Stratolaunch's Hypersonic Reset

Open Rotor Revival at GE-Safran

M&A in the Age of COVID-19

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AVIATION WEEK & SPACE TECHNOLOGY

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IAI Aviation Group – BEDEK MRO Services

Increasing Demand for Boeing 737 Conversions

As a world leader in Passenger to Freight (P-2-F) aircraft conversions, IAI BEDEK has successfully converted more than 260 aircraft, that have accumulated over 2,500,000 operational flight hours, over the past 40 years. Among these aircraft are different types of Boeing 737, 757, 767, 747, and the MD-11, with the conversion of the B777 currently under development at IAI.

The Boeing 737 makes up a significant part of IAