Dubois Lyon, France, and **Irene Klotz** Cape Canaveral

In the satellite industry, high throughput used to refer to a satellite's bandwidth. But these days it is starting to mean something else: fast-paced manufacturing.

For example, SpaceX is producing about seven Starlink broadband satellites per day at its factory in Redmond, Washington. After flying two prototypes in 2018, the company deployed 120 operational spacecraft during two Falcon 9 missions this year to test its planned global, mobile high-speed internet service.

Production of user terminals is taking place at a second Washington site, but that effort will need to be stepped up, says SpaceX President and Chief Operating Officer Gwynne Shotwell. "It's low-volume production. We can build them. They look beautiful, but they're still a little expensive."

SpaceX, which has yet to win approval to operate Starlink outside the U.S., is targeting a wide range of customers—individuals, businesses, educational institutes and government agencies, including the U.S. Defense Department, which is paying SpaceX for a series of Starlink tests to deliver high-speed data into jet cockpits under a program called Global Lightning.

SpaceX aims to roll out commercial service in mid-2020, depending on how quickly the initial 720-member network can be deployed. Starting in 2020, batches of 60 or so satellites will be launching every 2-3 weeks, says Shotwell.

SpaceX is hardly alone in seeking to revolutionize broadband access with a mega-constellation of satellites. The first six spacecraft owned by OneWeb reached orbit in 2019, with batches of about 30 to follow during monthly launch campaigns beginning in January 2020. OneWeb plans to initiate service in the Arctic in late 2020 and roll out global coverage in 2021.

OneWeb's manufacturing arm, OneWeb Satellites—a joint venture with Airbus—has become one of the first companies to rethink the construction of a satellite, ushering the industry into an era of high-volume production.

Thales Alenia Space and Northrop Grumman have built 80 Iridium Next satellites, the last of which reached orbit in February 2019. As a result, the two companies have created a dedicated production system in the process. But the satellites' large size did not lend itself to radically new construction processes. Production was much slower—as it was spread over several years—than the production rate OneWeb Satellites is aiming for, namely two spacecraft per day.

After manufacturing the first 10 OneWeb satellites at Airbus's facility in Toulouse, production shifted to a new factory in Florida adjacent to NASA's Kennedy Space Center. Two highly automated assembly lines have been set up there to output one satellite per line per day.

OneWeb Satellites does not say when that objective will be met. However, cost and weight are said to be on target—at less than $1 million and below 150 kg (330 lb.).

The target manufacturing time means each workstation has to produce a module every 8 hr. The production cycle for a given satellite will be measured in days.

OneWeb Satellites did not look to reinvent the wheel. Rather, its engineers imported methods that thus far had been used in other sectors, such as commercial aircraft manufacturing.

OneWeb Satellites has set up two production lines, each capable of completing one spacecraft per day.

They also adopted a design-to-manufacture approach. In other words, some parts have been designed for their installation to help prevent errors. Asymmetric bore locations can prevent an operator from mistakenly

putting two components together upside down.

OneWeb Satellites tapped suppliers new to the space sector, a group including partners selected for their expertise and skill in supporting low-cost manufacturing in the automotive, personal computing and other industries. New suppliers all had to undergo a qualification process. The idea was to have a purpose-designed part, as opposed to a one-size-fits-all component designed by a well-established supplier in the space industry.

The assembly lines outside Kennedy Space Center trace their design back to Toulouse, where a pilot factory produced the first 10 OneWeb satellites.

In Toulouse, Airbus devised and "debugged" the production process while automated guided vehicles helped streamline logistics. For example, a collaborative robot (cobot)

ONEWEB SATELLITES

holds up a heavy part while the operator fits it into a subassembly. A smart drill only starts when positioned with the correct angle.

Functional checks take place during the assembly process as well.

UNITED LAUNCH ALLIANCE

A Boeing CST-100 Starliner being prepared for orbital flight test.

Such time savings are conventional in commercial aircraft manufacturing.

Digital continuity also has been introduced, which allows a single component to be tracked over its life cycle. In-orbit satellites are supposed to share data that eventually may improve a part's design and its manufacturing process.

The Toulouse factory was created as an Airbus—as opposed to OneWeb Satellites—facility. It aims to parlay its expertise building high-quality, small spacecraft for broadband services to other applications and for other customers. While a second customer has yet to be found for the Arrow bus, Airbus has been awarded a contract from the Defense Advanced Research Projects Agency (DARPA) to develop a satellite bus in support of the Blackjack communications networks demonstration program. The bus to be built for DARPA will reuse the methods Airbus created for Arrow.

The satellite boom may be just beginning: A December 2019 report by consultancy Frost & Sullivan forecast a whopping 20,425 satellites will be launched in 2019-33. Northern Sky Research predicts more than 8,135 small satellites will launch in 2018-28.

Around 2,000 of those satellites could belong to OneWeb. SpaceX is proposing to operate 12,000-42,000 satellites. Details about a constellation owned by Amazon are pending. And those are just the more well-known of some 120 smallsat constellations currently planned for communications, Earth observation and other services. Northern Sky estimates about 18% of the networks will come to fruition.

Clock Is Ticking for NASA Commercial Crew Program

ANOTHER YEAR AND STILL NO HUMAN launches to orbit from the U.S., though four Virgin Galactic pilots and one engineer have made it into suborbital space during trial runs of SpaceShipTwo.

Virgin Galactic founder Richard Branson has talked about riding on SpaceShipTwo for years, but now he has started weightlifting and other activities to prepare for the flight, which he expects will occur in 2020, assuming the rest of the tests go as planned. Paying passenger flights are expected to follow.

Likewise, Jeff Bezos' Blue Origin has yet to include people on any of its suborbital flight tests of New Shepard, which conducted a 12th uncrewed mission in December. Company employees are expected to be aboard for flight tests next year.

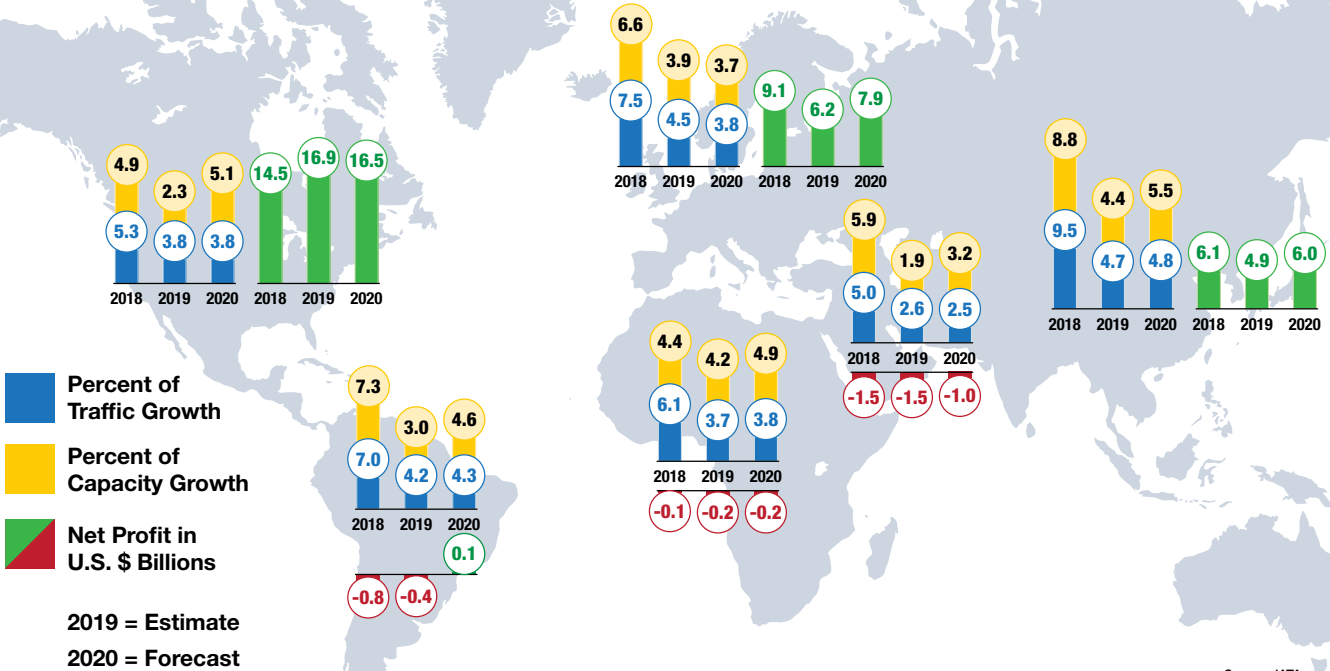
The stakes for U.S. orbital spaceflight are much higher as NASA is running out of launch slots for astronauts on Russian Soyuz spacecraft, currently the only transportation option for ferrying crews to and from the International Space Station (ISS.)

Due to early funding shortfalls and technical challenges, both Boeing and SpaceX are years behind in efforts to develop and operate commercial space taxis for NASA. But they are getting close: Boeing is due to complete an uncrewed orbital flight test of its CST-100 Starliner at the ISS in December, while SpaceX aims to polish off an inflight abort demonstration in early January. Those flights would leave both companies in position for launches with crews in early 2020, the last major milestones before certification and the start of operational crew rotation missions.

The clock is ticking. NASA's last paid ride on a Soyuz launches in April.

Gallery *See a review in photographs of key events in the satellite sector in 2019:* **AviationWeek.com/Rotors2019**

Traffic and Capacity Growth, Net Profit by Region



Source: IATA

2020 SHAKY ASSUMPTIONS

IATA forecasts slight rise in airline profits, but uncertainty is high

Jens Flottau Geneva

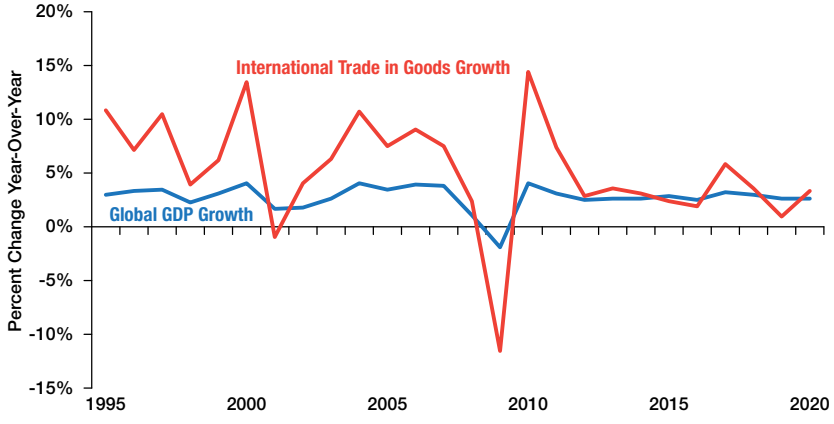
On the surface, the International Air Transportation Association (IATA) is offering an optimistic global airline industry outlook for the next year. After all, the $29 billion in net profits it forecasts is more than 10% higher than the $25 billion recorded in 2019. But when examined closely, the figures provide more reason for concern than for optimism. The golden times of 2015 and 2016, when the industry reported record margins, are unlikely to recur soon.

A quick look back delivers some context. A year ago, IATA predicted a $35 billion profit for the industry for 2019 and twice had to revise its guidance downward in what ultimately became a reduction of almost 30% compared to its initial forecast. The single most important reason why the result was so much different than expected: trade wars.

IATA Chief Economist Brian Pearce says the worldwide slowdown in air travel since early 2018 reflects "the damaging impact of the trade war on economic growth and business confidence." Air cargo is having "an extremely tough time," he notes, with demand contracting by 3.3% in 2019 and predicted to recover only slowly in 2020, if at all. And on the passenger side, the industry has deviated downward from its long-term growth path of around 5% annually and the much faster expansion it experienced over the past few years: IATA predicts passenger traffic will show only a 4.2% increase in 2019.

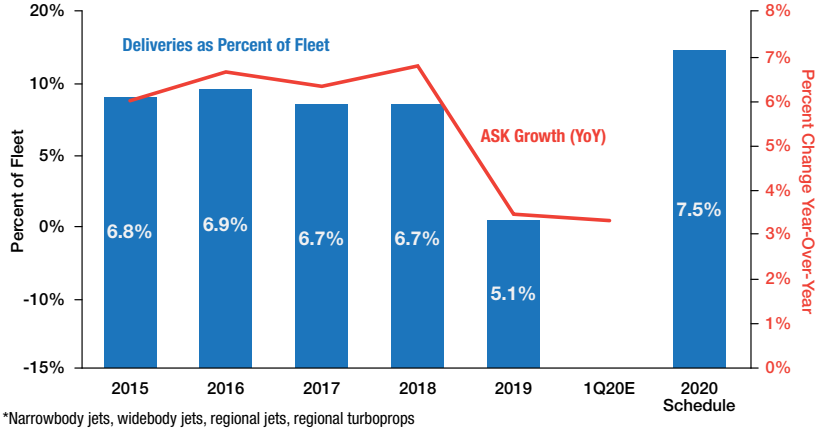
The lower 2019 profit basis is equivalent to around 50% of the peak margins airlines reached in 2015 and 2016. And there have been several high-profile failures, including tour operator Thomas Cook, taking with it a large part of its airline unit and Icelandic low-cost carrier WOW Air. Many other airlines are struggling, including Norwegian, a pioneer in the latest wave of long-haul low-cost travel. The truth is, as IATA describes it, only around 30 airlines globally "have been responsible for the improvement over the past 10 years," including, most importantly, the big U.S. carriers reaping the benefits of industry consolidation. "There is a long trail of airlines barely breaking even and a group making significant losses," Pearce says. For these, "performance has not improved over the last decade"—which he considers is the reason why "we have seen a series of airline failures over the last two years."

International Trade and Global GDP Growth



Source: IATA IMF World Economic Outlook

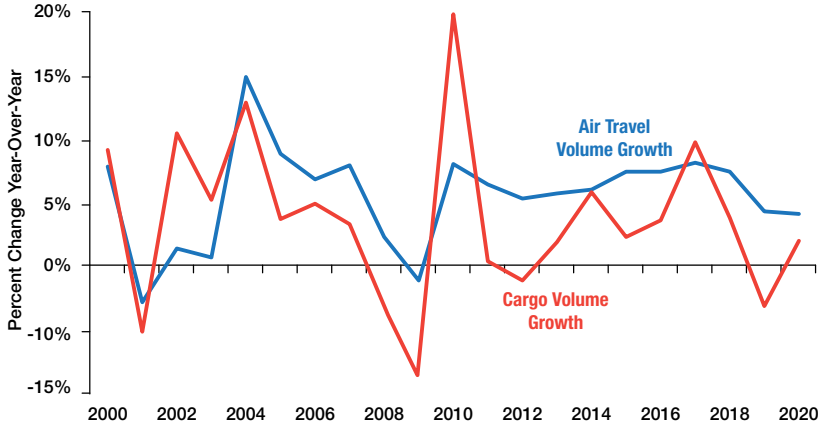
Aircraft Deliveries and Capacity Growth*



*Narrowbody jets, widebody jets, regional jets, regional turboprops

Source: IATA Ascend

Passenger and Cargo Demand Trends



Source: IATA

People To Watch

Steve Dickson, FAA Administrator

Steve Dickson, FAA administrator since August 2019, is not just the key figure in determining when and how the Boeing 737 MAX will return to commercial service. His other priorities include restoring confidence in the FAA, much criticized for having delegated too much to Boeing, and defining the agency's role in future aircraft certification programs and drone integration in the national airspace.

Patrick Ky, EASA Executive Director

Patrick Ky has been EASA's executive director since 2013. But he has never been in a more powerful position than now. The Boeing 737 MAX crisis cast doubts over the FAA leadership role and Ky already has indicated EASA intends to play a more active and independent role in future aircraft certification programs such as the upcoming 777X.

Stan Deal, Boeing Executive Vice President

Having previously been in charge of Boeing's project to transform its services business, Stan Deal is facing an even greater challenge: He has to solve the myriad problems facing the company's commercial aircraft segment—getting the 737 MAX back in service, solving the 777X development issues while finding new customers and making key strategy calls including on the planned new mid market airplane (NMA).

Jacob Schram, incoming Norwegian CEO

Over the past few months, acting Norwegian Chief Financial Officer Geir Karlsen has managed to stabilize an airline that looked close to a collapse a year ago. In January, Jacob Schram willl be taking over the airline, and he faces the difficult task of making Norwegian sustainable for the long-term. Schram, 57, has decades of experience in running large companies but is new to aviation.

Augustus Tang, Cathay Pacific CEO

Augustus Tang was away from Cathay Pacific for 11 years, having run maintenance company Haeco. He was hired back in 2019 to run the airline following the resignation of Rupert Hogg at what looked like the peak of the political crisis in Hong Kong. Since then the situation has become worse, not better, and Tang has had to deepen cuts to the airline's network to keep pace with the reduction in demand. His task: steering Cathay Pacific through one of its worst crises.

Scott Kirby, United Airlines President

It has been three years since Scott Kirby joined United as president, having just left American Airlines. Since then he has served as No. 2 under CEO Oscar Munoz. In May, Kirby will become the CEO of a major airline, after having been in top management for over 20 years. His know-how is undoubted, but now he will have to prove that he also has the people-management skills needed, too.

PHOTOS FROM TOP: FAA, EASA, BOEING, NORWEGIAN, CATHAY PACIFIC, UNITED

It is also the reason why the industry remains vulnerable, particularly to "cash-flow shocks" as the high levels of debt for some airlines mean a continuing burden of fixed expenses for repayment and interest.

While IATA no longer anticipates a recession and actually now believes global GDP growth could be higher in 2020, the industry group's current forecasts are based on the assumption of a "trade war truce," among other things. This assumes current tariffs will stay until at least the U.S. elections in November but will not be increased. As a result, international trade could grow from its 0.9% increase in 2019 to 3.3%, which IATA considers "still exceptionally low" and only marginally higher than the expected rise in global GDP.

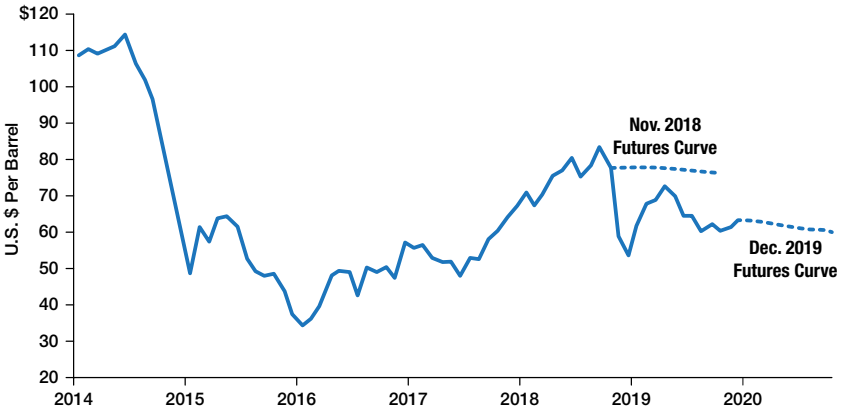
Another uncertainty is the degree of capacity growth. Airlines worldwide are expected to take delivery of more than 2,100 aircraft in 2020. At 7.5% of the in-service fleet, that is a higher share than has been seen for a number of years and much more than the 5.1% recorded for 2019.

The future of the Boeing 737 MAX is an obvious factor. There were no MAX deliveries after March 2019, and there will be none until early 2020. Whether airlines then are forced to add more capacity than justified by market conditions depends on several factors. It is not yet clear how long reintroduction of the MAX will take, and its real impact on capacity may only be felt in the summer or later. Airlines also have some flexibility, as they can resume aircraft retirements that were delayed to fill in capacity gaps with the MAX out of service.

Keeping capacity under tight control will be important. Even if there is a trade-war truce, IATA expects air travel to grow by only 4.1% in 2020. Cargo volume is expected to return from its 3.3% drop this year and show a slight, 2% growth.

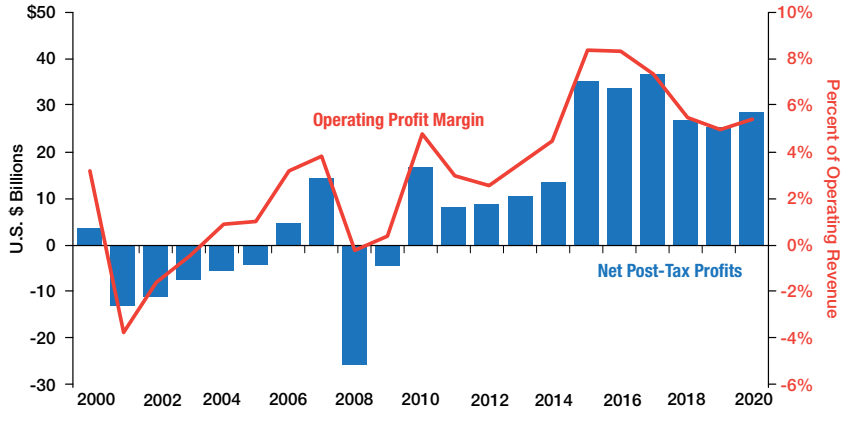
While the industry profit level will improve a bit, assuming no major events change the picture, financial sustainability is not evenly distributed. North American airlines will remain the most profitable players, followed by European carriers. Latin American and Asia-Pacific airline results are likely to remain below profit levels expected by investors, and the situation is even worse for airlines in the Middle East and Africa.

Oil Price Development



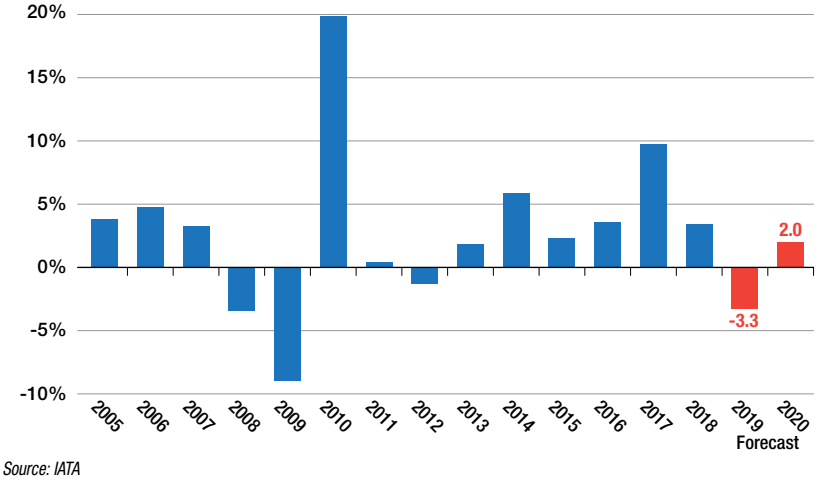
Source: IATA, Platts, Refinitive Datastream

Airline Industry Profitability



Source: IATA

Air Cargo Development



Source: IATA

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DEFINING YEAR

> BOEING TARGETS RETURNING 737 MAX TO SERVICE IN 2020

> CUSTOMER RECEPTION FOR MAX TO DETERMINE FUTURE PRODUCT STRATEGY

> AIRBUS A321XLR LEADS CONTINUING NEO SALES SUCCESS

> AIRBUS PRODUCTION CHALLENGES TO PERSIST THROUGH 2021

Jens Flottau Frankfurt, **Guy Norris** Los Angeles and **Bradley Perrett** Beijing

Looking ahead at the next year or so in aerospace normally entails reviewing aircraft programs that are awaiting certification, production challenges, the changing competitive landscape, and the outlook for trade and passenger demand, which typically translates into more or fewer aircraft orders—and more or less serious problems for airlines.

But even before it begins, 2020 will be different because, as the year gets underway, the industry will continue to grapple with the unprecedented turmoil caused by the grounding and production halt of the Boeing 737 MAX. The slower-than-expected comeback effort will overshadow everything—and its ripple effects will reverberate throughout the business, affecting regulators, suppliers, operators and Boeing's own product decisions.

First and foremost will be the repercussions for the company's proposed new midmarket airplane (NMA) and determining whether Airbus' market share advantage in the narrowbody segment is permanent and growing. It also will be an indicator of just how long Boeing will be able to extend the life of the MAX and whether development work on a new single-aisle will have to be accelerated.

As if all of that were not enough, the industry is facing the very real prospect of becoming entangled in an escalating trade war between Europe, the U.S. and China, the effects of which are already being felt by all sides. The U.S. is levying import tariffs on Airbus aircraft other than those built in Mobile, Alabama, or Montreal. Because of these trade tensions, China has not ordered the Boeing 787s the company needed to sustain the 14 aircraft per month production rate for its latest widebody. And when the World Trade Organization (WTO) authorizes the European Union to impose tariffs on

The Boeing 737-10 was rolled out in November, one rare bit of good news for the troubled MAX program.

BOEING

Boeing aircraft at some point in the first part of 2020, to compensate for damage caused by state subsidies, the fallout is all but guaranteed to become much worse.

BOEING RECOVERY

Events in 2020 will also largely dictate the fortunes of Boeing Commercial Airplanes for the rest of the decade across every sector, ranging from the single-aisle and midsize markets to the higher-capacity twin-aisle battleground.

Derailed by the global grounding of the MAX fleet in March 2019 and the subsequent temporary production halt in the wake of two fatal accidents, as well as by engine-related delays to the 777X program, Boeing's carefully choreographed product development master plan from the early 2010s has been significantly altered. Amid the overall MAX program woes, the last family variant—the 737-10—has entered development, with first flight expected in the first quarter.

The aircraft, which is 66 in. longer than the 737-9, was rolled out at Renton during a low-key employee event in November 2019 and is designed to carry up to 230 passengers in a single-class layout. Equipped with the updated flight control system and software developed for the other family members, the test campaign will focus on unique elements of the stretched design including wider midaircraft-exit doors for faster passenger evacuation, handling qualities and semi-levered landing gear. The program may also benefit from lessons learned in dealing with earlier design issues uncovered with the additional exits in 2019 during tests of the high-capacity 737 MAX- 200 variant of the 737-8.

The MAX return to service is meanwhile dragging into the new year as Boeing completes the last milestones for recertification. Following the FAA certification flight to finalize fixes to the MCAS software, these remedial steps include Boeing's final submission of certification materials to the FAA and its package of proposals to the Joint Operational Evaluation Board's simulator training evaluation to finalize pilot training requirements.

Depending on the progress made through these steps, the return to commercial service for U.S.-registered aircraft is now expected in March at the earliest, with other internationally registered fleets possibly following several weeks or months later. Another factor that may cause additional delays is the FAA's decision, announced in late November, to bring certification for airworthiness and export certification in-house for all grounded and stored, undelivered 737s until it is confident Boeing has "fully functional quality control and verification processes in place" and the delivery process is "stable," the agency says.

One of the biggest mid-to-long-term impacts of the MAX crisis was Boeing's difficult decision, announced on Dec. 16, to temporarily halt production starting in January 2020. Instead of building up more inventory, the move enables Boeing to focus on dispatching the backlog of 400+ undelivered aircraft built during 2019 in addition to supporting the return to service of the 387 MAXs stored around the world since the grounding. Amid this disruption to the manufacturing system, as well as the uncertain timeline for recertification, it now seems unlikely that Boeing's original plan to ramp up 737 production to 57 per month can be achieved until late 2021 at the earliest.

The unprecedented scale of the MAX grounding also has affected the company's plans to launch the NMA. While there has been speculation that Boeing may be considering pushing back the NMA and even reprioritizing its next project focus toward a new/replacement single-aisle airplane (NSA/RSA), sources within the company's product development strategy unit tell Aviation Week that launching the NMA remains the near-term goal.

Although Boeing originally had hoped the NMA could be launched in time to enter service in 2025, the focus on putting the beleaguered MAX back into service has delayed moves to close the business case and seek permission in 2019 from the company's board for formal authority to offer (ATO). With resolution of the MAX crisis drifting deeper into 2020, the ATO for the NMA is expected to come later in the year.

However, the NMA business case suffered a setback when United Airlines placed an order for 50 Airbus A321XLRs to replace its fleet of Boeing 757s. The airline clearly came to the conclusion that the larger versions of the MAX were not a viable replacement alternative for the 757, nor was it worth waiting for Boeing's NMA. American Airlines has ordered 50 A321XLRs and Delta Air Lines also has a large A321neo order that could conceivably be converted to the XLR although Delta has made clear it remains interested in the NMA as these carriers, like United, seek replacements for their aging Boeing 757 fleets. "We have never believed that the NMA business case added up, nor do we believe that the particular market segment (250 seats/4,000-5,000 nm) has ever justified a stand-alone new model," Agency Partners analyst Sash Tusa wrote in a note to clients. "With the 757 replacement now sewn up by the XLR, we think that Boeing will have to move swiftly and publicly toward offering a 737 MAX replacement."

Nonetheless, Boeing for now is still proposing to offer two main NMA versions—the 225-seat NMA-6X and 275-seat NMA-7X, with the larger of the pair expected to be developed first. No firm decisions have yet been announced by Boeing on the prospective timing of the program or the identity of key suppliers such as the engine partner. The GE-Safran CFM International joint venture is competing against Pratt & Whitney to be the sole-source supplier, Rolls-Royce having officially dropped out of the contest in early 2019.

Engines could also be a key pacing factor for Boeing as it weighs any moves to accelerate plans for a 737 replacement. With all the major engine makers challenged by costly development programs and, in the case of Pratt and Rolls-Royce, expensive upgrade issues for in-service products, the appetite for a second all-new engine beyond the 50,000-lb.-thrust class designs for the NMA remains limited.

But the engine manufacturers are more than eager to find new applications for existing products. GE has floated the idea of reengining the 767-400 with a new variant of the GEnx-2B currently built for the 747-8. Dubbed the 767-XF, the new variant would be offered first as a freighter-only version of the venerable twinjet but could—in principle—form the basis for a lower-cost passenger option for the NMA.

Meanwhile, Boeing is poised to deliver the first 767 produced at the recently stepped-up rate of three per month. Although the company delivered the final passenger 767 in 2014, production of the freighter version has continued, underpinned largely by the

Airbus has suffered some setbacks for its widebody backlog and has to hope sales will gain momentum in 2020.

AIRBUS PHOTOS

KC-46A tanker variant for the U.S. Air Force. The rate increase, announced in April 2018, reflects consistent orders from freight operators FedEx and UPS. As of early December, the undelivered backlog stood at almost 100 aircraft, most of which are for FedEx.

Boeing is simultaneously bolstering sales and marketing campaigns in 2020 for the 777 and 787, both of which are facing weaker demand amid sluggish sales for twin-aisles and headwinds from trade tensions with China. In response to these pressures, Boeing has already decided to trim back production of the 787 from the current 14 per month to 12 starting in late 2020. Production of the 777 is also due to slow from 3.5 per month to three during the same timeframe.

The company hopes 787 production will accelerate again around 2022, when a wave of small-to-medium widebody replacement orders is expected. Overall, Boeing forecasts a requirement for around 1,000 aircraft in this sector by the late 2020s. The backlog for the current 777 has dwindled to around 60 aircraft, the bulk of which are 777F freighter models, and provides a weaker-than-hoped-for "bridge" to sustain the line until production of the follow-on 777X steps up from 2020-21 onward.

The initial 777X variant, the 777-9, is expected to make its first flight in January, following the delivery of retrofitted flight-compliant GE9X engines in October and November. The revised engines incorporate changes to improve durability following the discovery of issues with the compressor inlet guide vanes, which have delayed the start of flight tests from mid-2019 to early 2020. First deliveries to Emirates and Lufthansa have subsequently been pushed back to 2021.

AIRBUS CHALLENGES

For Airbus, 2020 also looks like a year of recovery but in a very different way than Boeing. Although it is not banned from delivering its highest-volume aircraft, Airbus continues to struggle simply with the overwhelming amount of work needed to ramp up production and introduce multiple new aircraft variants at the same time.

Finally getting its production process sorted out will be the top priority for Airbus in 2020. Customers worldwide continue to see delivery dates of their aircraft orders—mainly versions of the A321neo—being pushed back by weeks and often months. International Airlines Group CEO Willie Walsh has long called the delays unacceptable, and he is one of many. Air Lease Corp. Executive Chairman Steven Udvar-Hazy has also had numerous conversations and meetings with Airbus about the issue. As a result of the delays, New York-based JetBlue Airways had to scale back its fleet growth to what it calls an "unusually low" level. The airline had planned to take 13 A321neos in 2019 but was told by Airbus that it would receive only six.

To the surprise of many, Chief Commercial Officer Christian Scherer said at the recent Dubai Airshow that he expected the A321neo delays "to evaporate over the next few months." Even his boss Guillaume Faury, while staying diplomatic, called that assessment "optimistic." Indications are that the delays will be overcome in 2021 at the very earliest. The issues on the A320neo family go back to 2018, when Airbus had to stop deliveries for several months mainly because of engine rework on the Pratt & Whitney PW1100G. When the engines were fixed and the delivery stream seemed on the verge of being normalized, Airbus discovered that Pratt and CFM International were not the only ones to blame. At that point, the Hamburg final assembly line moved into the spotlight. "In 2019, we woke up to the [Airbus Cabin Flex (ACF)] challenge," Faury says.

The ACF is the far more complex A321neo cabin designed to allow more spacious, comfortable premium layouts mainly for the A321LR and XLR that should eventually become common on all A321neos. ACF-related changes include the removal of the exit doors located forward of each wing, which are replaced with overwing emergency exits. The third door pair, located aft of the wings, are also moved further back.

Building the ACF requires around 30% more work than a standard A321neo. Airbus continues to produce the standard variant, but the majority of A321neos will be ACFs. Chief Operating Officer Michael Schoellhorn adds that the A321XLR variant requires another 10-15% of extra work on top of the already-complex configuration.

With the transition from the final batch of the A320ceo family to the Neos, and the rate increases, the production problems have spiraled out of control. Faury's target is now to "stabilize delays in spite of the ramp-up." Getting back on track and on schedule is a project that he believes can be completed only by 2021. "I think we are doing the right things," he says. One of the main pillars of this recovery effort is an additional final assembly line in Toulouse, mainly to be used for A321neos.

The move is part of a broader production study undertaken by Schoellhorn to provide more capacity quickly to tackle the severe delays. Airbus so far has eight final assembly lines (FAL) for the A320/A320neo family. Four are in Hamburg, two are in Toulouse, and the remaining two are in Mobile, Alabama, and Tianjin, China. The German site added the fourth line in 2017 to grow capacity, but teething issues have led to less efficient production there in the early years.

Toulouse builds A319s and A320s, while Hamburg makes all three models. Mobile also produces A321s but not so-called "heads of versions"—the first aircraft for a new customer or in a new configuration. Mobile and Tianjin currently build a combined 10 aircraft per month, with the majority of the rest allocated to Hamburg. Airbus delivered an average of 48 single-aisles per month in the first 11 months of 2019 (not counting 41 A220 deliveries), less than the 52 handed over in the first half of 2019. The company does not publish a precise split between production at Hamburg and Toulouse.

"We need greater flexibility in the Airbus-wide production network," Schoellhorn says. Adding a line in Toulouse will "relieve Hamburg, where the main burden of the ramp-up of the long-range versions and their complex cabin configurations lies."

Airbus planned to achieve an output of up to 60 narrowbody aircraft per month by the end of 2019, a target that now looks likely to slip into 2021 even if the traditional year-end rally allows some recovery. The manufacturer has committed to 63 per month in 2021.

With 3,201 firm orders at the end of November, the A321neo makes up almost 45% of the firm order backlog of the A320neo family. The model will represent about 50% of Hamburg production soon, driven by demand for higher-capacity narrowbodies and the new A321LR and XLR versions. In comparison, the A321 share of sales was only 22% in the classic A320 family. The A319 had 18% and the A320 60%.

Toulouse was chosen, among other reasons, because of the winding down of the A380 program, with the last aircraft being handed over to Emirates in 2021 although likely to be built next year. That meant that Airbus needed to identify other ways to fill the large existing facilities there.

However, the shift to Toulouse is less straightforward than it initially appears. The two existing FALs for the A319 and A320 are in urgent need of modernization. As new tools and processes are introduced, capacity can be expected to temporarily decline—an effect that the third line would have to compensate for initially before providing room for growth. The timing of such modernization moves also depends on the progress in fixing A321neo ACF bottlenecks.

The year 2020 will witness the final drizzle of A320ceo deliveries. At the end of November, only seven A319s, 23 A320s and 47 A321s remained in the backlog.

Airbus also has to manage the transition from the A330ceo to the A330neo despite continuing delays in Rolls-Royce Trent 7000 engine deliveries. Airbus has yet to deliver 21 A330-200s, 19 -300s and four A330Fs before the first-generation line is closed. The backlog for the -900 is solid at 285 aircraft, 37 of which have been delivered. Kuwait Airways remains the only customer for the -800 for now.

The A350, Airbus' most important widebody program, is running smoothly at a production rate of 10units per month. Given the economic uncertainties and recent cancellations or deferrals (including one from United Airlines), Airbus has decided to keep output stable for now rather than moving to higher rates. Some see a risk of having to slow down production post-2022 if orders remain at low levels. The A350-1000 now can accommodate a 480-seat configuration, 40 more than previously. The 777-9 exit limit is at 475.

The narrowbody production issues come at a time when Airbus could take advantage of the MAX crisis and gain an even bigger share of the narrowbody market. Whether and when that will happen depends on the extent to which Boeing succeeds in regaining customer trust in the aircraft.

Airbus has another lever that provides much-hoped-for growth potential: the A220. A year and a half after Airbus took control of the former Bombardier C Series, sales are gaining momentum and the strategic value of the takeover has become undeniable. As Boeing ponders its future product strategy, Airbus has the most modern and efficient single-aisle model in its portfolio. It does not have to worry about whether the A319neo will be a success; it has the A220-300 instead. Further into the future, Airbus can easily position an A320neo-family successor with higher capacities because the A220-300 and the stretched -500 already on the drawing board can backfill the gap that exists around 150-180 seats.

As for the A320neo, the challenge lies in the execution. Airbus has started construction of the third A220 final assembly line in Mobile. The first two are based at the former Bombardier facility in Mirabel near Montreal. The first Mobile-built A220 is still made in the adjacent A320 hangar and will be delivered in 2020. The A220-dedicated building is to open late next year, allow-

Air France took delivery of its first A350 and ordered more, trading in its fleet of A380s.

ing Airbus to build up to four A220s per month once production is in full swing.

All A220s earmarked for U.S. customers are to be delivered from Mobile—so far, customers include Delta, JetBlue and David Neeleman's Moxy. Mobile provides welcome relief for Airbus as the company battles the fallout from new tariffs on aircraft imported into the U.S., currently set at 10%, in the dispute over state subsidies in a World Trade Organization (WTO) case. The European case against the U.S. and Boeing is likely to reach the retaliation stage fairly soon, at which point the European Union could impose tariffs on Boeing imports in the spring of 2020, providing an unwelcome opportunity for further escalation.

As Airbus is starting to reap the benefits of its A220 deal, Boeing's proposed takeover of Embraer's Commercial Aircraft unit is still up in the air, with the European Commission (EC) having launched an in-depth stage two regulatory review. The EC argues that the Embraer E2 family provides some level of competition at the lower end of the narrowbody segment, though most in the industry would disagree with the assessment that the E2 competes with any of the MAX versions. However, the EC is concerned that the U.S.' aggressive stance on trade matters and tariffs could lead to a de facto monopoly for Boeing in the U.S., with Airbus unable to export aircraft as tariffs rise.

Boeing Brazil Commercial was expected to have been set up by the end of 2019, but the start date is now shifting well into 2020. That process is more complex than it appears, as administrative dismantling and the relocation of staff into the future, smaller Embraer and the commercial unit is already well underway. Running the business while the company is being restructured will be a burden well into next year.

Once Boeing and Embraer have received the all-clear from regulators, they can go about proving that the combination was the right move in the first place. There are still two schools of thought about this. Embraer's management argues that the company had no choice but to find a strong partner, as it is now competing against behemoth Airbus rather than financially struggling Bombardier, which has now exited the commercial aircraft business following the sale of the CRJ program to Mitsubishi and of the Q400 to Longview.

The other school believes Embraer acted out of fear and could have thrived without the tie-up, particularly now that the A220 appears to be moving upmarket with the sales success of the -300, the declining role of the smaller -100 and the expected -500 launch, which will move it away from direct competition with Embraer. Many also fear that Boeing has no real interest in selling the E2 and that the potential for joint campaigns with the MAX will be limited anyway. The one upside for Embraer is its possible involvement in developing future Boeing aircraft such as the NMA or a large role in a new narrowbody. Gaining market momentum for the E2 is the near-term challenge.

Orders for Comac's first airliner—the ARJ21 regional jet—are exceeding expectations, the state company says. In an obviously coordinated move, the three biggest Chinese airlines each ordered 35 ARJ21s Aug. 30. Deliveries are due to begin in 2020.

Japan's dimensionally comparable but more advanced regional jet, the Mitsubishi Aircraft SpaceJet, was due for first delivery in mid-2020 after 12 years of development. But the president of the program majority owner Mitsubishi Heavy Industries, Seiji Izumisawa, said in November the test-flight program was under review. Delivery could be further delayed.

CHEN CHENG

In early December, the fifth C919 prototype left Shanghai to transfer to a test base at Nanchang.

DEVELOPMENT IN ASIA

The Craic CR929 widebody airliner program should wrap up supplier selection in 2020, around three years after full-scale development was launched. The consortium of Comac and United Aircraft Corp. (UAC) passed a milestone late in 2019 when the two sides finally agreed that the engineering center would be in Moscow. The CR929 will enter the market in the mid-2020s, says Anatoly Serdyukov, the head of aviation businesses at UAC partner Rostec, apparently referring to the timing of first delivery.

Comac looks like it will have a complete fleet of flight-test aircraft for its C919 narrowbody program in 2020, achieving the milestone later than it was expected, in the first half of 2019. The first delivery aircraft is also due for completion in 2020—though not due for actual delivery until 2021. Certification of the C919 is now due in 2021, a year later than the earlier schedule.

This slippage raises the possibility that lead operator China Eastern Airlines will not get its first C919 until 2022.

The type was formerly known as the MRJ. A new version, the SpaceJet M100, replaces the originally planned MRJ70 with the aim of achieving as much payload-range capability within the gross-weight limit imposed on outsourcing carriers by pilot contract terms (scope clauses) at major U.S. airlines. The larger version, the SpaceJet M90, formerly the MRJ90, does not comply with those terms. It will be the first version to enter service.

The first airframe of Avic's MA700 regional turboprop program has entered production and will be used for static strength-testing. The state company plans to fly the first complete MA700 in 2020. As of September, the airframe of that aircraft was due for completion around the end of 2019. Three more flight-test aircraft should be delivered in 2020, followed by a static fatigue-test airframe. Avic plans to achieve MA700 certification in 2022.

Gallery *See a review in photographs of key events in commercial aviation in 2019:* **AviationWeek.com/Commercial2019**

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BOEING

Changes in how aircraft are certified could affect the Boeing 777X program.

Added Scrutiny

> GLOBAL REGULATORS TO VALIDATE EACH OTHER'S WORK MORE OFTEN

> HUMAN FACTORS MUST HAVE MORE INFLUENCE IN AIRCRAFT DESIGN

Sean Broderick Washington

In the coming years, aircraft certification efforts are likely to be more drawn out and scrutinized, human factors experts will have greater influence throughout the design and approval processes, and regulators will evaluate each other's decisions more closely rather than embracing blanket reciprocity—even if they have collaborated for years.

These are just some of the changes the Boeing 737 MAX saga will trigger in global aviation safety. Signs of change already are evident in the FAA's approach to gaining consensus on Boeing's proposed MAX changes. The group of pilots evaluating the MAX's modified flight control computer software as part of formal approval efforts have come from around the world and have varied experience levels. In the past, the FAA relied heavily on feedback from U.S. pilots.

Change is evident at the industry level as well. Late-summer simulator demonstrations by Boeing of the modified MAX software included at least one pilot with no MAX experience.

While seemingly subtle, the new approach constitutes an acknowledgment that regulators and manufacturers must view their work with a broader perspective.

"Over the years, the FAA has exercised a leadership role in the promotion and development of global aviation safety. We have helped raise the bar on safety standards and practices around the world, working with [the International Civil Aviation Organization (ICAO)] and other civil aviation authorities," says FAA Administrator Steve Dickson. "We have an opportunity to do even more."

For regulators that certify air transport aircraft, this process includes recognizing their decisions have ramifications beyond the companies they regulate. In the U.S., for instance, a 2013 rule change increased minimum standards for airline first officers to at least 750 hr. for pilots with military experience, and as many as 1,500 hr. if other qualifications are not met. Airlines that the FAA regulates must abide by the new rules, but the aircraft the agency certifies are flown by carriers around the world, and many countries have different requirements.

"We've always done the [pilot training] evaluations with the mindset of our system and our understanding of our system," a senior U.S. government official says. "[The MAX situation] has highlighted that when you have the majority of the fleet going [to other countries], maybe we have to look at it differently."

The MAX ordeal has spotlighted numerous issues that regulators and industry must address. Boeing lobbied the FAA to keep information about the MAX's Maneuvering Characteristics Augmentation System (MCAS) flight control law out of pilot manuals and training materials. Boeing's rationale: Pilots would evaluate MCAS-related malfunctions as common failures, such as a runaway stabilizer. They did not need to know what was causing the issue—just how to respond. The FAA approved the requests.

Two fatal MAX accidents within five months showed Boeing was wrong. The FAA has acknowledged pilots should have known about the MCAS, which was added to the MAX to address handling stability issues created by the model's larger engines compared to those on the previous generation of 737s. Changes to the MAX that the FAA is expected to mandate include adding the MCAS to manuals and training.

The FAA's oversight of the MAX development and approval has raised concerns with other regulators. One immediate result: Many plan to validate at least some of Boeing's proposed changes on their own instead of accepting the FAA's judgment. This likely will carry into future certification programs, starting with the Boeing 777X.

"In the case of the MAX, there were some shortcomings on the Boeing side and in the relationship between Boeing and the FAA," European Union Aviation Safety Agency Executive Director Patrick Ky says. "It is a bit too early to draw definite conclusions. We have started discussing with the FAA what we are going to do next, and how we will be organizing ourselves in the future. I'm certain that the FAA will review some of their processes after all of this."

Bigger-picture issues linked to pilot performance also will be addressed—and likely debated.

"Basic assumptions about trained

and qualified flight crew response to malfunctions used in the design and certification of the 737 MAX 8 did not appear to hold in the two accident cases, based on preliminary information," says a report into the MAX's flight control system from the Joint Authorities Task Force (JATR), which comprised representatives from 10 regulators.

The task force determined the long-accepted pilot recognition and reaction time standards, extant since the 1960s, need revisiting. "No studies were found that substantiate the FAA guidance concerning pilot recognition time and pilot reaction time," the JATR says. A NASA study of airline pilots "found substantially longer recognition times and reactions time, even in the case of expected events," than the FAA's figures, the task force adds.

"Modern aircraft can have subtle failure modes that may take substantial amounts of time to be recognized," the report continues. "Furthermore, automation can mask some failures and significantly delay the possibility for the pilot to recognize the malfunction."

One remedy: Lean on scientific studies to establish "appropriate pilot recognition times and reaction times" and incorporate these into guidance. Recommendations from the NTSB triggered by the MAX accident investigations also cited as a weakness a lack of human factors input into flight deck design.

Improved aircraft design will help bridge gaps between hardware and human performance. But some regulators, including the FAA, are urging actions on the operational side as well.

"If we are to continue to raise the bar for safety across the globe, it will be important for the FAA and our international partners to foster improvements in standards and approaches, not just for how aircraft are designed and produced but also how they are maintained and operated," Dickson says.

A paper copresented by the U.S., Canada, Peru, and Trinidad and Tobago last September urged ICAO to examine "automation dependency" around the world and develop recommendations to address areas of concern.

"Although increased use of automation has enhanced safety, this trend is also likely contributing to a lack of practice and therefore potentially a degradation of pilot skills in flight path management using manual flight control," the paper says. "These skills are essential for pilot confidence and competence, and they are necessary to take control of the aircraft when automated systems do not function as intended. This issue may be complicated further by the variations in pilot training, skills and experience entering air carrier service worldwide."

The MAX's phased grounding created another issue that must be addressed.

As other regulators banned the MAX in the two days after Ethiopian Airlines Flight 302's (ET302) March 10 accident, the FAA held firm. On March 12, then-Administrator Dan Elwell said the information the agency had "provides no basis to order grounding the aircraft, nor have other civil aviation authorities provided data to us that would warrant action." Overnight, the FAA received new details from ET302's accident site as well as satellite tracking data that changed its view.

Such a lack of unification creates problems for airlines that routinely operate single flights that traverse airspace in multiple countries. Having the same aircraft grounded in one jurisdiction and not another also raises questions.

As regulators work on finding common ground on global aviation safety issues, agreeing on a threshold for when to ground aircraft demands a place high on the list.

The lack of regulator unification over the MAX's grounding and return to service is troubling for the industry.

JASON REDMOND/GETTY IMAGES

The Year of Sustainability

> GLOBAL CARBON-DIOXIDE POLICY TAKES EFFECT

> CARBON OFFSETTING SCHEME STARTS IN 2020

Lee Ann Shay Chicago

The year 2020 could have been dubbed "the year of sustainability"—even before 16-year-old Greta Thunberg was named *Time* magazine's Person of the Year for her global climate change activism.

The reason: 2020 will be a pivotal year for the aviation industry in many ways.

First, a global carbon-dioxide (CO_2) policy for aircraft takes effect in 2020. This is part of the International Civil Aviation Organization (ICAO) goal of capping aviation's CO_2 emissions beginning in 2020 and achieving carbon-neutral growth.

The policy, approved by ICAO in 2016, sets a CO_2 emissions standard for new aircraft types launched after 2020. The agreement, the first such standard for aircraft, also will be phased in for all existing types in production beginning in 2023, even if the model was introduced before 2020.

The CO_2 standard focuses on cruise-flight performance because that is when the most fuel is consumed and the most CO_2 is emitted, according to the Air Transport Action Group (ATAG). While aircraft and engine efficiency has continually improved over time—the International Air Transport Association confirmed CO_2 per passenger has dropped 50% since 1990—this standard provides a measure to monitor maximum metric value (fuel burn per flight-kilometer).

Second, in 2016 ICAO also adopted the Carbon Offsetting Scheme for International Aviation (Corsia), which starts in 2020. Corsia is designed to ensure carbon-neutral growth for most international flights beginning in 2020 and to raise about $40 billion from airlines to offset their carbon emissions. Half of the world's 20 largest airlines offer carbon

Electric Propulsion Milestone

Graham Warwick

WITH THE DEC. 10 FIRST FLIGHT OF A DE HAVILLAND Canada DHC-2 Beaver taken from Harbour Air's commercial seaplane fleet and modified to electric propulsion, 2019 ended with a milestone in the electrification of aircraft to reduce their emissions (page 16).

Next steps will include test flights of Ampaire's Electric EEL, a Cessna 337 Skymaster modified to hybrid-electric propulsion, on a route flown by Hawaiian regional Mokulele Airlines. French startup VoltAero also is flying a modified Skymaster as a testbed for a small hybrid-electric regional aircraft.

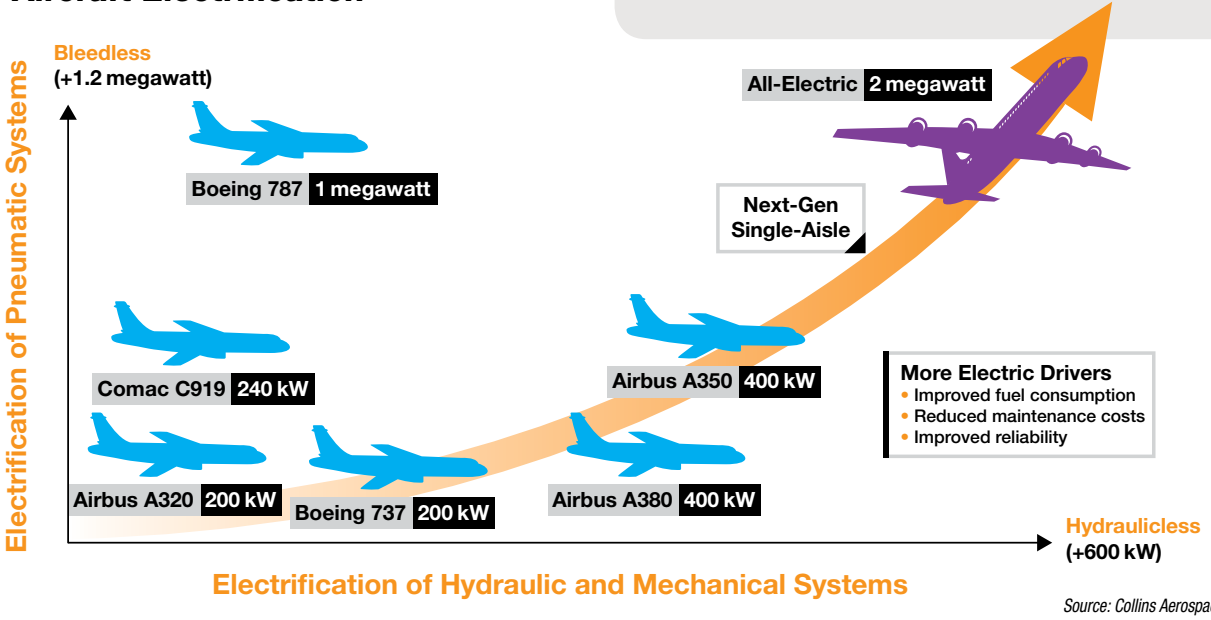
U.S. startup Wright Electric plans to fly a 9-seat turboprop converted to hybrid-electric propulsion in 2020 and MagniX—whose 750-hp Magni500 motor powers Harbour Air's eBeaver—is working with AeroTEC to fly a Cessna 208 Caravan converted to all-electric power in 2020.

The first small regional aircraft designed from the outset around battery-powered all-electric propulsion—Israeli startup Eviation's 11-seat Alice—is planned to fly in 2020 at AeroTEC's flight-test center in Moses Lake, Washington. Alice is powered by three MagniX or Rolls-Royce (formerly Siemens) motors.

More milestones in the electrification of commercial aviation are planned over the next two years. Airbus' E-Fan X, an Avro RJ with a 2-megawatt electric-propulsion system replacing one of if its four turbofans, is planned to fly in 2021 to demonstrate hybrid-electric power for large regional jets.

In 2022, United Technologies plans to fly a de Havilland Canada Dash 8-100 with a 2-megawatt hybrid-electric system replacing one of its two turboprops, and the UK's Cranfield Aerospace Solutions plans to fly an island-hopping Britten-Norman Islander converted to hybrid-electric propulsion.

The Progress of Aircraft Electrification



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2% **The percentage of all human-induced CO_2 emissions that aviation produces**

offsetting, and 41 airlines offer voluntary carbon-offsetting options to passengers, according to ATAG.

IATA argues Corsia is being hindered by some governments—France, Germany, the Netherlands and Switzerland—which are passing carbon taxes for airline passengers. "Taxation aimed at stopping people from exercising their freedom to fly will make travel more expensive but do very little to reduce emissions," says Alexandre de Juniac, IATA's director general and CEO.

12% **Aviation's portion of all transport sources' CO_2 emissions**

Third, by mid-2020, expect the outcome of a cross-functional industry study outlining how the industry can meet its 2050 goal of reducing aviation's net CO_2 emissions to half of their 2005 level. The group working on the analysis includes experts from technology, fuel, airline operations, infrastructure, manufacturing, policy and research. ATAG expects the process, known as Waypoint 2050, to be important guidance for the airline industry.

80 million **Winglets retrofitted on aircraft have saved 80 million tons of CO_2 since 2000**

While the industry has implemented many environmentally friendly concepts on its own—from washing engines to save fuel, to eliminating hazardous chemicals, to adding winglets—the efforts cannot come quickly enough. Climate change activists such as Thunberg will continue putting pressure on the industry, and passenger traffic is growing faster than was expected even 10 years ago.

Expect to see more in the following areas in 2020:

- Investment in more efficient aircraft and engines, including electric propulsion development (see sidebar page 90).
- Sustainable aviation fuel development—yet supply-and-demand principles are keeping fuel costs higher than they need to be (see sidebar below).
- Operational improvements to decrease fuel consumption.
- Airport and infrastructure improvements to cut CO_2 emissions.

Commercialization of Sustainable Aviation Fuel Is Gaining Momentum

Graham Warwick

Beginning Jan. 1, fuel suppliers in Norway must blend 0.5% of biofuel into all jet fuel, the first sustainable aviation fuel (SAF) mandate in the world. Norway's goal is to increase this ratio to 30% by 2030. Sweden and Finland are expected to follow, and the Netherlands could take a similar path.

After rapid technical progress in developing drop-in alternative jet fuels that can be produced from renewable feedstocks, the financial crisis of 2009 dramatically slowed the eagerly anticipated commercialization of SAF as access dried up to the capital required to scale up production.

Now the momentum is beginning to build again. More feedstock-to-fuel pathways are pending approval, but more important, several commercial-scale plants will come on line globally over the next few years, and more airlines are signing long-term offtake agreements despite SAF's higher cost.

In 2019, less than 7 million gal. of SAF was produced, according to the Air Transport Action Group, but construction projects already underway will add 450 million gal., and a further 350 million gal. of capacity is in the advanced planning stage. By 2025, SAF could account for 2% of total aviation fuel supply—a drop in the ocean of jet fuel consumed by airlines, but a step in the right direction.

Current Airports With Regular Sustainable Aviation Fuel Supply

Source: Air Transport Action Group

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> NEAR-TERM DELIVERIES RISE ON NEW MODELS

> LONG-TERM PROJECTIONS CONTINUE TO SHRINK

Gulfstream's new G700 is the largest purpose-designed business jet to date.

GULFSTREAM

Graham Warwick Washington

Business aircraft manufacturers enter the new decade leaner and more focused but more dependent than ever on introducing new products to sustain demand. Factoring in economic and political uncertainties around the globe, most analysts forecast a stable market at best, with the only prospects for growth coming from new models.

This is illustrated by 2019, with business jet shipments expected to end the year up about 10% over 2018, boosted by the first deliveries of new types. Further modest increases are forecast for 2020-21 as production of new models ramps up. But this more positive near-term outlook does not translate into long-term confidence in market growth.

While Honeywell is forecasting deliveries of 690 jets in 2019, up from 633 in 2018 and increasing to 740 in 2020 before flattening to 730 in 2021, this is against a continuing decline in projected long-term demand for aircraft. The company's 10-year forecast for deliveries has contracted from 9,200 in 2015 to 7,600 for its latest 2020-29 projection. While still described as a "healthy market," this downward trend in demand has increased pressure on manufacturers to get their houses in order.

Bombardier is entering the final year of a five-year turnaround plan that has seen the Canadian manufacturer focus on business aviation and divest its commercial aircraft interests. Ramp-up of the ultra-long-range Global 7500 to 40 a year by the end of 2020 will grow revenues, and deliveries of the upgraded Global 5500/6500 will also accelerate over the coming year. But any new aircraft, perhaps to replace the large-cabin Challenger 650, await completion of the turnaround by the end of 2020.

Embraer's delayed commercial aircraft joint venture with Boeing is now expected to be finalized early in 2020, leaving the Brazilian manufacturer focused on executive aircraft and defense. Introduction of the midmarket Praetor 500/600—upgrades of the Legacy 450/500—boosted backlog and deliveries in 2019, but any further updates or replacements for its aircraft will come only after the split is complete.

Gulfstream is in transition between generations of aircraft, shedding jobs as it winds down output of its top-end G650, ramps up production of the new G500/G600 large-cabin family and begins flight-testing a new ultra-long-range flagship, the G700. Deliveries of this stretched derivative of the G650, with the Symmetry flight deck from the G500/G600, are due to begin in 2022.

Dassault is working to broaden its product range, with the widebody Falcon 6X on track to fly in 2021. Replacing the canceled Falcon 5X—a false start that cost four years—the 6X will fit below the long-range Falcon 7X and 8X when deliveries begin in 2022. The next Falcon—dubbed the 9X—is in preliminary design and expected to be a medium-to-long-range widebody optimized for low noise and emissions.

A second attempt to take Cessna's Citation brand upmarket into the large-cabin category ended in July 2019 when Textron Aviation suspended development of the Hemisphere, citing continuing problems with Safran's Silvercrest engine. This leaves the company focused for now on speeding production of the super-midsize Longitude, deliveries of which began in October 2019 after final FAA certification.

Textron's immediate priorities are certification of the utility twin-turboprop Cessna SkyCourier, now expected to fly early in 2020, and the single-turboprop Cessna Denali, first flight of which has also slipped into 2020 because of delays to its GE Catalyst engine. Pilatus will capitalize on the delay, with deliveries of its upgraded PC-12 NGX to begin in the second quarter of 2020.

While the business aircraft market has skewed massively toward the heavy-metal (or high) end since the 2009 downturn, some analysts see the global rise in trade tensions reducing demand for long-range, large-cabin jets. Any shift to smaller aircraft would benefit Embraer and Textron, which have new midmarket models ready, and could influence where Bombardier and Gulfstream move next.

Sustainability is another factor that could influence product strategy. Business aircraft may be a small contributor to aviation's emissions, but they are a ripe target for the "flight-shaming" movement. Increasing the availability of sustainable aviation fuel is the near-term solution but, longer term, pressure to improve efficiency and reduce emissions could shape industry thinking.

Gallery *See a review in photographs of key events in business aviation in 2019:* **AviationWeek.com/BizAv2019**

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> NEW MEDIUM HELOS NEAR CERTIFICATION

> INTEREST EMERGING IN HYBRID PROPULSION

Tony Osborne London

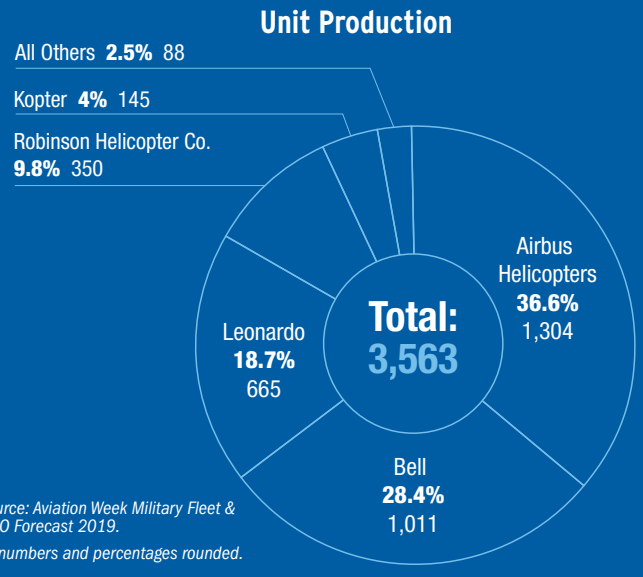
With a commercial helicopter market that remains stubbornly stagnant, it is perhaps no wonder the big helicopter OEMs are reluctant to make major investments in new conventional rotorcraft.

Instead, the focus appears to be on delivering long-running programs and making incremental improvements. Leonardo had already accepted that the AW609 tiltrotor would not achieve FAA powered-lift certification by the end of 2019, but the company is determined to deliver the first aircraft by the end of 2020, more than 15 years after its first flight.

Less certain is the timeline for certification of Bell's fly-by-wire Model 525 Relentless super-medium helicopter. Progress has been slow since the loss of a prototype in 2016, but in recent months pilots from several major operators have flown the aircraft and praised the flight control system, a hint that certification likely will be achieved early in 2020.

In March, Sikorsky lifted the veil on a modernized version of its S-92 heavy helicopter, incorporating the first elements of the company's Matrix automation technology. While Sikorsky has developed a list of options for new-build S-92Bs and retrofitted S-92A+s, only the level of market interest will decide how many of the new capabilities will be introduced.

Civil Rotorcraft Market Share, 2020-24



Source: Aviation Week Military Fleet & MRO Forecast 2019.

All numbers and percentages rounded.

Urban Renewal

> UBER ELEVATE PLANS TEST FLIGHTS OVER THREE CITIES IN 2020

> NASA WILL BRING DEVELOPERS TOGETHER WITH REGULATORS

EHANG

Graham Warwick

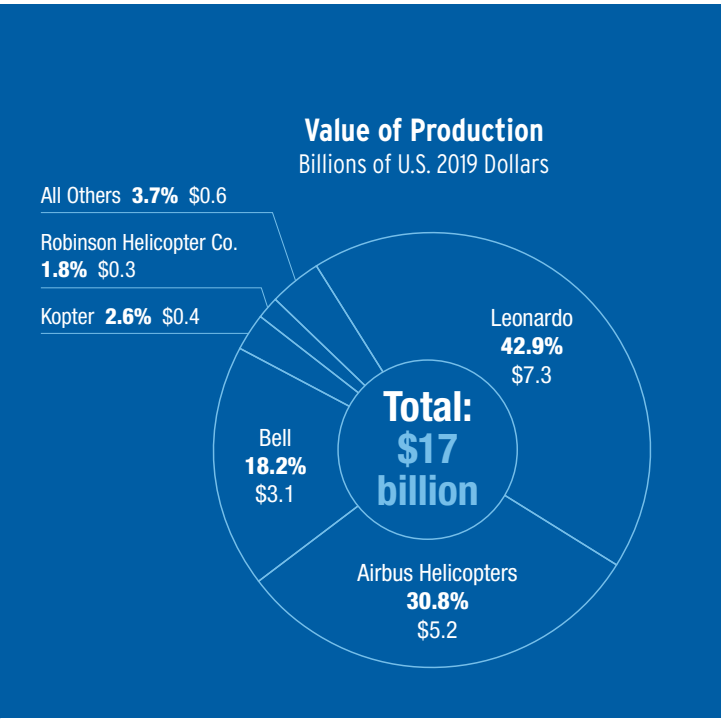
The rubber hits the road for urban air mobility (UAM) in 2020, with demonstrations and challenges planned that will put the technology through its first realistic operational tests.

Uber plans test flights for its Elevate aerial ride-sharing service in Dallas, Los Angeles and Melbourne, Australia, using experimental electric vertical-takeoff-and-landing (eVTOL) vehicles. The company is maintaining its commitment to launch commercial service in 2023 with small fleets of certified vehicles flying a handful of routes in these pilot cities.

NASA plans an initial event in 2020 for its Grand Challenge to improve UAM safety and accelerate scalability through integrated demonstrations that bring together vehicle developers and providers of airspace operations-management services. An initial development test event is planned for July-November, paving the way for the first Grand Challenge in 2022.

EHang 216s conducted a public demonstration over downtown Guangzhou in December.

And ensuring that transformative vertical flight will grab headlines in 2020, the GoFly Prize will stage its final flyoff on Feb. 29, 2020, at Moffett Field in California. Supported by Boeing, Google and Pratt & Whitney, the event is offering $2 million in prizes for building a safe, quiet, ultracompact, near-VTOL personal flying device.



After a protracted development, Airbus is expected to begin deliveries of its H160 medium helicopter in 2020. The company has also developed a version of its popular H145 light twin-turbine helicopter with a five-blade rotor that helps to boost useful load by 150 kg (330 lb.). This will become the standard production version once certification is achieved, expected in the first quarter of 2020.

Russian Helicopters plans to fly its new VRT500 single-engine coaxial-rotor light helicopter in 2020, following selection of the Pratt & Whitney PW207V turboshaft, and is looking to complete development of its Kamov Ka-62 medium twin helicopter during 2020. Another new entrant in the light single-turbine market, Swiss startup Kopter's Honeywell HTS900-powered SH09, is aiming for certification in 2020.

Turkish Aerospace is continuing testing of its T625 Gokbey medium twin, and CEO Temel Kotil stated in December that it would fly in 2020 with a locally developed engine replacing the LHTEC T800s that powered the prototype first flown in June 2019. The T625 and other new medium twins are targeting a market dominated by the Leonardo AW139, which passed the 1,000-delivery milestone in September 2019.

Many of the manufacturers, meanwhile, are studying the potential of hybrid-electric propulsion. Airbus plans to fly a single-turbine helicopter, probably an H130, equipped with a backup electric motor during 2020, while Russian Helicopters wants to install a hybrid power system into the VRT500 in the early 2020s, potentially enabling it to get around limitations imposed on flying single-engine aircraft over urban areas.

Gallery *See a review in photographs of key events in the rotorcraft sector in 2019:* **AviationWeek.com/Rotors2019**

The technology behind eVTOL and UAM has made significant progress since NASA engineer Mark Moore, now with Uber Elevate, produced the first concepts a decade ago. The Vertical Flight Society lists more than 200 projects worldwide, but few have any significant financial support. Even those with backing from investors or manufacturers still face technical and operational challenges.

While full-scale prototypes of at least 17 eVTOLs have so far flown, it is not yet clear which vehicles will be available and capable of conducting demonstration missions for Uber and NASA in 2020.

Only one manufacturer, China's EHang, has begun production, shipping initial batches of its self-piloted single- and two-passenger vehicles to customers in 2019 for demonstration flights and operational trials while it works with regulators to gain certification for the multicopter eVTOLs. EHang is preparing for UAM demonstration flights in 2020 in its home city of Guangzhou.

Other developers have shown significant progress. Germany's Volocopter in 2019 flew its prototype two-seat eVTOL over Helsinki Airport and downtown Singapore, demonstrated its VoloPort UAM terminal, unveiled its VoloCity production configuration and raised an additional $55 million.

Kitty Hawk passed the 1,000 test-flight mark with its Cora eVTOL in March, and in December unveiled a UAM joint venture with Boeing, called Wisk, that will develop and operate the two-seat self-piloted air taxi. Service is planned to begin in New Zealand, where the prototypes are being tested.

Other eVTOL vehicles being flight-tested in greater or lesser secrecy include Airbus' four-seat ducted-rotor CityAirbus, Joby Aviation's four-seat tiltrotor S4 and the five-seat tilt-fan Lilium Jet. The UK's Vertical Aerospace completed flights of a second full-scale prototype, the multirotor Seraph, in 2019.

The UAM sector continues to attract investment. Airbus and Boeing are funding internal R&D as well as investing in developers of batteries and other enabling technologies. Bell is developing eVTOL cargo and passenger vehicles. Honeywell is investing heavily in developing systems for eVTOL and has partnered with Volocopter, Vertical, Pipistrel and Jaunt Air Mobility. BAE Systems is investing in UAM electrification.

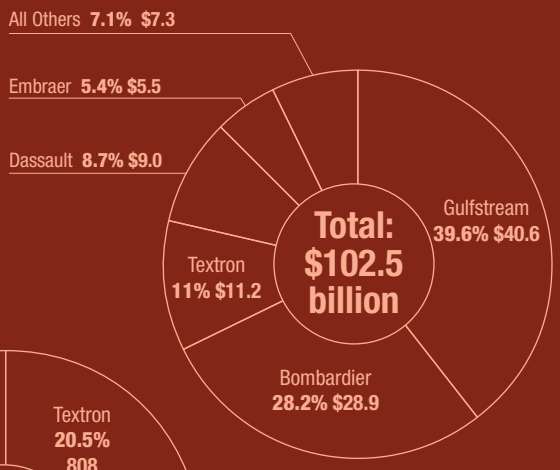
UAM startups Joby, Karem, Lilium and Volocopter between them have raised more than $350 million so far, and EHang is planning a $100 million U.S. initial public offering. But the big money still lies ahead, with Lilium seeking $400-500 million in 2020 to certify and industrialize its aircraft, reports TechCrunch.

Automotive manufacturers have been significant investors in UAM, led by Daimler, Toyota and China's Geely. South Korea's Hyundai has formed a UAM division, and Porsche has partnered with Boeing on premium personal eVTOL. But automakers face multibillion-dollar bills to electrify their road-vehicle product lines, and whether they are willing to invest heavily in UAM going forward remains to be seen.

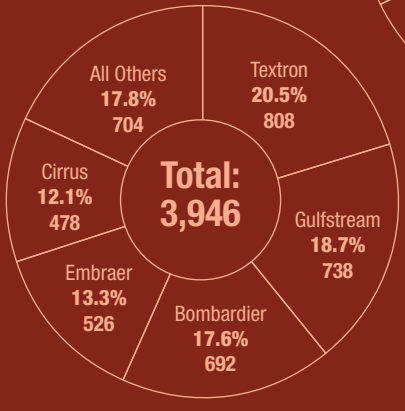
DATA CENTER

Business Aircraft Costs, 2020-24

Five-Year Unit Production



Five-Year Unit Production
Billions of U.S. 2020 Dollars



Snapshot

Some aircraft redefine their classes. For the narrowbody airliner, it is the long-range versions of the Airbus A321neo, the XL and XLR. For the business jet, it is the ultra-long-range, ultra-large-cabin Bombardier Global 7500.

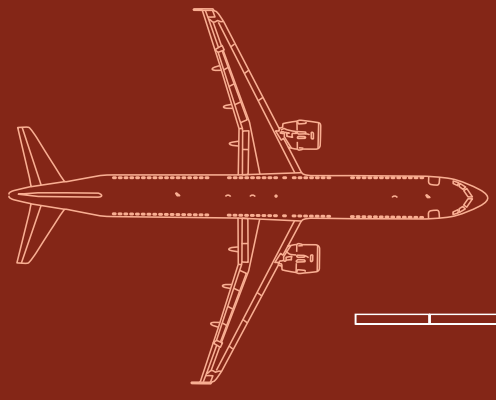
A321neo Series

Range (206 passengers)

A320neo 3,500 nm
A321LR 4,000 nm
A321XLR 4,700 nm

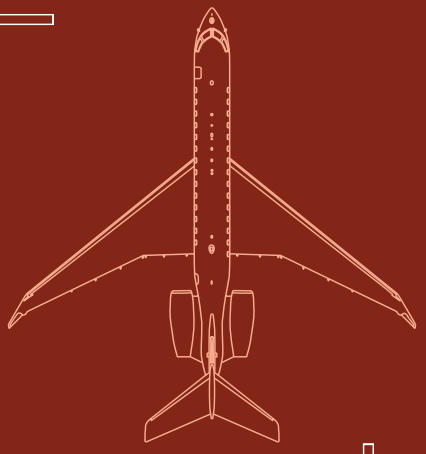
Orders: **3,200** (As of Nov. 30, 2019)

>500 A321XLR orders/commitments



BUSINESS AIRCRAFT TO WATCH

MODEL/ DESIGNATION	WING SPAN (FT.)	MAX. LENGTH (FT.)	MAX. HEIGHT (FT.)	MAX. CABIN WIDTH (IN.)	MAX. T/O WEIGHT (LB.)	MAX. LANDING WEIGHT (LB.)	POWERPLANT (NO./TYPE)	THRUST (LB.)	MAX. SPEED	MAX. RANGE (NM @SPEED)	OPERATING ALTITUDE (FT.)
AERION											
AS2	77	170	22	90	133,000	—	3 X GE Affinity	—	M 1.4	4,200 @ M 1.4 5,400 @ M 0.95	<60,000
BOMBARDIER AEROSPACE											
Global 5500	94	96.8	25.5	95	92,500	78,600	R-R Pearl 15	15,125 ea.	M 0.9	5,900 @ M0.85	51,000
CESSNA (TEXTRON AVIATION)											
Citation Longitude	68.9	73.2	19.4	77	39,500	33,500	2 X Honeywell HTF7700L	7,600 ea.	M 0.84	3,500	45,000
DASSAULT											
Falcon 6X	85.1	84.3	24.5	102	77,460	66,190	2 X P&WC PW812D	13,000-14,000 ea.	M 0.9	5,500 @ M 0.8	51,000
EMBRAER											
Praetor 600	70.5	68	21	82	42,860	37,480	2 X Honeywell HTF7500E	7,528 ea.	M 0.83	3,900 @ LRC	4,500
GULFSTREAM											
G700	103	109.8	25.4	98	107,600	83,500	2 X R-R Pearl 700	18,250 ea.	M 0.925	7,500 @ M 0.85	51,000



Global Family

Range (Mach 0.85)

Global 5500 5,900 nm

6500 6,600 nm

7500 7,700 nm

Price (2018*)

Global 5500 $46 million

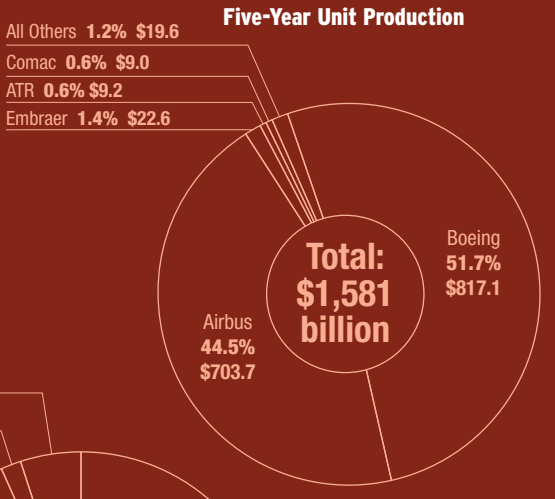
6500 $56 million

7500 $73 million

*Completed aircraft

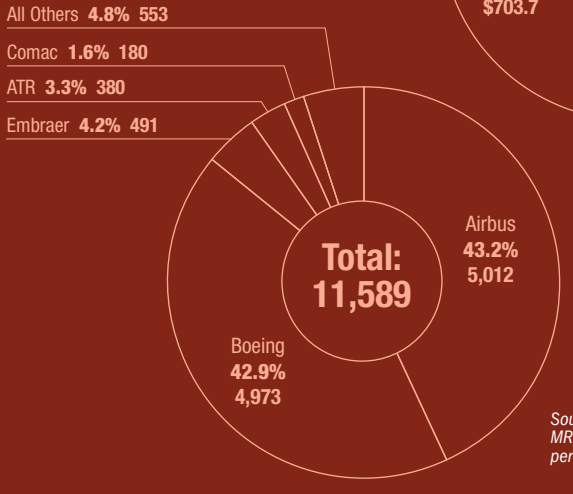
Commercial Aircraft Costs, 2020-24

Five-Year Unit Production



Five-Year Unit Production

Billions of U.S. 2020 Dollars

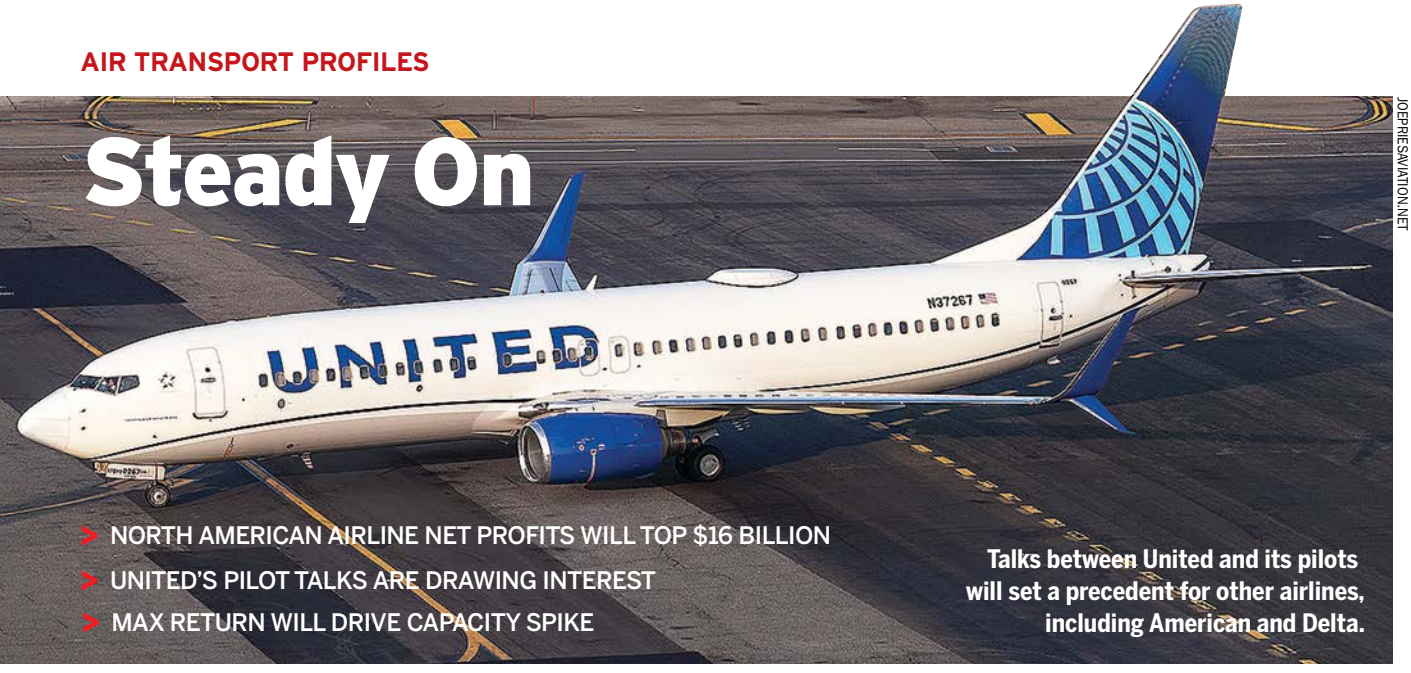


Source: Aviation Week Military Fleet & MRO Forecast 2019. All numbers and percentages rounded.

COMMERCIAL AIRCRAFT TO WATCH

MODEL/ DESIGNATION	PAX	WING SPAN (FT.)	WING AREA (SQ. FT.)	MAX. LENGTH (FT.)	MAX. HEIGHT (FT.)	EMPTY WEIGHT (LB.)	GROSS WEIGHT (LB.)	POWERPLANT (NO./TYPE)	MAX. SPEED	CRUISE SPEED	RANGE (NM)
AIRBUS											
A220-300	130-160	115.1	1,209	127	37.7	—	149,000	2 X P&W PW1500G	M 0.82	M 0.78	3,300
A321neo	185-236	117.4	1,313	146	38.6	—	206,100 213,800 (LR)	2 X CFM Leap 1A or P&W PW1133G	M 0.82	M 0.78	3,700
A330-900neo	287-440	210	—	209	55.1	—	533,520	2 X Trent 7000	M 0.86	M 0.82	6,550
A350-1000	366-440	212.5	4,770	242.1	56	—	679,000	2 X R-R Trent XWB-97	M 0.89	M 0.89	7,950
BOEING											
737 MAX 10	188-230	117.8	1,370	143.8	40.3	99,360	194,700	2 X CFM Leap 1B	—	—	3,215
777-9	400-425	235.4/ 212.7	5,025	251.8	64.5	362,000	775,000	2 X GE GE9X-105B	—	—	7,600
787-10	300-330	197	3,500	224	56	—	553,000	2 X GE GEnx-1B or R-R Trent 1000-Ten	M 0.89	M 0.85	7,000
COMAC											
C919	156-172	117.5	1,390	127.6	39.2	92,815	159,835/ 170,400	2 X CFM Leap 1C	—	M 0.785	2,200/ 3,000 (ER)
EMBRAER											
E195-E2	120-146	115.2	1,110	136.2	35.8	—	135,580	2 X P&W PW1919G	—	—	2,600
IRKUT (UNITED AIRCRAFT CORP.)											
MC-21-300	163-211	117.8	—	138.8	37.8	—	174,720	2 X Aviadvigatel PD-14 or P&W PW1400G	—	—	3,300
MITSUBISHI AIRCRAFT											
SpaceJet M100	84	91.3	—	113.2	33.9	—	92.594	2 X P&W PW1200G	M 0.78	—	1,910

Steady On



JOEPRESSAVIATION.NET

- NORTH AMERICAN AIRLINE NET PROFITS WILL TOP $16 BILLION
- UNITED'S PILOT TALKS ARE DRAWING INTEREST
- MAX RETURN WILL DRIVE CAPACITY SPIKE

Talks between United and its pilots will set a precedent for other airlines, including American and Delta.

Sean Broderick Washington

The primary watch items for North American airlines in 2020 have a familiar ring: the Boeing 737 MAX's status, new labor deals and fuel prices that, while not rock-bottom, continue to act as a tailwind.

Airlines were hit particularly hard by the MAX grounding, both in terms of aircraft removed from service and deferred deliveries. Boeing's hope of winning initial approvals to reintroduce MAXs in late 2019 faded away, seemingly leaving U.S. airlines a best-case scenario of beginning to get MAXs back into revenue service early in the second quarter of 2020.

The most affected carriers are Air Canada, American Airlines, Southwest Airlines, United Airlines and WestJet Airlines, which had a combined 109 MAXs grounded and were slated to see their MAX fleets more than double by the end of 2019. Most now expect it will take into 2021 to reintroduce the grounded MAXs and see Boeing catch up on deliveries.

How quickly the MAXs come back will have a major influence on growth. Cowen & Co.'s mid-December 2019 projections saw U.S. airlines boosting available seat-miles, or capacity, 5.6% year-over-year in 2020, nearly doubling 2019's estimated 2.9% increase. The story is similar in Canada, where a 7% capacity jump is expected in 2020 following 2019's modest 1.7% rise. MAX operations help explain most of these statistics, so if the fleet remains grounded deep into the first quarter the 2020 forecast will be revised downward.

The region's bigger-picture trends are solid. Demand remains strong, particularly in the domestic market, where MAX operators have been canceling flights since the grounding last March. One result has been an increase in load factors, even at carriers that did not operate the model. "We operated over a 90% load factor, pretty much from April through August," says Delta Air Lines Chief Financial Officer Paul Jacobson, noting both peak-season demand and the MAX as contributing factors.

Despite a slowing economy, airlines are bullish on revenue trends.

"We've had a great fourth quarter of the year," Delta CEO Ed Bastian said during the carrier's December investor day. "That demand has carried us forward as we close out the year for the holidays. We see that revenue growth going into 2020. All signs are the U.S. consumer continues to do well."

The Conference Board research organization sees U.S. GDP growth dipping to 2% in 2020 from 2.3% in 2019. The Conference Board of Canada sees GDP growth there falling below 2%, slightly less than for 2019.

Fuel costs are not expected to be an issue. Cowen & Co. analysts see prices dropping slightly in 2020, matching rates last seen in early 2019. Cowen's projected U.S. airline cost is $2.07 per gallon, while it predicts Canadian carriers will spend C$0.76 per liter.

On the labor front, United and its Air Line Pilots Association members' leadership care more than a year into talks over a contract that became amendable in January 2019. Discussions, which could be wrapped up before CEO Oscar Munoz hands the reins over to Scott Kirby in May, focus on the usual issues of pay, benefits and scope, or how much the airline can leverage regional-airline partnerships to grow its network. Pilots at American and Delta are due for new contracts soon as well.

"Other airlines and investors are focused on United's pilot negotiations, especially the scope and pay rates," Cowen's Helane Becker says.

An emerging issue that major airline pilot agreements must tackle is how joint ventures play into scope clauses. Delta's pilots in December called on the U.S. Transportation Department to ensure joint ventures benefit all parties.

Delta pilots have grown increasingly skeptical of the benefits of immunized alliances following their experience in the years since the Delta-Virgin Atlantic joint venture was approved in 2012. Since then, Virgin's total block hours between the U.S. and UK increased 33%, while Delta's rose just 2%, reports Delta's Master Executive Council (MEC), or pilot leadership.

"Scope, including joint ventures, matters to the Delta pilots," says Capt. Ryan Schnitzler, chairman of ALPA's Delta MEC. "It is the foundation of our contract, and we will continue to enforce and seek enhancements to our scope language."

While labor talks rarely are free of acrimony, carriers in the region have plenty of incentive to keep the peace. The International Air Transport Association (IATA) projects North American carriers will post a net profit of $16.5 billion in 2020. While down

slightly from 2019's $16.9 billion and the five-year average of $17.5 billion, it is still laudable—and more than all of the other regions' projected combined total profits.

"[In] 2020, unit revenue and profitability are expected to decline," IATA says.

Given the steady macro environment, carriers can continue to focus on leveraging their strengths and not scrambling to survive. All of them will continue to pursue ancillary revenues, with the full-service carriers pushing the availability of "basic economy" to ward off low-cost operators and adding more "upper-end economy" seat options to protect against business travelers going to the back of the aircraft if travel budgets wobble. Low-cost operators will push their menus of options, charging for everything from stowing a backpack in an overhead bin to jumping the airport checkpoint queue.

Projected mid-single-digit capacity jumps in both the U.S. and Canada will be inflated by the MAX's return, but some smaller carriers still are prioritizing passenger volume. Both Allegiant Air and Spirit Airlines are expected to see their volumes grow in the double-digits, with Spirit approaching 20%.

JetBlue Airways has dialed back growth plans due to Airbus A321neo delivery delays. Planned 2020 capacity growth is 5.4%, Cowen projections show, or about 2 points below its original plans. The New York-based carrier will continue to focus on maximizing its New York John F. Kennedy International Airport hub real estate and slots, while building up in Boston and Fort Lauderdale, Florida.

Alaska Airlines expects to continue to benefit from synergies following its purchase of Virgin America. It also is due to receive some MAXs; its first was slated to arrive in mid-2019. Alaska's biggest opportunity is in product segmentation. The airline, with about half of its trips 5 hr. or longer, is rolling out new premium and basic economy offerings as part of cabin refreshes.

American plans to add about 5% in capacity, with 1.5 points linked to the MAX's return. Its network strategy will emphasize improving margins at its Dallas/Fort Worth and Charlotte, North Carolina, hubs.

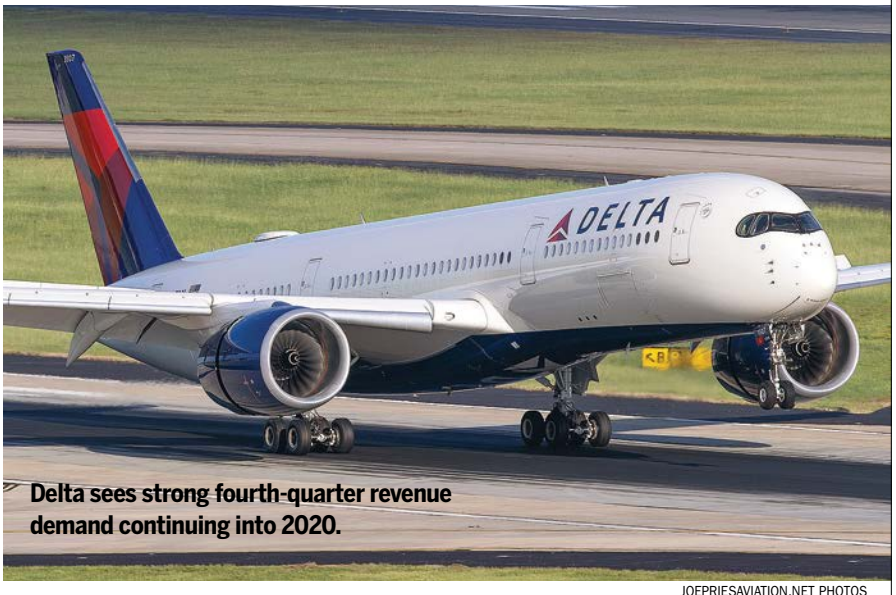
"In recent years, the company's domestic growth has favored regional aircraft, but as they optimize their network they are looking to increase gauge at their two most important and most profitable airports," Cowen explains.

United will continue to emphasize its mid-continent hubs in Chicago, Houston and Denver. The airline's introduction of Bombardier CRJ550s—CRJ700s with premium seating and a new type certificate—give it a revenue-generation opportunity that aligns with its hub flow-building strategy.

Southwest's plans are the most uncertain among the region's large operators because of its reliance on the MAX for growth. The all-737 operator expected to have 75 MAXs by now, which would have accounted for 10% of its planned fleet. It was to start 2020 with 34 in storage and none in service. If deliveries resume in the first quarter, Southwest's full-year capacity boost could approach 8%. The good news: Its key Hawaiian market relies not on the MAX but on a subfleet of ETOPS-approved 737-800s.

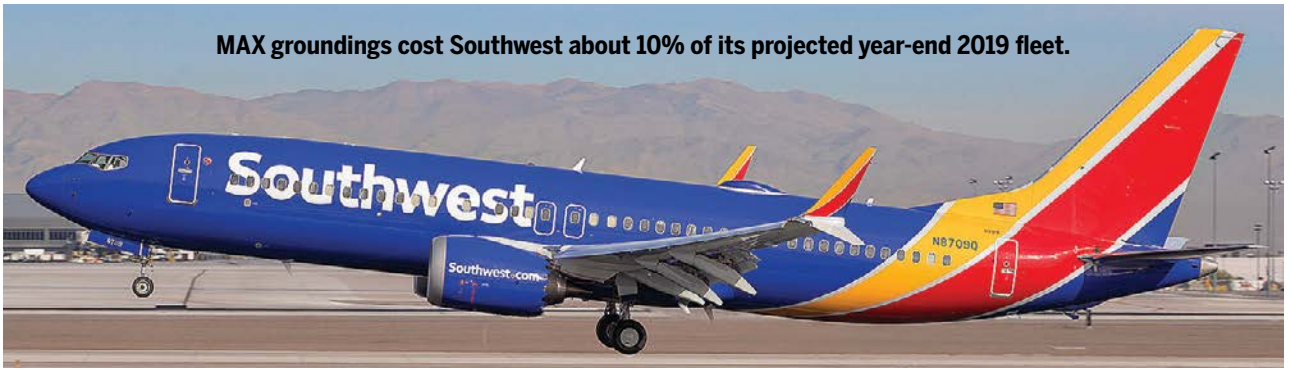
Air Canada expects to take 26 MAXs in 2020, giving it 50, but management anticipates it will take about a year to catch up after Transport Canada's approval. Also on the agenda: closing the Air Transat purchase and deciding how to leverage the tour operator's assets.

WestJet expects to welcome back its 13 MAXs and will continue to take Boeing 787s to expand its intercontinental long-haul services. Private-equity firm Onex closed its $3.8 billion purchase of the Calgary, Alberta-based carrier on Dec. 11 and plans to keep the airline's growth plans in place.



Delta sees strong fourth-quarter revenue demand continuing into 2020.

JOEPRIESAVIATION.NET PHOTOS



MAX groundings cost Southwest about 10% of its projected year-end 2019 fleet.

Europe's Airlines Get Ready for a Tough 2020

> OVERCAPACITY IS PILING ON THE PRICING PRESSURE

> ENVIRONMENTAL CREDENTIALS ARE INCREASINGLY UNDER SCRUTINY

Helen Massy-Beresford Paris

After a year littered with airline failures and increasing environmental scrutiny added to prevailing headwinds, Europe's air transport industry is again preparing for a rough ride in 2020, even if strategic cuts to capacity plans help profitability.

"Overall, we see a deterioration in both the economic climate and the airline industry," says Diogenis Papiomytis, global program director for commercial aviation at Frost & Sullivan.

"Airlines have been profitable for a record 10 consecutive years [2010-19] and will likely continue to be profitable next year," he says. "But the business environment is affected by slower global GDP growth, higher fuel prices and the U.S.-China trade war."

Ratings agency Moody's also was gloomy in a Nov. 14 report: "As the global economy continues to slow toward a lower long-term trend, business sentiment across major economies has become downbeat, with a growing concern that a recession is only a shock away."

Thomas Cook had the highest profile in a string of 2019 airline collapses.

Moody's says it expects continued deceleration for the U.S. and China in the next year. "In the UK, political instability and persistent uncertainty over the timing and terms of Brexit have begun to harm the UK's economy," the agency said. "In other emerging markets, growth prospects will remain sluggish, even though the pace of economic activity will improve, with the exception of China."

The Organization for Economic Co-operation and Development's latest outlook from November, which projects that the world economy will grow by a decade low of 2.9% annually in 2020, and 3.0% in 2021, is worrying in a highly cyclical industry, says Papiomytis. Airlines in Europe and North America are better equipped to deal with a downturn because of the consolidation and transformation programs implemented in the past few years, he adds.

With the U.S.-China trade war affecting the global economy, overcapacity weighing on prices and the continuing uncertainty over Brexit dampening consumer demand, Europe's airlines are well aware of the challenges they will face over the next 12 months.

The collapse of a string of carriers—in September, UK leisure operator Thomas Cook, France's Aigle Azur and XL Airways and Slovenian flag carrier Adria Airways all went out of business—underlines issues that continue to threaten the industry in 2020.

ALAN WILSON/WIKIMEDIA

"Economic growth, fuel prices and the trade war with China will remain [on] top of the risk agenda," says Papiomytis, who believes consolidation

INA FASSBENDER/GETTY IMAGES

EasyJet plans to offset all its emissions as environmental pressure grows.

JOEPRIESAVIATION.NET

will intensify as a potential economic downturn provides further incentives for airlines to join forces.

"We are also seeing large airline groups, which did not exist 10 years ago, having both the appetite and competitive pressure to keep growing," he adds. "Consolidators are easy to identify in both Europe and North America. Primary targets will be medium-size airlines that enjoy a distinct competitive advantage of value to consolidators."

Air Europa, purchased by International Airlines Group (IAG) in a

More sector consolidation is likely after IAG's Air Europa buy.

€1 billion ($1.1 billion) deal announced Nov. 4, offered its Latin American network, Papiomytis notes.

He sees low-cost carriers benefiting more than large full-service carriers from consolidation, with their flexible business models that allow them to move fast to fill any void. "We are already seeing collaboration among low-cost carriers," he says. "I see this becoming more of a trend, and why not large acquisitions by them?"

Hefty fuel bills remain a concern for the region's airlines. "Thinking about fuel prices is always important for airlines because fuel represents 20-30% of their cost base, depending on the type of airline," says Callum Macpherson, Investec's head of commodities. "As we know from recent trends, it can vary enormously."

However, the good news, amid a grim outlook on many fronts, is that Europe's airlines have hedging policies in place. "In Europe many airlines are hedged out through much of the next year, and some have a proportion of their hedging needs covered for part of the next year after that," says Macpherson. "What oil prices do over the next 12 months won't be a massive issue for airlines that are well-hedged."

Airlines are also facing growing pressure to find ways to limit their environmental impact as the *flygskam* or flight-shaming movement gains ground and governments step up calls for a Europe-wide aviation tax.

EasyJet announced Nov. 19 it was offsetting all its carbon dioxide emissions with immediate effect in a move that should cost £25 million ($33 million) in the 2019-20 financial year, following IAG's pledge earlier in the month to reduce net emissions to zero by 2050.

For the long term, EasyJet's plan to develop electric aircraft in partnership with Wright Electric is already underway. In France, the government's controversial plan to introduce an eco-tax on all flights departing the country's airports, a move Air France has said will cost it over €60 million a year, is set to come into force in 2020.

European airlines will have to bear increasing financial liabilities to meet environmental regulations to cut emissions, S&P Global Ratings said in a Nov. 21 report. "The additional cost burden of emissions regulations will be marginal over the short to medium term, relative to existing volatile fuel expenses, aircraft lease payments, and depreciation charges, any further cost pressure in the extremely competitive, highly cyclical, capital-intensive European airline market will add to pressures and may gradually further widen the difference between Europe's few strongest airlines and the weaker majority," says S&P Global Ratings credit analyst Rachel Gerrish.

She added that airlines would likely achieve most of their net CO_2 emissions reductions via market-based measures including the EU Emissions Trading Scheme, the global Corsia and operating and fleet efficiencies.

For Papiomytis, the industry needs to do more: "Environmental sustainability is a medium-term risk, but action is needed now. The industry has yet to grasp the potential impact of environmental activism in shaping public opinion and influencing political agendas in Europe and elsewhere."

With the continued grounding of the Boeing 737 MAX as well as Airbus delivery delays, capacity cuts and slower growth are already on the agenda for European airlines, a development set to go some way toward protecting their margins next year even amid a challenging operating environment.

"The 'Flood of Planes' is temporarily slowing to a trickle. This will enable airlines to capture more of the pending fuel benefit for themselves and likely provide a less challenging revenue environment," Bernstein analyst Daniel Roeska wrote in a Nov. 13 research note. "With these positive signs, 2020 is set to be one of the most profitable years in EU airlines despite slower macro developments."

The region's carriers are already scaling back their capacity plans, with Air France targeting a 15% reduction of its short-haul capacity in terms of available seat-kilometers (ASK) by the end of 2021. EasyJet said Nov. 19 that it is expecting capacity growth for the year ending Sept. 30, 2020, to be at the lower end of its historic guidance of 3-8% per year, while IAG said at its Nov. 8 capital markets day that it was revising downward its capacity planning for the next three years, with plans to grow capacity by an average of 3.4% in the next three years.

That compares to the previous target of a 7.4% compound annual growth rate (CAGR) and leads to IAG offering 13.3% less capacity in 2022 than it had originally planned. With all of the operating units slowing expansion, British Airways will still contribute the largest share to growth in absolute terms.

Roeska estimates European summer capacity growth of around 4% year-over-year, partly tempered by the ongoing MAX groundings. "Over the past weeks, airlines have added less capacity to next summer than they usually would at this point in the year. This gives us more confidence in our thesis that 2020 will see a tactically lower growth following the delays in MAX (and Airbus), bankruptcies, and general cautious view of macro," Roeska added.

BACKGROUND:ISTOCK

Asia-Pacific Fleet Moves Continue Despite Uncertain Outlook

> COOLING DEMAND RAISES FINANCIAL CONCERNS FOR AIRLINES

> NEW DELIVERIES WILL RENEW FLEETS, EXPAND ROUTE OPTIONS

P. PIGEYRE/AIRBUS

AirAsia X is looking to new markets with its Airbus A330-900 deliveries.

Adrian Schofield Auckland

The next 12 months could be a pivotal period for the Asia-Pacific airline industry. There are increasing signs across this region that demand and profitability are under pressure, with factors such as global economic uncertainty and international political disputes playing a role.

Many of the full-service airlines are initiating cost-cutting programs and reducing capacity plans to adjust to the changing market conditions. However, fleet renewal will also continue to advance rapidly in 2020. Several airlines are due to receive new-generation widebody and narrowbody types, whose longer aircraft ranges make more routes viable.

Adding to the challenges for the full-service airlines is the continued expansion of the region's low-cost carriers (LCC). Capacity growth and aircraft orders for the LCCs have not abated, and the threat is not just on short-haul regional routes. These airlines are now increasingly turning to widebody aircraft to extend their network range, encroaching on more of the routes that have traditionally been the domain of the legacy airlines.

SOUTHEAST ASIA

The prospect of softening demand and broader economic fragility are not good news for those legacy flag carriers already in a vulnerable position. Some large Southeast Asian airlines are struggling or restructuring, and in a few cases even government stakeholders are expressing frustration with their progress.

This is certainly the case for Malaysia Airlines, which is still battling to turn around losses after a state bailout and takeover in 2014. Government leaders have discussed their desire to sell a strategic stake in the carrier to outside investors, but no such deal has emerged. The management of the airline has implemented a new recovery plan, and a major feature of this is forming close alliances with strong Asian carriers such as Japan Airlines and Singapore Airlines.

Another airline deeply in the red is Thai Airways. It presented a fleet plan to the Thai government this year, including a proposal for much-needed aircraft orders for fleet renewal. However, the plan was sent back to the airline to be revised. A new fleet strategy will likely be submitted in 2020.

Turmoil in the Hong Kong market has affected many Asia-Pacific airlines, and none more so than Cathay Pacific. The airline had been on track with a financial recovery initiative, but this progress is under threat due to major demand declines in Hong Kong travel. Cathay has also replaced its senior leadership due to political fallout from the civil unrest. The new team has a host of obstacles to confront to regain Cathay's momentum.

Garuda Indonesia has been another of those airlines struggling finacially in recent years, resulting in order deferrals and a restructuring plan. Positive signs emerged with a return to net profit for the first nine months of 2019, but the true test will be whether this can be sustained.

Singapore Airlines is once again the standout among Southeast Asian carriers in terms of financial health and stability, and this is unlikely to change in 2020. The airline group is still fine-tuning its multiple-business-model approach with the integration of SilkAir into the parent airline and some routes being transferred to its Scoot LCC subsidiary. The group has 159 widebodies and narrowbodies on order, although fleet plans have been disrupted by delays to Boeing 737 MAX deliveries.

NORTH ASIA

Japan's two major carriers have been looking ahead to 2020 for some time, as this is expected to be a big year for the country's airline industry. The Summer Olympics will be held in Tokyo, bringing an influx of visitors. And the government is allowing an increase in daily flights at key gateway Tokyo Haneda Airport from late March. Japan Airlines and All Nippon Airways have kept growth relatively low over the past few years, but expansion is likely to pick up again in 2020 to take advantage of these developments.

The Haneda expansion results from 50 new slots created following airspace changes. Half of the slots have been allocated to Japanese airlines and the remainder to foreign carriers. In some cases, the new slots will be used to relocate flights from Tokyo Narita Airport, but there will also be new services launched.

Japanese airlines are not immune to the issues facing the wider region, however. JAL saw its net profit drop by about 30%, and ANA's was down 23% for the six months through Sept. 30, their fiscal first half. The carriers cited weaker demand in certain market segments. ANA projects these trends to continue, causing it to cut its profit forecast for the full fiscal year. JAL has not adjusted its profit forecast but is undertaking a cost-reduction program to offset lower revenue.

In the South Korean market, Korean Air expects to begin taking delivery of Airbus A321neos and Boeing 737 MAXs in 2020, after significant delays to both

types set back its narrowbody replacement program. Additional Boeing 787 deliveries are due later in 2020. Deliveries of these types will allow Korean Air to introduce onboard Wi-Fi.

The future of Asiana Airlines appears brighter, as a prospective buyer has emerged. The carrier's largest stakeholder, Kumho Industrial, decided to sell its share to alleviate financial concerns, and a consortium including Hyundai Development Co. was selected as preferred bidder.

A sharp drop in demand on Japan-South Korea routes has been a headache, particularly for Korean-based airlines, which are more heavily exposed to this market than Japanese carriers. Korean Air and other airlines have dramatically cut capacity on Japan routes. Political and trade tensions are the main reason for the fall in demand, so the airlines will be hoping these disputes can be resolved.

ASIAN LCCs

The low-cost carrier sector generally faces the same economic headwinds as the full-service airlines. But as always, the LCCs intend to keep growing, and there are plenty of startups in the pipeline. The trend of LCCs looking to extend their reach with new widebodies and longer-range narrowbodies is also continuing.

The AirAsia Group is significantly boosting capacity in its short-haul LCCs. The six franchises were expected to increase their collective fleet by 20 aircraft to a total of 244 by the end of 2019, with another 37 narrowbodies to be added in 2020.

Sister company AirAsia X, which operates widebodies, is introducing A330neos that will allow it to fly longer routes than its current A330ceos. The Thai AirAsia X unit received its first two leased A330neos in August 2019, and the parent Malaysian operation is due to start taking delivery of its A330neos in 2020. The group has said the Neos will enable nonstop flights to Europe, likely from Thailand first.

The South Korean LCC market is already fiercely competitive, and the expected launch of new entrants will raise the pressure further. The government has approved three LCCs to start in 2020. Air Premia is the most intriguing, as it is ordering Boeing 787s to compete on routes from Seoul Incheon International Airport. It intends to start with Asian flights from September, extending to long-haul markets in the U.S. in 2021.

In Japan, the addition of longer-range aircraft will help drive the next phase of LCC network growth. The JAL group is looking to launch a long-haul LCC named Zipair to complement its short-haul LCC joint venture, Jetstar Japan. Zipair is expected to launch flights in May 2020 with an initial fleet of two Boeing 787-8s. LCC Peach, a subsidiary of the ANA Group, intends to add A321LRs to its fleet in 2020 to serve medium-haul routes.

Asian LCCs continue to dominate narrowbody orderbooks, with carriers such as AirAsia, IndiGo, Lion Air and VietJet accounting for hundreds of orders each. India in particular has massive numbers of LCC deliveries coming—IndiGo has more than 630 narrowbodies on order following its latest deal in 2019, SpiceJet more than 150 and GoAir over 100.

Japan Airlines aims to grow in 2020 despite softer profits.

JOEPRIESAVIATION.NET

AUSTRALASIA

Cooling demand and weaker financial performance are becoming a concern for airlines in Australasia, causing some of the major players there to implement cost-cutting programs. However, this is not preventing airlines from taking fleet-renewal steps and pushing range boundaries with ultra-long-haul routes.

Qantas has been putting a lot of time and effort into assessing its proposed Project Sunrise nonstop routes from Australia's east coast cities to London or New York. The airline is due to make a final decision by March on whether to go ahead with these flights, which it would aim to start in early 2023. Qantas has already announced Airbus A350-1000s as its preferred aircraft choice. Once the Project Sunrise decision is out of the way, Qantas intends to turn its attention to assessing other fleet needs. It has signaled it will consider a narrowbody aircraft order in 2020, for the eventual replacement of its Boeing 737s. The carrier says both the A320neo and Boeing 737 MAX families are in the mix, and it is interested in Boeing's proposed new midmarket airplane (NMA). Qantas will also examine replacements for its regional fleet of Boeing 717s and Fokker 100s.

Air New Zealand is also targeting new long-range routes and plans to launch a flight from Auckand to New York in October 2020. This would be its longest flight and the fifth-longest in the world. At the same time, however, the airline will cut its flight to London, which it operates as a one-stop via Los Angeles.

Cost reduction and capacity management will be priorities in 2020 for Air New Zealand and Virgin Australia, as they look to strengthen their financial performance. Both have launched programs to identify cost savings, and have pared back their capacity plans. Virgin is suspending some domestic and international routes.

The pair have also deferred some scheduled aircraft deliveries. Air New Zealand has pushed back delivery of some of its A321neos and an A320neo, and Virgin has taken the more drastic step of delaying first deliveries of its 737 MAX aircraft by about 20 months to July 2021. Both carriers will be watching closely in case more action is required.

Beijing Demands Cuts in Subsidies

> OFFICIALS PAY FOR AIR SERVICES TO BOOST ECONOMIES

> LOCAL GOVERNMENTS INVEST IN AIRLINES, TOO

STATE-OWNED ASSETS SUPERVISION AND ADMINISTRATION COMMISSION

Bradley Perrett Beijing

In the first half of 2019, Chinese airlines banked subsidies equal to 86% of their profits. If authorities in Beijing get their way, that number will decline in 2020.

The central government is demanding a reduction in subsidies to industries in general. The measure will not affect airlines only, but commercial aviation is a sector that has a notable dependence on public cash. Taxpayer money is given to foreign as well as Chinese carriers.

Reduction and standardization of subsidies was one of several points made by Vice Premier Liu He at a state council (cabinet) meeting on Nov. 12, according to an official account. This was associated with a mention of strengthening control of public finances. The implication of the subjects being "mentioned" is that the state council is demanding action. Central government departments and the governments of provinces and cities are supposed to take note and adjust policies accordingly.

Provinces and especially cities frequently subsidize new business activities—notably air services, which are seen as lifting economies generally. These lower-level governments are also often keen to fill underused airports. Cash might be paid as an amount per flight or a bonus for opening routes, especially those seen as valuable. The biggest subsidies are generally paid for intercontinental services, sometimes to foreign airlines.

In profit reports for the first half of 2019, Chinese airlines said they had received 8.38 billion yuan ($1.2 billion) in subsidies, local aviation consultancy Cadas calculates. In the same period their profit was 9.71 billion yuan.

This does not mean that they would barely make profits without the subsidies, since many of the routes that receive government support are loss-makers the airlines would drop if they did not get help. But if those routes are dropped, then Chinese airlines presumably would need less capacity.

The official report of the state council meeting did not mention a specific degree by which subsidies are supposed to be reduced. And lower levels of government tend to resist orders from the top to a degree that often surprises foreigners. One factor is that the pressure on officials can be contradictory. In this case, officials are told to spend less public money to boost business activity—but they must consider that local economic growth is a strong factor in their prospects for promotion.

Only nine days after the state council issued its demand, the Guangxi provincial and Guilin city governments said they had set aside 200 million yuan for a fund to support air routes at Guilin in southern China. They intend to use the money to build up Guilin Liangjiang International Airport as a hub. And, like so many other lower-level governments in China, they aim to open intercontinental connections.

China Southern Airlines has a large presence at Guilin, a city long famous in China for the natural beauty of its surrounding countryside. HNA Group's Air Guilin is based there.

The province and city said the fund would be "used for the promotion of Guilin, striving to open inter-

The second terminal of Guilin Liangjiang International Airport opened in 2018. Local governments want the airport to be busier.

continental routes to Europe and the Americas, starting services from Guilin to countries in the Association of Southeast Asian Nations and those of northeast Asia, and increasing flights to [Chinese] cities with international connections."

They did not publish a schedule of available subsidies, as other governments have. Airlines providing air services desired by local officials typically get more money for routes that are longer and those that connect to economically important cities.

Such support is usually available only for two or three years and diminishes after the first year. In line with that, the Guangxi and Guilin governments referred to the allocated money as a fund for fostering air routes—implicitly, not for sustaining them.

A flow of subsidies is not the only way in which local governments in China get air connections they want; they can also pour capital into an airline, either to offset its losses or to build it up for greater things. This has happened repeatedly over the past two years for carriers owned by Hainan Airlines, part of the struggling HNA Group.

In November, the Chongqing city government said it would invest in Hainan Airlines' low-cost subsidiary West Air. After the transaction, Chongqing will hold at least 70% of the shares, the city and Hainan Airlines said.

Hainan Airlines, itself a part of the HNA Group, will be the second-largest shareholder. The staff that it has established at West Air will continue to operate the carrier, which is based in Chongqing, a southwestern city.

The municipality has been a minority shareholder in West Air, which, an industry source says, is among HNA's most profitable carriers. The number and value of West Air shares to be transferred to Chongqing is not disclosed. The airline's registered capital is 12.5 billion yuan.

Big Gulf Carriers Continue Shift to New Business Models

> AIR ARABIA EXPANDS TO BUILD ABU DHABI BASE

> REGIONAL CONFLICTS BURDEN SHORT-HAUL CARRIERS

FIXION/AIRBUS

Jens Flottau Dubai

Some time around the end of the first quarter of 2020, Air Arabia Abu Dhabi will enter the Middle East air transport market, operating its first flight from a new base in the United Arab Emirates. A first flight from a new market happens almost every day in global air transport, but this one will be about more than just opening a new city-pair.

Air Arabia's move into the Abu Dhabi market, so far the fortress of Etihad Airways, symbolizes how much the regional focus has shifted, change that will become even more visible in 2020 as airlines abandon old business models and assume new ones. The launch of the Air Arabia joint venture with Etihad shows that even in the Gulf, low-fare carriers are now the ones driving growth rather than the big three legacy airlines that transformed intercontinental air travel with multibillion-dollar fleets.

The development is no surprise to long-term observers. For years, Qatar Airways, Etihad and Emirates have grown rapidly following similar business models and often opening the same destinations in tandem. Now they are splitting paths.

Qatar Airways, burdened by the financial impact of the blockade against its home country, nonetheless continues to expand with a mandate from its government to do so at almost all cost. While the pace of growth has slowed, the carrier continues to take delivery of aircraft on order.

Emirates has made crucial decisions to transform its fleet of the future, taking delivery in 2020 of its last batch of Airbus A380s ordered when times were different. Structural change to its fleet will happen only later, with the arrival of its first Airbus A350s and Boeing 787s.

Etihad has long been contracting, having given up on aggressive global expansion and now focusing more on supporting the diversification of Abu Dhabi's oil economy. The airline canceled 42 of the 62 A350s it had on firm order and recently agreed with Boeing to take 20 fewer 787s than planned over the next five years. The carrier is placing some of its newly delivered A350s into long-term storage.

According to CAPA - Centre for Aviation data, Etihad has stored 23 aircraft and operates 109. Among the stored aircraft are four A350-1000s and 16 A330s. The airline also has 101 aircraft on firm order including 25 777Xs that it is trying to cancel. Its recently introduced five-year strategy that targets a return to group profitability by 2023 assumes a fleet of no more than 120 aircraft, suggesting more deferrals and cancellations are planned. Etihad posted a combined $4.7 billion net loss for 2016-18.

Beyond failed business strategies, the Gulf carriers are affected by the slowdown in the global trade that is fundamental to their model of connecting long-haul to long-haul. Currency fluctuations also have affected the airlines' finances of late, and exchange-rate volatility will continue to be a major risk factor into 2020.

While still a tiny fraction of its overall business, Emirates' introduction of another fifth-freedom service, this time Barcelona-Mexico City, is a watch item for competitors. The airline so far operates daily services from Athens and Milan to New York. Should the flight become profitable soon, it could encourage management to add more fifth-freedom services. Such operations from Europe to the U.S. constituted a major concern when the big three U.S. legacy airlines launched their lobbying campaign against Gulf carriers.

Air Arabia is betting on the Airbus A321XLR as it expands its network.

Qatar Airways' 49% investment in Air Italy has been used by Delta to restart its lobbying, saying the Italian carrier can expand to the U.S. only with massive help from its Qatari shareholder. Air Italy's North Atlantic market share is negligible, although it has plans to grow its long-haul services in 2020.

The global grounding of the Boeing 737 MAX also has affected Middle East flights. Most affected is Dubai's second airline, FlyDubai. The carrier has 13 MAXs on the ground, and deliveries of many more are delayed indefinitely, seriously crimping the company's growth plans. To fill some of the gaps, FlyDubai has entered into wet leases for some aircraft in early 2020.

FlyDubai's other main strategic push, closer cooperation with Emirates, is progressing more to plan. During the next year, FlyDubai wants to shift more flights from its base to the other side of Dubai International Airport to ease connections with its sister company. Flights with little or no connecting traffic will remain at Terminal 2.

Another issue with some Middle East carriers is their substantial exposure to markets affected by the myriad conflicts from Libya to Syria and Iraq that make flying all but impossible. Resolution of some of the conflicts would open new business opportunities for Middle East and European airlines flying into some potentially lucrative markets, but no short-term improvement is likely.

There are some bright spots politically, nonetheless. The recent relaxation of Saudi Arabia's strict visa requirements for tourists already has led to greater demand for flights to the country and even on domestic routes, providing carriers like Flynas or Flyadeal with a welcome boost.

Time To Invest

> AFFILIATIONS CHANGE AFTER DELTA'S LATAM DEAL

> JOINT VENTURES, NEW PARTNERSHIPS TO EMERGE

Mark Nensel Brasilia and Washington

The commercial aviation industry in the Latin America-Caribbean region heads into 2020 in a state of flux, especially as political tensions and economic convulsions for the myriad countries that make up the region intensify. Add in excessive taxation, wildly varying regulatory policies, largely inadequate infrastructure and uneven coordination of air traffic control, and the outlook becomes somewhat disheartening.

But for the industry executives who gathered recently at the ALTA Airline Leaders Forum in Brasilia, an optimistic mood prevailed once all the issues had been aired. And as aviation and tourism ministers from the region's South American countries pledged to meet regularly and compete less, the focus turned instead to coordinating inter-regional travel programs and promotions, building on the possibilities in a region where passenger numbers are expected to double in the next two decades at a 4.1% compound annual growth rate.

The Latin American-Caribbean aviation market saw 5.7% growth in 2019 as GDP in the region expanded 1.2%. As a result, the potential for Latin American aviation growth is

AVIANCA

Avianca has secured up to $375 million in loans.

gaining the attention and investment of North American carriers. Delta Air Lines' intent to acquire up to 20% of LATAM's shares, a $1.9 billion investment, is the most significant example. Emboldened by a decision in May from the Chilean Supreme Court, Delta plans to establish a joint business agreement with the Chilean carrier. In May, the Chilean Supreme Court quashed a proposed joint business agreement between LATAM and American Airlines after deciding the combined carriers' market power "would be hard to challenge in a post-deal scenario." Subsequently, LATAM will end its long-standing codeshare with American Airlines by year-end. Its agreement with SkyTeam member Delta means LATAM likely will leave the Oneworld alliance by Oct. 1, 2020.

The joint venture between Star Alliance carriers United Airlines, Colombia's Avianca and Panama's Copa, originally announced in November 2018, is on hold until regulators from the carriers' three countries grant full approval. Copa CEO Pedro Heilbron indicated the filing with regulators for the venture would not likely happen until 2020, pushing back the collaboration until 2021 at the earliest.

The financial and operational status of Avianca are significant factors in the United-Avianca-Copa linkup. After a financial drubbing in 2018, the Colombian carrier hired a new management team led by CEO Anko Van Der Werff, restructured its debt and embarked on an ambitious transformation plan involving the cutting of unprofitable routes, asset divestitures and reducing capacity with aircraft sales and returns. On Dec. 9, the Colombian airline completed the last of its debt restructuring agreements with its creditors, triggering a $250 million loan, courtesy of shareholders United and Kingsland International Group. It also announced an additional $125 million in financing from several investors.

Pundits suggest American Airlines will possibly seek out other unattached South American airlines such as Brazil's GOL, Chile's Sky Airline or Aerolineas Argentinas. Executives at Brazilian carrier Azul suggested at their investor day in mid-October that they were considering joining the

ROB FINLAYSON

LATAM is expected to leave the Oneworld alliance by Oct. 1, 2020.

proposed United-Avianca-Copa joint venture. Instead, Azul pivoted to a proposed transatlantic joint venture with TAP Portugal on Nov. 7.

"American [Airlines], traditionally, has been the leader in the region," says Peter Cerda, regional vice president of the Americas for the International Air Transport Association (IATA). "American will look at what's the best fit to supplement their hubs and connectivity to the region."

The Latin American-Caribbean region is clawing its way back from a disappointing 2018, a year in which it collectively posted a net loss per passenger of $2.78. For 2019, the region is forecast to show a net loss of $1.32 per passenger, according to data from IATA. The forecast figure for the Latin American-Caribbean market is considerably lower than the industry-wide $6.10 net profit forecast for 2020. By comparison, North American carriers, profit is forecast at $16.81 per passenger, with European carriers at $5.21 and Asia-Pacific carriers at $2.92.

"Latin American carriers will end up with about a $400 million net loss, though 2019 was a better year than 2018's nearly $800 million loss," Cerda says. "[This is] very different from our counterparts in North America and Europe, in that their [profit] numbers are $16.9 billion and $6.2 billion [respectively]."

Among the major Latin American airlines, Copa has the strongest financial results at the nine-month point, showing a $244 million net profit that nearly matches the same period in 2018. Azul is posting an adjusted (for foreign currency fluctuation) net income of $196 million, down about 5% year-over-year. Mexican LCC Volaris has a $69 million net profit for the period through Sept. 30, reversing a $10 million loss in the first three quarters of 2018. The remaining major Latin American carriers are all reporting nine-month net losses: LATAM has lost $37 million; GOL has a $62 million net loss; Aeromexico is posting a deficit of $117 million; and Avianca, despite its turnaround efforts, reported losses of $516 million.

Positivity Amid the Gloom for Air Cargo

> PROTECTIONIST POLICIES THREATEN CARGO SECTOR

> E-COMMERCE PROVIDES SOME CAUSE FOR CHEER

Helen Massy-Beresford Paris

If 2019 was challenging for air cargo operators coming off two years of growth, 2020 is likely to be characterized by a toxic mix of global macroeconomic uncertainty and political and trade tensions. That suggests the year ahead is not likely to provide much relief for the cargo industry.

But operators are focusing on areas of the business that do provide cause for optimism, including fast-growing e-commerce.

The International Air Transport Association (IATA) said Dec. 4 that demand measured in freight ton-kilometers (FTK) dropped 3.5% year-over-year in October. That dip, a weak start to the traditional end-of-year peak season for air cargo, marked the 12th consecutive month of year-over-year declines. Meanwhile, capacity, measured in available freight ton-kilometers (AFTK), rose 2.2% year-over-year—capacity growth outstripped demand for the 18th consecutive month.

"Demand is set to decline in 2019 overall—the weakest annual outcome since the global financial crisis. It has been a very tough year for the air cargo industry," says Alexandre de Juniac, IATA's director general and CEO.

Paul Bingley, commercial manager for Antonov Airlines UK, expects "another tough year" for the global cargo industry. "Continuing trade wars, stagnant economies and global uncertainties such as Brexit will continue to dictate the immediate future," he says.

Cheryl Gorman, vice president for Cargo, Hoist & Winch at Collins Aerospace, says the company sees "some pressure on demand in the near term, particularly in the larger routes such as Asia-North America."

But like others in the industry, Gorman maintains a positive outlook in the face of near-term difficulties. "The fundamentals for the air cargo industry remain strong, with cross-border e-commerce continuing to gain market share, and international express services growing to meet the rapid delivery expectations of an expanding global middle class," Gorman says.

Demand can also rebound quickly, she adds, noting that after the 2008 downturn, global air cargo demand measured in FTKs regained its pre-recession levels by early 2010.

ANTONOV AIRLINES

Antonov says aerospace and energy are driving demand.

Steven Polmans, chairman of The International Air Cargo Association (TIACA), also strikes a slightly more upbeat note despite near-term uncertainties. He says that although the likes of Brexit, oil prices and the trade war make forecasting difficult, there could be a light at the end of the tunnel when it comes to economic outlook.

"According to economists, 2020 should provide a more favorable business backdrop for the air transport industry overall than 2019 has delivered—especially taking into account the [International Monetary Fund] expectations that economic activity will lift in 2020," Polmans says.

He expects current trends to continue in the first and perhaps the second quarter of the year. "But we should see an improvement after," Polmans adds. "To my mind, the protectionist reflex currently being seen all over the world is a longer-term concern."

For now, even in the context of the U.S.-China trade war, operators are focusing their attention on the trade flows that are holding up.

Research specialist eMarketer estimates the global e-commerce market will grow 20.7%, to $3.54 trillion, in 2019. And that figure could approach $5 trillion in 2021, even if growth rates are set to fall below 20% in 2020.

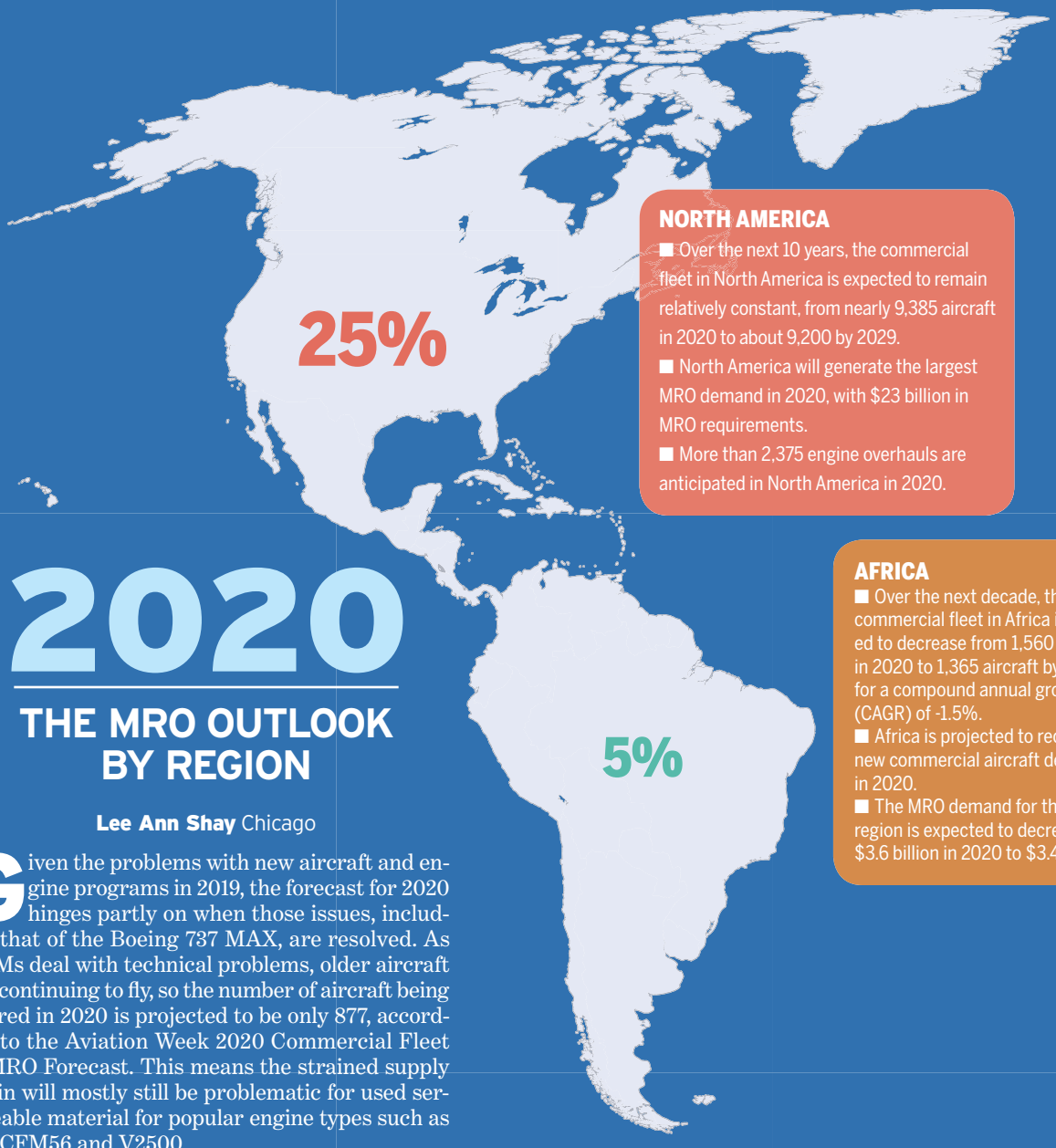
For all-cargo operator Antonov's An-124 business, aerospace and energy should also keep driving demand, Bingley says. "The continuing investment in space will see multiple satellites launched in 2020, meaning that, as always, we can rely on the aerospace sector to keep us busy," he adds.

Sustainability is set to be an important issue in 2020. Initiatives to cut waste, increase efficiciency and reduce the weight of packaging and equipment are among the measures in the offing. Tackling emissions is also an important focus for air cargo operators, even more so as scrutiny over the broader aviation industry's contribution to climate change intensifies.

"We are particularly focused on providing lighter cargo handling systems to reduce fuel consumption and increase aircraft efficiency on the whole," Gorman says.

The company's Freighter Common Turntable—which combines stop, brake, steer and drive functions into a single package and provides more than 200 lb. in weight savings at the system level—is currently flying on the Boeing 777 and 747.

TIACA launched its first sustainability award this year. "I'm confident that collective awareness about sustainability in the broad sense will arise across the whole industry in 2020," Polmans says.



2020

THE MRO OUTLOOK BY REGION

Lee Ann Shay Chicago

Given the problems with new aircraft and engine programs in 2019, the forecast for 2020 hinges partly on when those issues, including that of the Boeing 737 MAX, are resolved. As OEMs deal with technical problems, older aircraft are continuing to fly, so the number of aircraft being retired in 2020 is projected to be only 877, according to the Aviation Week 2020 Commercial Fleet & MRO Forecast. This means the strained supply chain will mostly still be problematic for used serviceable material for popular engine types such as the CFM56 and V2500.

At the same time, 2020 should see a record number of deliveries if Boeing resumes handovers of the MAX early in the year. But expect Airbus A320neos to lead regardless—which means CFM Leap 1B engines will lead the engine deliveries. The forecast projects that 2,743 aircraft will enter service, almost 500 more than the following year, when more aircraft will retire as those deliveries take place.

Looking at regional fleet growth rates over the 10-year forecast period, India leads with 10.6%, followed by the Middle East with 8.5% and Latin America with 5.7%.

However, North America still leads MRO demand in 2020, followed by Western Europe and the Asia-Pacific region (excluding China and India).

NORTH AMERICA

- Over the next 10 years, the commercial fleet in North America is expected to remain relatively constant, from nearly 9,385 aircraft in 2020 to about 9,200 by 2029.
- North America will generate the largest MRO demand in 2020, with $23 billion in MRO requirements.
- More than 2,375 engine overhauls are anticipated in North America in 2020.

AFRICA

- Over the next decade, the active commercial fleet in Africa is expected to decrease from 1,560 aircraft in 2020 to 1,365 aircraft by 2029, for a compound annual growth rate (CAGR) of -1.5%.
- Africa is projected to receive 70 new commercial aircraft deliveries in 2020.
- The MRO demand for the African region is expected to decrease from $3.6 billion in 2020 to $3.4 billion in

LATIN AMERICA

- During the 10-year forecast period, the aircraft in-service fleet in Latin America will grow from 2,440 aircraft in 2020 to nearly 4,025 aircraft by 2029, with a CAGR of 5.7%.
- MRO demand in Latin America is expected to increase from $5.3 billion in 2020 to $8.2 billion in 2029, for a CAGR of 4.9%.
- Engines (42%), components (28%) and line maintenance (20%) will comprise the largest shares of the MRO market in Latin America in 2020.

WESTERN EUROPE

- The top five aircraft family deliveries in Western Europe in 2020 are: the Boeing 737 MAX 8 (29%), Airbus A320neo (21%), Airbus A321neo (9%), Airbus A350-900 (8%) and Boeing 787-9 (7%).
- Western Europe by itself will rank second in MRO demand in 2020 compared to other world regions, reaching $19 billion.
- More than 1,460 engine overhauls are anticipated in Western Europe in 2020.

EASTERN EUROPE

- The active commercial fleet in Eastern Europe is expected to increase from 2,075 aircraft in 2020 to nearly 2,770 aircraft by 2029, a CAGR of 3.2% during the forecast period.
- The Boeing 737 MAX 8 holds the largest share of new aircraft deliveries in Eastern Europe, with 36% of the total, followed by the Sukhoi Superjet and Airbus A321neo with 12% and 8%, respectively.
- The MRO demand for the Eastern Europe region will grow from $5 billion in 2020 to $6 billion in 2029, a CAGR of 1.8%.

CHINA

- Over the next 10 years, the Chinese commercial fleet will grow from 4,315 aircraft in 2020 to 5,970 aircraft by 2029, a CAGR of 3.7%.
- China will see 415 new aircraft deliveries in 2020.
- The 10-year MRO demand for China is $109.6 billion in constant dollars.

INDIA

- Over the next 10 years, the Indian commercial fleet is forecast to grow from 800 aircraft in 2020 to nearly 1,975 aircraft by 2029, exhibiting the highest regional CAGR, 10.6%.
- The top three aircraft deliveries in India for 2020 will be: Airbus A320neo (45%), ATR (18%) and Boeing 737 MAX 8 (14%).
- MRO demand for the Indian region is expected to grow from $2.0 billion in 2020 to $4.3 billion in 2029, a CAGR of 8.2%.

MIDDLE EAST

- Over the next 10 years, fleets in the Middle East are expected to nearly double, growing from 1,760 aircraft in 2020 to 3,670 aircraft in 2029, a CAGR of 8.5%.
- MRO demand in the Middle East is projected to double and could reach $16.5 billion by 2029.
- Engine MRO requirements will have the fastest growth in the region, representing 46% of total spending.

ASIA-PACIFIC (excluding China and India)

- Nearly 425 new commercial aircraft are expected to be delivered in the region in 2020.
- MRO demand in the Asia-Pacific region is expected to grow from $18 billion in 2020 to $26.5 billion in 2029, a CAGR of 4.3%.
- Engine maintenance will capture a 44% share of all MRO demand, followed by line maintenance (22%) and components (21%) in 2020.

Source: Aviation Week Network

Comparing MRO Markets

> COMMERCIAL AND MILITARY MRO WILL DOMINATE DEMAND IN 2020

> COMPOSITION OF MRO DEMAND VARIES WIDELY ACROSS SECTORS

Lee Ann Shay Chicago

The combined 2020 MRO market for commercial, military, business aviation and civil helicopters should be valued at $184.3 billion, according to the Aviation Week Network 2020 Fleet & MRO Forecasts. The commercial and military MRO segments alone represent $165.8 billion. However, the forecasts call for commercial aircraft to generate 91.2 million flight hours and military aircraft to generate only 9.9 million, so the cost per flight hour for military aircraft is much higher.

Expect field maintenance to generate 49% of all military MRO expenditures, followed by components, airframes and engines.

This is very different than the mix for commercial aircraft, where the MRO forecast calls for engine maintenance to generate 43% of MRO demand, followed by line maintenance, components, modifications and airframe maintenance.

One thing that the commercial, military and civil helicopter MRO demand forecasts have in common is geography: The top MRO generators for all three will be North America, then Europe, followed by the Asia-Pacific region.

For business aviation, however, the top three regions are North America, Europe and Latin America. Asia-Pacific MRO demand for this segment in 2020 will be less than half of that for Latin America.

For each of the forecasts, the aircraft expected to generate the most MRO demand in 2020 will be the Boeing 737-800 (commercial), Lockheed Martin F-35 (military), Eurocopter H125/H130 (helicopter) and Bombardier GlobalExpress (business).

For more about Fleet & MRO Forecasts, go to:
https://pgs.aviationweek.com/Forecasts

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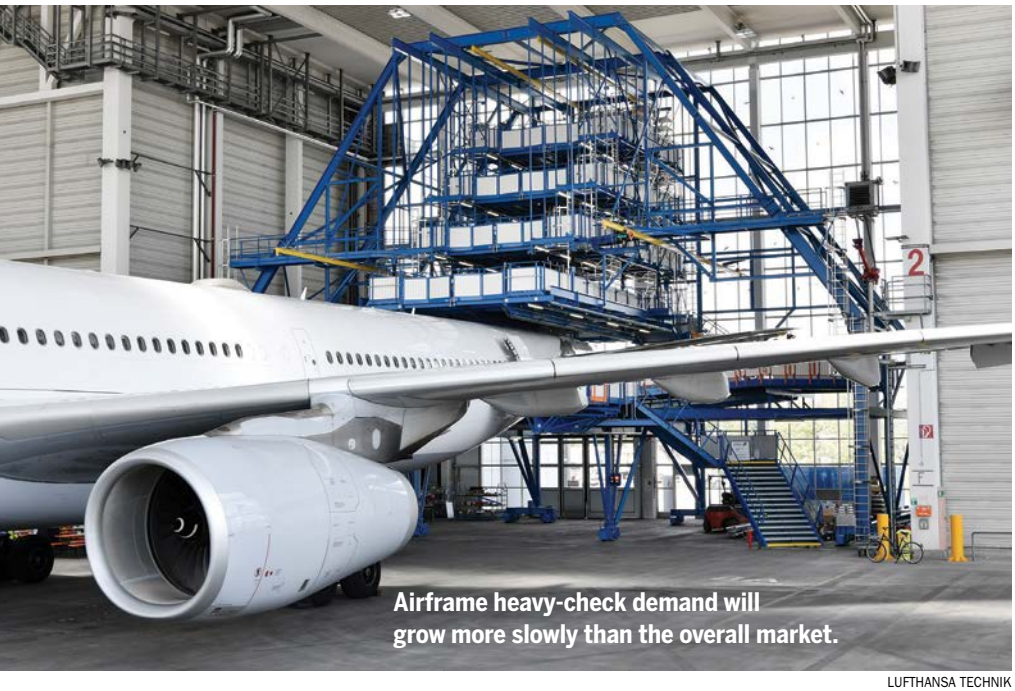
2020 Forecasts: Comparing Aircraft Segments

	COMMERCIAL AIRCRAFT	BUSINESS AIRCRAFT	CIVIL HELICOPTERS	MILITARY AIRCRAFT
Fleet Size	33,887	31,746	21,744	40,728
Flight Hours	91.2 million	11.9 million	9.9 million	9.9 million
New Aircraft Production Values	$316.0 billion	$20.5 billion	$3.2 billion	Undetermined
MRO Demand	$82.5 billion	$12.2 billion	$6.3 billion	$83.3 billion

Source: Aviation Week 2020 Fleet & MRO Forecasts



Airframe heavy-check demand will grow more slowly than the overall market.

LUFTHANSA TECHNIK

Airframe Maintenance Work Will Moderate

> AIRFRAME WORK PROJECTED TO GROW 2.7% ANNUALLY

> 737 MAX'S RETURN, FUEL PRICES WILL AFFECT NEAR-TERM DEMAND

Sean Broderick

A strong heavy maintenance market is projected to moderate in the coming years as demand for major airframe checks returns to a more historical norm, but industry will be watching a few key trends that could affect near-term aircraft usage and, by extension, aftermarket activity.

Aviation Week's 2020 Commercial MRO forecast sees the airframe maintenance market for the global, Western-built fleet of 33,700 aircraft certified for 10 or more seats increasing at an average compound annual growth rate (CAGR) of 2.7% through 2029. The figure is slightly below the overall MRO market's 2.9% projected average CAGR over the next decade, which is projected to start with annual rates closer to the mid-single digits.

The fleet in 2020 is expected to generate nearly 10,600 airframe maintenance events, defined as C or D checks or the equivalent in phased inspections, and $4.9 billion in revenue. Not surprisingly, the two workhorse narrowbody models, the 737-800 and A320ceo, will generate the most 2020 activity. The venerable Boeing twin will account for 1,750 airframe events, while the baseline A320 model will undergo 1,363, the forecast shows.

The 2020 forecast combined with market intelligence suggests a deceleration before the market returns to a steady historical growth pattern. The heavy airframe maintenance market was particularly strong in 2019, lifted in part by demand for freighter conversions—particularly 737s and 767s. A Canaccord Genuity survey of about 40 aftermarket providers reported airframe heavy maintenance demand running 8% above year-earlier levels through the first half of 2019, and projected a full-year increase of 9%—in line with the MRO market as a whole. Looking ahead, respondents foresee growth slowing to 5% in 2020 for both the airframe and total MRO markets.

A decline in heavy checks would go hand-in-hand with upticks in both retirements and deliveries. Retirements have been trending below recent historical averages, falling to 1-2% of the in-service fleet, thanks to a combination of sustained strong demand for lift and issues with new airframe and engine programs that have slowed deliveries. Aviation Week sees commercial retirements rising in each of the next four years to approach 1,200 in 2023—more than twice the expected final 2019 figure.

The Boeing 737 MAX is the most prominent example of new-program issues affecting fleet plans. As 2019 headed into 2020, airlines were making up for not having some 750 MAXs they had planned to be operating. About 380 were in service when a global grounding parked the fleet in mid-March, and the rest have been built but not handed over, as Boeing halted deliveries with the grounding.

Quantifying the MAX grounding's effect on aftermarket demand is challenging, but few dispute there has been an uptick. Several carriers announced fleet changes linked to the MAX situation's uncertainty, unveiling plans to keep operating older narrowbodies a few years longer than expected. Examples with immediate ramifications include Southwest Airlines retaining seven 737-700s slated to be parked in 2019, and American Airlines keeping 10 757s that were to have been parked by now.

Fleet-planning headaches have not been limited to the narrowbody segment. Rolls-Royce's Trent 1000 engine struggles—a series of durability issues that have affected all variants of the Boeing 787 powerplant—have forced operators to turn to lessors or delay retirements while Rolls works to manufacture enough spare parts and line up

Top Five Airframe Heavy Maintenance Events, 2020

AIRCRAFT GROUP	TOTAL EVENTS
Boeing 737-800	1,750
Airbus A320ceo	1,363
Airbus A321ceo	564
Boeing 757	418
Embraer 170/175	395

Source: Aviation Week 2020 Commercial Fleet & MRO Forecast

Optimization programs are helping operators such as Emirates lower costs on legacy aircraft types.

TEAMTIME/DEPOSIT PHOTOS

MRO capacity to meet demand. Virgin Atlantic planned to park the rest of its Airbus A340s last year as its first A350s were delivered. But issues with its Trent-powered 787s led Virgin to keep at least one A340 in service into 2020.

Such issues rarely have a direct influence on heavy airframe maintenance—Virgin did not put any of its A340s through heavy checks to get them in shape for 2020, for instance. But the knock-on effect can lead to changes in airframe maintenance demand, such as delaying the transition of older airframes into the freighter-conversion pipeline—a process that includes a heavy maintenance visit.

Two factors that could influence near-term heavy maintenance demand are fuel costs and retirement rates. Normally, as fuel costs rise, fares increase to compensate. Demand falls, and the most expensive aircraft to operate—usually older, less efficient models—are bumped from schedules.

The good news for airlines is the price of fuel is not expected to jump soon. As of mid-December, prices had dipped 40% since midyear to around $70 per barrel for Brent crude. Production in places such as Brazil, Norway and the U.S. means the Organization of Petroleum Exporting Countries and its allies cannot control prices as they once did. Even a manufactured price spike by the consortium would hit a ceiling by making feasible more expensive production options such as fracking.

All of this points to a slight decline in 2020 fuel costs for airlines in the largest geographic market, analysts from Cowen and Co. project. They see U.S. airlines paying $2.07 per gallon, down a penny year-over-year, and 16 cents—or 7%—from 2018. Canadian carriers will enjoy a similar run, paying about U.S. $0.76 per liter in 2020, slightly down year-over-year.

The coming year will not be a normal one, however. The presumed return of the MAX fleet will see the industry absorbing a significant amount of capacity in a short time. The MAX's

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return will be phased, with countries including China and India undertaking their own reviews and delaying approvals until well into 2020, at least. North America will be on the front end, starting with the FAA. Canada is expected to follow in short order.

Many MAXs were earmarked for growth, so the fleet's return will not bring a one-for-one removal of older aircraft. But many MAX operators made contingency plans, keeping older aircraft flying or leasing capacity to help replace the lost seats. This has helped boost aftermarket activity.

The MAX's return will not necessarily mean a related decline in MRO opportunities, however. Retirements may jump, which means less in-service work but a boost for used-parts feedstocks. Getting MAXs back also could help free up a few older, prime narrowbodies, likely 737-800s, for cargo conversion.

The long-term trend in airframe maintenance calls for fewer events over an aircraft's useful life. The newest designs integrate more composites and other materials that do not corrode and offer more general durability than older models. Under Boeing's baseline assumptions, a 787-8 will require about half as many heavy-check labor hours as a 767-300ER over comparable expected useful lives. Part of the savings will be offset by labor-cost increases, which could accelerate as the industry struggles to meet demand for technicians as it grows.

While most major advances in heavy maintenance efficiency are coming via new designs and materials, older models are helping to lower maintenance burdens as well. Programs such as Boeing's Optimized Maintenance Program (OMP) help operators modify maintenance intervals using their own data. In many cases, the results include longer heavy-check intervals. Emirates, which operates about 10% of the world's 777s, is using OMP to extend C check intervals on most of them to 18,000 flight hours or 1,200 days—increases of 20% compared to the 2006 program.

Retirements are projected to rise in 2020 as the 737 MAX returns.

NIGEL HOWARTH

Engine MRO in 2020

> ENGINE SEGMENT'S AFTERMARKET SHARE STANDS AT 42%

> NORTH AMERICA WILL SEE HIGHEST ENGINE MRO SPENDING IN 2020

James Pozzi London

The CFM56 and V2500 families will account for around one-third of commercial engine aftermarket spending in 2020, with MRO demand boosted as mature models are kept in service longer owing to the slower pace of their successors entering service.

This slowdown is the result of technical issues related to CFM International's Leap, the CFM56's successor, and the Pratt & Whitney PW1000G geared turbofan (GTF) over the past few years. In a commercial engine segment valued at $34.7 billion for the year by Aviation Week's latest Fleet & MRO Forecast, the CFM56 and V2500 are forecast to generate $12.9 billion in combined spending over a 12-month period.

MTU MAINTENANCE

The CFM56 family is projected to have approximately 23,058 units in service this year, with the -7B variant powering the Boeing 737NG the most prominent, accounting for more than half of the CFM56 fleet. Meanwhile, the V2500 engine found on the Airbus A320 aircraft family will have 6,000 units in service.

While the surplus of work will be good news for repair specialists, the longevity of the CFM56 and V2500 also could ensure that MRO market capacity will remain tight for the next 2-3 years at least. The availability of spare engines and related materials likely also will be scarce for the next few years, until relief comes in the form of retirements hitting the market and supplying more used materials.

These retirements are expected to pick up starting in 2023 for CFM56 engines, when for the first time more than 1,000 will be retired during that year. By the end of the decade in 2029, an estimated 8,858 CFM56 engines will leave service. Retirements of the V2500 also will increase gradually. Numbering just 98 in 2020, over a 10-year period approximately 2,178 V2500s will be phased out.

While the arrival of the new narrowbody engines has been sluggish, the influx of the Leap and GTF is nevertheless still expected to pick up. According to Aviation Week data, around 2,600 deliveries of the Leap are expected in 2020. However, this figure could be dependent on the fortunes of the -1B variant, the engine option for the Boeing 737 MAX program.

In 2019, the aircraft was dogged by problems unrelated to its Leap engines, leading to the grounding of the fleet in March. Boeing said it intends to have the aircraft back in service during 2020, but the groundings have hit some OEMs hard.

While some airlines have since placed large orders for the MAX (such as British Airways' for 200 aircraft), others have chosen to look elsewhere. These include low-cost carrier Flyadeal of Saudi Arabia, which canceled its order for up to 50 of the Leap-powered aircraft in summer 2019. The Leap 1A variant for the A320neo, which entered service in 2015, will not see any significant MRO spending until 2024.

Aviation Week predicts the widebody engine segment will account for $16.5 billion of the market in 2020. The segment, dominated by GE Aviation and Rolls-Royce, which hold 50% and 33% shares of the market, respectively, will account for an estimated 2,257 maintenance events throughout the year. Of GE Aviation's market share, 30% will emanate from the CF6-80C2, used on several Boeing and Airbus widebody aircraft including the A330, 747 and 767.

The V2500, with the CFM56, will account for a significant proportion of engine MRO spending in 2020.

Powering the 787, a popular aircraft option for airlines looking to reduce fuel consumption costs, GE Aviation's GEnx engine will see the highest delivery volumes, with 248 engines set for 2020. This will be followed by Rolls-Royce's Trent XWB, the exclusive option for the A350, which will see 240 deliveries in 2020, according to Aviation Week data. GE's CF6-80 model, powering aircraft including the A330, 757 and 767, will have the highest volume of retirements over 10 years, numbering 1,649 units in 2020-29.

In the turboprop segment, which accounts for just 5% of the global commercial fleet, aftermarket spending is centered on just a handful of engine types. Pratt & Whitney Canada will hold more than 80% of the market in 2020, with much of this related to the PW100 engine, primarily found on the ATR42 and 72. With no new entrants expected in the turboprop segment, the OEM's market dominance will grow over the next decade—standing at around 92% by 2029.

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TOP 10 MRO PREDICTIONS FOR 2020

What to watch for **in the civil aviation aftermarket in 2020**

Lee Ann Shay Chicago

ERIC PIERMONT/GETTY IMAGES

1 | M&A: Hot, Hot, Hot

Mergers and acquisitions will continue to be hot from all sides, including OEMs and other non-MROs buying, as well as private equity buying and selling. However, expect few large acquisitions because the easy pickings are gone, and valuations of any remaining sizable acquisition targets are high.


INVERT ROBOTICS

2 | Robotics

Robotics are going to start truly taking off within MRO for improving safety and accuracy with tasks such as aircraft inspections, paint removal and nondestructive testing.


DONECLE

3 | Drone Inspections

Drone trials will continue to proliferate for aircraft inspections. Could 2020 be the year regulators approve drone inspections as a stand-alone procedure?


BOEING

4 | MAX Impact

With a prolonged 737 MAX grounding and growing pressure on capacity, there will be an impact on the aftermarket for the CFM56-3/7B on Boeing 737 Classics/NGs—and possibly even the V2500/CFM56-5 on Airbus A320s—as operators continue to defer maintenance in the short-to-mid-term.


AEROLUS ENGINE SERVICES

5 | Parts Shortages

Next-gen engines such as the PW1000G-JM will need maintenance on top of scheduled upgrades, and older aircraft are staying online due to delivery delays, so the shortage of used serviceable material for popular engine types—especially CFM56s, V2500s and CF6s—will be even worse in 2020. This will drive prices higher and also lead to more repair development.


THAI AIRWAYS

6 | Southeast Asia

MRO facility growth in Southeast Asia will continue, with new or expanded facilities in places like Batam, Indonesia; U-Tapao, Thailand; and Kuala Lumpur.

GOL

7 | Latin Expansion

Investment is underway as airlines gain partners and expand in-house maintenance services. For example, Brazil's GOL launched a new business unit in late November, GOL Aerotech. Azul Airlines will open a hangar in 2020 to bring maintenance in-house. Delta plans to invest in LATAM, while United is doing the same with Avianca. Pratt & Whitney opened an engine overhaul center in Belo Horizonte on Dec. 11.


TONEFOTOGRAFIA/GETTY IMAGES

8 | Big Data

To really accelerate big data analytics, companies need to start sharing more positive outcomes to demonstrate the value of the field and show why companies should consider sharing data.

FAA

9 | Slow Dance

Expect longer approval times for anything a regulator touches and a potential logjam for FAA certification projects if ODA is scaled back.


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10 | 'Let's Just Get Along'

Strife over foreign repair station approvals could erupt if the FAA carries out the U.S. Congress' mandate for revamped oversight.

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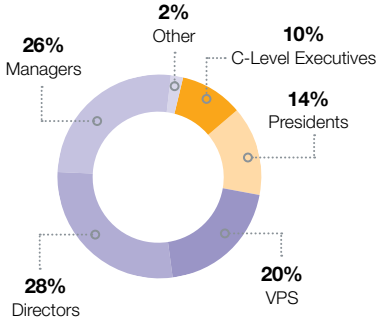

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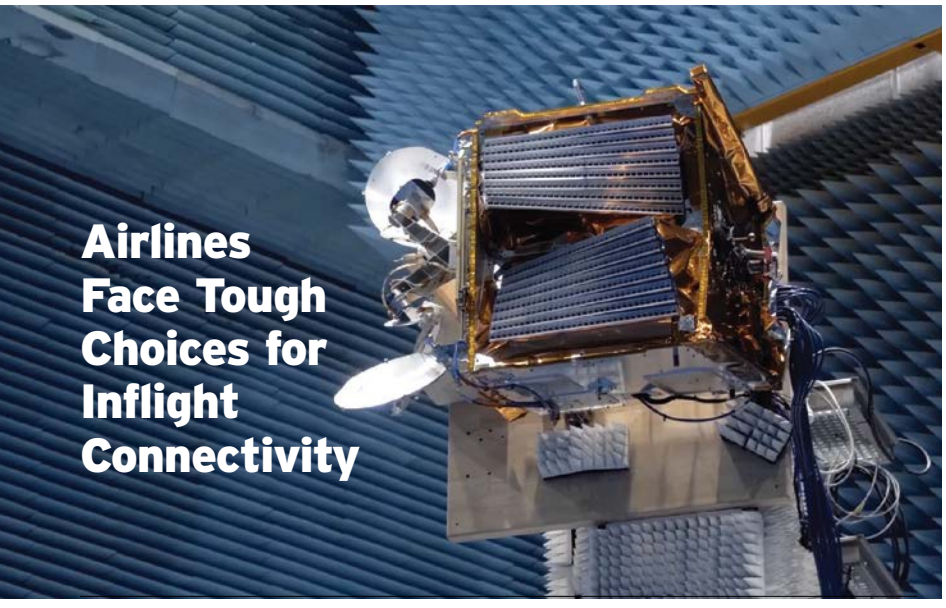


Airlines Face Tough Choices for Inflight Connectivity

> SEAMLESS AIR ALLIANCE SEEKS EASY PASSENGER CONNECTIVITY

> STANDARDIZED COMPONENTS EYED TO HELP LOWER COSTS

Kerry Reals London

Decisions on which satellite-based inflight connectivity (IFC) technology and providers to use are becoming more complex for airlines.

Not only do carriers still face the Ku-versus-Ka-band dilemma, their choice now is between installing a system based on geostationary (GEO) satellite technology available today, or taking a chance and waiting several years until new constellations of low-Earth-orbit (LEO) satellites are ready to provide airborne Wi-Fi services.

The good news is that regardless of what they decide, equipment and maintenance costs are likely to come down as standardization takes hold and plug-and-play components become more commonplace.

A growing number of satellite companies, IFC providers, airlines and equipment manufacturers have joined the Seamless Air Alliance (SAA) in its quest to enable passengers to connect to the internet on their personal devices as easily in the air as on the ground. Part of that quest involves finding a way of standardizing components, which the alliance believes will result in greater interchangeability and lower installation and maintenance costs.

"There is a huge benefit of standardizing this equipment for airlines," says SAA CEO Jack Mandala. "To begin with, there is an industry-level economy of scale that comes from standardization to reduce equipment costs. Next, standards reduce the cost of spare-parts programs and the overhead of training maintenance staff on the operation and repair of disparate systems."

The alliance's "ultimate goal," says Mandala, is to make every component in the system interchangeable and allow for true plug and play of equipment.

UK satellite company Inmarsat joined the SAA because "it was the right thing to do to make sure we're part of shaping what the industry looks like" going forward, says Kurt Weidemeyer, vice president for strategy and business development at Inmarsat Aviation. On modularity, Weidemeyer says it "drops the price for everyone if everyone is working to the same standard."

Inmarsat, which provides Ka-band inflight broadband through its GX Aviation system and a hybrid air-to-ground and satellite-based system known as the European Aviation Network, announced plans in 2019 to launch a number of additional GEO satellites and GX payloads to support its Global Xpress network.

The launch of Inmarsat's GX7, 8 and 9 satellites, manufactuerd by Airbus Defense and Space, in the first half of 2023, together with GX payloads (GX10A and 10B) on two additional satellites operated by Space Norway and placed into highly elliptical orbits to enable coverage across the Arctic, means Inmarsat's IFC offering will be "future-proofed for the next two decades," says Weidemeyer.

His suggestion to airlines weighing satellite-based IFC options is to ask two questions:

A Gogo 2KU antenna uses a symmetrical, phased-array design that has significantly fewer moving parts.

- Who has control of the network and can offer a global, end-to-end solution?
- Are they building for the future and ensuring equipment installed today will work with evolving satellite technology?

"Airlines want [IFC to do] what it says on the tin, and they want to know if it's going to last a long time. With our network, whatever you put on [the aircraft] today will work for the next decade-plus," says Weidemeyer.

Inmarsat's decision to invest in payloads that add Arctic coverage to its GX network suggests connectivity over the North Pole is becoming an important factor for airlines when mulling IFC options. Indeed, Emirates said in July the addition of two elliptical-orbit satellites by Inmarsat means passengers on its U.S.-bound flights, which often travel over the polar region, would no longer "find themselves without connectivity for up to 4 hr."

Newcomer OneWeb, which plans to offer a Ku-band inflight broadband service through a constellation of 650 LEO satellites beginning in the first half of 2022, will provide "polar coverage from day one," says Ben Griffin, the startup's commercial aviation vice president.

OneWeb is pushing full global coverage and low latency as its key selling points to airlines, and it is hoping this will convince them to bet on an unproven network.

Latency—the amount of time it takes to send and receive data to and from a satellite—is "under 100 millisec." with LEOs, versus 700-800 millisec. with GEOs, says Griffin.

"Four or five years ago, it was all about Ku versus Ka, and airlines were being educated in things they didn't want to be educated in," he notes. To avoid further confusion when presenting its "step-change" LEO solution, OneWeb prefers to "leave the science to one side" and talk instead about what the technology can deliver.

OneWeb is a founding member of the

SAA and is keen to see a greater degree of modularity across IFC components.

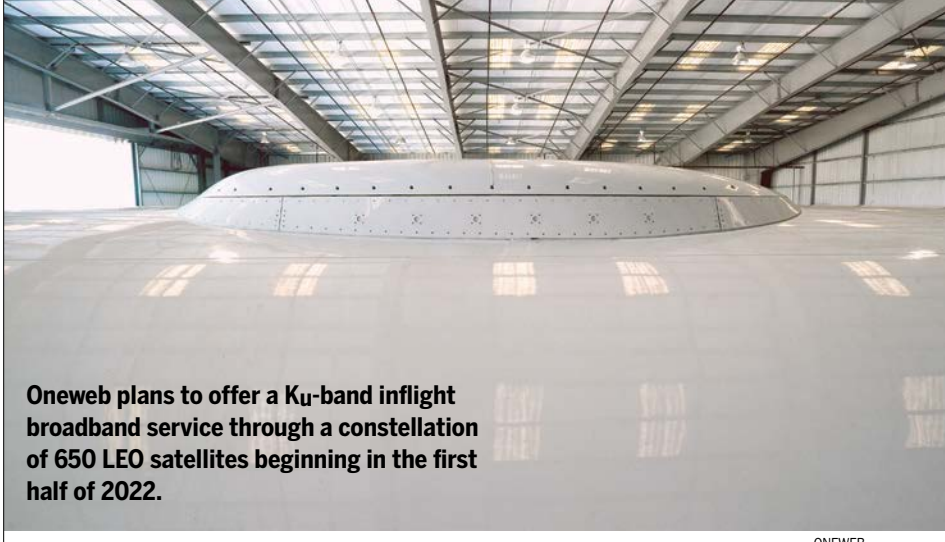
"There's a whole raft of IFC options out there for selection," says Griffin, adding that "standardization of equipment is fairly key."

IFC provider Gogo is another proponent of standardization. "The goal is to standardize form, fit and electrical interfaces of [line replaceable units] intended for line-fit installation in commercial aircraft," says John Wade, president of the company's commercial aviation division. "Modular systems work well, provided the candidate airframe can partition functions while allowing systems to interact effectively."

But Viasat, which is building a global Ka-band GEO network that will culminate in the launch of a third satellite constellation—ViaSat-3, due to be fully operational by the second half of 2022—appears unconvinced of the merits of joining the SAA, says Don Buchman, vice president for commercial mobility.

Viasat plans to offer a hybrid Ku/Ka antenna to widebody aircraft operators that do not want to wait another three years for its Ka-band service to become global. Buchman says he expects the hybrid service to launch "within a quarter or two," with an "announceable customer."

Another choice facing airlines is whether to opt for a connectivity provider that owns and operates the satellites, such as Inmarsat or Viasat, or one that leases satellite capacity and is more technology-agnostic.



Oneweb plans to offer a Ku-band inflight broadband service through a constellation of 650 LEO satellites beginning in the first half of 2022.

ONEWEB

Gogo falls into the latter camp, and Wade explains why: "By leasing satellite capacity, Gogo can quickly leverage the advances in satellite technology once mature enough for commercial use. Our open satellite ecosystem allows us to add capacity on demand, strengthen our network and maintain redundancy. Being locked into a closed system can leave airlines tied to older and more expensive satellites for many years, even as new ones are launched."

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MRO Workforce: Help Wanted

Maintenance workforce shortage will be more pronounced in the 2020s

Lindsay Bjerregaard

Global Technician Demand

According to Boeing's Pilot & Technician Outlook for 2019-38, there will be a need for **769,000** *new maintenance technicians globally over the next* **20** *years.*

Technician Demand by Region

Asia-Pacific	266,000
China	124,000
Southeast Asia	56,000
South Asia	36,000
Northeast Asia	22,000
Oceania	11,000
North America	193,000
Europe	137,000
Middle East	69,000
Latin America	52,000
Africa	27,000
Russia/Central Asia	25,000

Technician Demand by Aviation Segment

Commercial Aviation	632,000
Business Aviation	93,000
Rotorcraft	44,000

Regional Challenges

U.S.

Oliver Wyman projects that a gap between supply of and demand for mechanics will develop by 2022 and reach a peak of **9%** by 2027.

According to FAA U.S. Civil Airmen statistics, in 2018 only **2.4%** of mechanics and **5.2%** of repair technicians were women.

The U.S. Bureau of Labor Statistics says **the median age of aviation mechanics is 51 years**—nine years older than the median age of the broader national workforce.

ATEC projects that the mechanic population will decrease **5%** in the next 15 years.

Asia

The workforce crunch is expected to be felt first in Asia, where the bulk of aircraft fleet growth is set to occur.

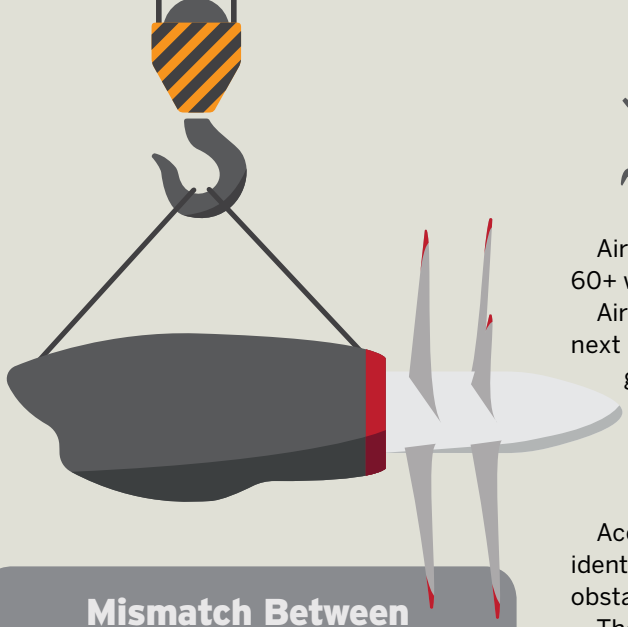
According to the Aviation Week Network's 2020 Commercial Fleet & MRO Forecast, the Asia-Pacific region (including China) will account for **31%** of the world's MRO share over the next decade and will continue to grow.

Europe

The Aviation Week Network's 2020 Commercial Fleet & MRO Forecast projects that Western Europe's mature fleets will generate **20%** of estimated MRO demand—nearly matching that of North America, which will lead with **21%**.

Airbus' Global Workforce Forecast for 2019-29 projects that Europe will be badly affected by increasing **retirements of baby boomers**.

Europe's population is expected to decline **4%** between 2013-50, a continuation of a long-term trend.



Mismatch Between Workforce Supply and Demand

Airbus projects that the following countries will have the largest surpluses and deficits in MRO talent over the next decade.

Top 10 Countries With Greatest Talent Surplus

1. India
2. Indonesia
3. Colombia
4. South Africa
5. Brazil
6. Morocco
7. Czech Republic
8. Egypt
9. Qatar
10. Peru

Top 10 Countries With Greatest Talent Deficit

1. Taiwan
2. Japan
3. Poland
4. Italy
5. Chile
6. Greece
7. South Korea
8. Canada
9. U.S.
10. UK

Worldwide Challenges

Retirements

Airbus' Global Workforce Forecast estimates that people aged 60+ will make up **21%** of the population by 2050.

Airbus expects **50,000** employees to leave the company in the next decade and **80%** of its staff in 2027 to be composed of generations Y and Z.

TEC's 2018 Pipeline Report states that **30%** of the mechanic population in the U.S. is 60 or older.

Wages and Benefits

According to an Oliver Wyman survey, **51%** of respondents identified aviation mechanics' current wages and benefits as an obstacle to recruitment.

The U.S. Bureau of Labor Statistics reports that in 2018, the mean hourly wage for aircraft mechanics and technicians was **$31.36** and the mean annual salary was **$65,230**.

Technology Advancement

Airbus estimates that the worldwide annual supply of industrial robots grew at an average of **13%** per year between 2015-19.

A recent survey by PwC found that **37% of workers were worried about potentially losing their jobs to automation.**

An Oxford Economics study estimates that by 2030, millions of jobs will have been lost to robots. **On average, each industrial robot is replacing 1.6 human workers.**

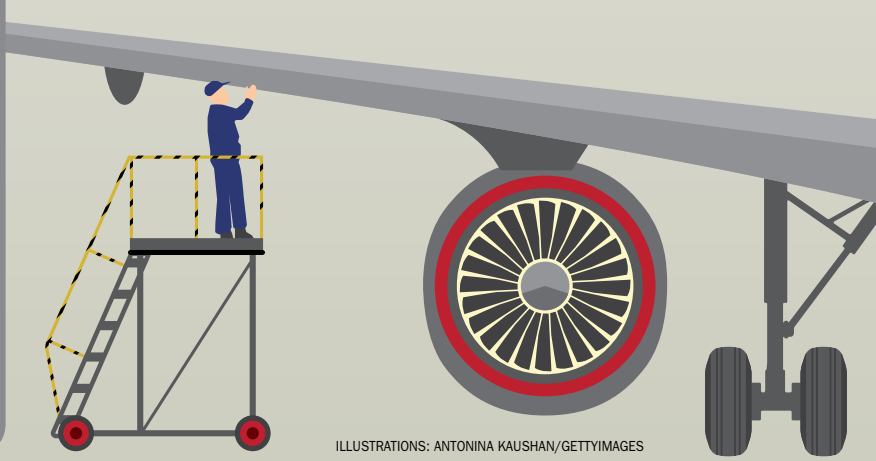
Boeing projects that advances in airplane technology will drive demand for a new set of skills.

Training

ATEC estimates that **30%** of students who finish an aviation maintenance training course eventually **accept employment in another industry.**

ATEC members report that the largest barrier to recruiting, accepting, retaining or graduating technical program students **is insufficient soft skills such as communication, strong work ethic and time management.**

As new technologies demand different skills, Part 147 training schools continue to lag behind in their curriculum—while costs to obtain training continue to rise.



ILLUSTRATIONS: ANTONINA KAUSHAN/GETTYIMAGES

Top 10 Cool New MRO Products

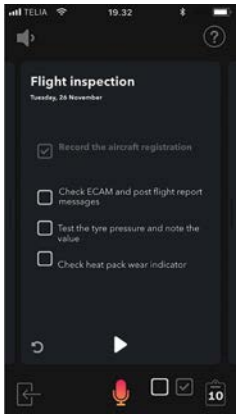
Lindsay Bjerregaard Chicago

1. Robotic Livery Printing

Company: **Xyrec**
Product: Automated Paint Robot
Specifications: Developed in collaboration with Airbus and Southwest Research Institute, Xyrec's Automated Paint Robot can print any aircraft livery design on an aircraft fuselage more efficiently than traditional masking and spray guns. In addition to printing the livery design, the robot can sand the fuselage, clean it after paint has been stripped, spray primer and clear coatings, and dry clear coatings in just 2 hr. Xyrec says the robot will be available commercially in 2020 with a direct print feature coming in 2021.
marketplace.aviationweek.com/product/completely-automated-paint-solution

2. AI-Based Voice Guidance

Company: **Whispr**
Product: Voice guidance system
Specifications: Whispr's hands-free voice guidance platform is powered by artificial intelligence and natural language processing, which converts text to speech and vice versa, to turn work instructions and checklists into interactive voice guidance. Workers are guided through tasks in their native language and can ask questions or receive reminders about tasks that need to be completed, which Whispr says solves language, accent and literacy challenges while helping workers better understand different work processes. Whispr is currently working to pilot the technology with Iberia and says the platform can help airlines and MROs improve the speed, accuracy and safety of aircraft inspections and turnarounds.
marketplace.aviationweek.com/product/whispr-aviation-and-mro

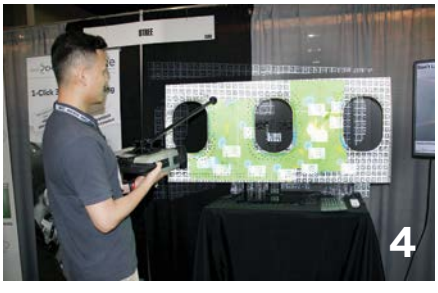


3. Versatile Tool Mat

Company: **Grypmat**
Product: Nonslip flexible tool mat
Specifications: Designed to increase mechanics' efficiency, safety and productivity, Grypmat is a flexible tool mat that bends around and sticks to curved surfaces while keeping tools in place with its high-grip material. In addition to protecting surfaces from scratching or damage, Grypmat is nonmagnetic—so it will not collect metal shavings. Grypmat says the product can increase maintenance efficiency by up to 33% while reducing tool loss and improving organization. Grypmat comes in a variety of sizes for different aircraft types, and the company says it is currently used at a number of regional and commercial airlines.
marketplace.aviationweek.com/product/never-lose-your-tools-again

4. Mapping Entire Aircraft Bays

Company: **8tree**
Product: DentCHECK pano inspection system
Specifications: Building on its original DentCHECK 3D damage-mapping tool, 8tree has released DentCHECK pano, which can inspect entire aircraft bays in less than 10 min. The product produces a digital collage that can be archived for comparison during future maintenance and 8tree says it has produced time-savings of more than 95% compared to traditional methods during customer trials. 8tree is now beta-testing PanoLite, which it says makes the process of large area inspection even faster, easier and more user-friendly. 8tree says PanoLite is a more agile solution suited for broader use cases, such as in the hangar, on the line or in AOG settings.
marketplace.aviationweek.com/product/oem-approved-damage-mapping-point-click-done



5. Simplifying Unscheduled Maintenance

Company: **SynapseMX**
Product: SynapseMX MRO data platform
Specifications: The SynapseMX cloud-based platform seeks to help carriers solve unscheduled maintenance headaches through the use of real-time data tools, which forecast potential impact, timing, parts needs and more,

Go to MROLinks.com for more information.

for maintenance events occurring in varying conditions and locations. The platform enables teams to monitor issues in real time, assign jobs, sign off on work, track job progress and use performance metrics to identify where bottlenecks are taking place. SynapseMX recently added functionality for language translation, image and video capture, and alerts about maintenance gate calls, which users can customize to receive the most relevant notifications.
marketplace.aviationweek.com/product/real-time-maintenance-management-execution-platform

6. Plug-and-Play Aircraft Washing

Company: **Riveer**
Product: Wingman aircraft washing system
Specifications: Riveer's "plug-and-play" Wingman washing system has been designed to eliminate aircraft corrosion or damage caused by leftover soap residue and excessive water pressure. The electric hot water foam and rinse system consists of a high-efficiency electric boiler, two hot water guns and a high-volume foam system, which Riveer says is easy to install and works with the 480-volt, three phase outlets currently found in many aircraft hangars. According to Riveer, Wingman's built-in combination of water temperature and pressure control is ideal for in-hangar washing of fixed wing and rotary aircraft.
marketplace.aviationweek.com/product/wash-your-aircraft-hangar-wingman

7. Tackling Tool Tracking

Company: **Xerafy**
Product: MRO Starter Kit
Specifications: Xerafy's MRO Starter Kit for Workshop Tool Management is aimed at helping MROs, airlines and OEMs implement the company's tool-tracking solutions on a small-scale trial basis. The kit comes with a selection of tool-tracking elements, including RFID tags for hand tools and equipment, an RFID handheld scanner and demonstration software. According to Xerafy, the technology can be used to solve productivity and compliance issues in MRO environments and the starter kit can help customers see how the solutions might fit into their workflow and facilities.
marketplace.aviationweek.com/product/automated-tool-control-starter-kit

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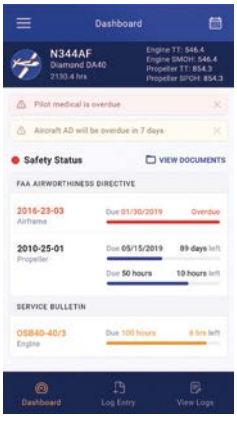

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8. 3D Scanning

Company: **Artec 3D**
Product: Artec Leo handheld scanner
Specifications: As one of the newest products in Artec 3D's line of scanning solutions, the Artec Leo is a handheld wireless scanner that uses structured light technology to produce a three-dimensional replica of aircraft parts and spaces. Artec says the Leo's ability to scan in smaller spaces or more unstable environments makes it ideal for use cases such as scanning inside aircraft lavatories or on aircraft wings. The Leo can be used for a variety of applications within aerospace and MRO such as quality assurance, damage scanning and reverse engineering of parts.
marketplace.aviationweek.com/product/artec-leo

9. Maintenance Tracking for General Aviation

Company: **Crewchief Systems**
Product: Crewchief GA MRO app
Specifications: Aimed at helping general aviation operators manage maintenance, operations and compliance, Crewchief GA from Crewchief Systems is an app that enables users to track maintenance timelines, receive personalized alerts about needed service, digitalize maintenance history and logbooks, and review aircraft usage analytics and reports. The company is now working to build out two new versions of the app—Crewchief MX, aimed at mechanics, and Crewchief FM to help maintenance facilities keep track of all the aircraft they are managing.
marketplace.aviationweek.com/product/crewchief-systems-mobile-app

10. Enhanced Portable Data Loading

Company: **Teledyne Controls**
Product: PMAT XS dataloader
Specifications: The PMAT XS is a smaller, lighter version of Teledyne Controls' PMAT 2000 portable dataloader featuring enhanced data security and a rugged design. The dataloader integrates with ground management systems to download engine data and automatically distribute software and application updates for avionics systems. The PMAT XS features battery, aircraft and ground power options and can be updated via ethernet, Wi-Fi, cellular networks or Teledyne software, which Teledyne says enables flexibility for ground crews.
marketplace.aviationweek.com/product/introducing-all-new-pmat-xs

*Go to **MROLinks.com** for more information.*

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Aerospace Calendar

To submit Aerospace Calendar Listings
email: aero.calendar@aviationweek.com

Jan. 6-10—American Institute of Aeronautics and Astronautics (AIAA) SciTech Forum. Hyatt Regency Orlando. Orlando, Florida. See aiaa.org/home/events-learning/event/2020/01/06/default-calendar/SciTech2020

Jan. 14-16—2nd International Academy of Astronautics (IAA). Conference on Space Situational Awareness. Hilton Arlington. Arlington, Virginia. See reg.conferences.dce.ufl.edu/ICSSA

Jan. 15-16—Military Aviation & Air Dominance Summit. Stone Event Center. Huntsville, Alabama. See govevents.com/details/34997/2nd-military-aviation-and-air-dominance-summit

Jan. 16-30—RTCA Plenary Sessions. Various locations. See rtca.org/content/upcoming-committee-meetings

Jan. 19-21—Airline Economics Growth Frontiers Dublin. The Shelbourne Hotel. Dublin. See aviationnews-online.com/conferences/dublin

Jan. 21-23—Transformative Vertical Flight 2020. Doubletree Hilton. San Jose, California. See vtol.org/events/2020-transformative-vertical-flight

Jan. 27-30—HAI Heli-Expo 2020. Anaheim Convention Center. Anaheim, California. See rotor.org/home/heli-expo

Jan. 29-30—FAA Commercial Space Transportation Conference. Ronald Reagan Building. Washington. See cstconference2020.com

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Jan. 22-23—MRO Latin America. Cartagena, Colombia.

Feb. 4-5—Aero-Engines Americas. Miami.

Feb. 4-6—Routes Americas 2020. Indianapolis.

Feb. 5-6—CAPA Qatar Aviation Aeropolitical & Regulatory Summit. Doha, Qatar.

Feb. 24-26—MRO Middle East Summit & Expo. Dubai.

March 2-3—CAPA Middle East & Africa Aviation Summit. Dead Sea, Israel.

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

March 9-11—Commercial Aviation Industry Suppliers Conference and Aerospace Raw Materials & Manufacturers Supply Chain Conference. Beverly Hills, California.

March 11-12—MRO Australasia. Brisbane, Australia.

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SECOND TAKE
2010-2019

2011

OCTOBER The first more-electric, advanced composite airliner enters service **Boeing 787**

2012

AUGUST The first space probe to leave the Solar System **NASA's Voyager 1**

2013

FEBRUARY Certification of the first large geared turbofan engine **Pratt & Whitney PW1500G**

MAY The first catapult launch of an unmanned aircraft from a carrier **Northrop Grumman X-47B**

2014

NOVEMBER The first soft landing on a comet nucleus **European Space Agency's Rosetta mission**

2015

MARCH The first spacecraft to orbit a dwarf planet **NASA's Dawn mission to Ceres**

APRIL The first remote-control air traffic control tower is deployed **Saab and Sweden's LFV**

JUNE The first trial of aircraft inspection by drone **EasyJet and Blue Bear Systems Research**

JULY Crossing of the English Channel by an all-electric demonstrator **Airbus E-Fan**

The first spacecraft to explore Pluto **NASA's New Horizons**

DECEMBER The first return and vertical landing of an orbital rocket stage **SpaceX Falcon 9**

2016

JANUARY Unveiling of the first electric vertical-takeoff-and-landing autonomous air taxi **Ehang 184**

APRIL The first run of the world's most powerful turbofan engine **General Electric GE9X**

JULY The first circumnavigation of the world by a piloted solar-powered aircraft **Solar Impulse 2**

The first FAA-approved autonomous drone delivery to a home **Flirtey and 7-Eleven**

2018

DECEMBER The first dedicated small-satellite rideshare launch **Spaceflight Industries and SpaceX**

2019

JANUARY The first soft landing on the far side of the Moon **China National Space Agency Chang'e 4**

FEBRUARY The first test passenger flown on a commercial suborbital spacecraft **Virgin Galactic VSS Unity**

APRIL The first flight of the world's largest aircraft by wingspan **Scaled Composites Stratolaunch**

OCTOBER The first commercial satellite-servicing spacecraft is launched **Northrop Grumman**

The 2010s saw the Stratolaunch (top) become the largest aircraft to fly and the X-47B (below) the first carrier-launched unmanned aircraft.

TOP: STRATOLAUNCH SYSTEMS; BOTTOM: U.S. NAVY

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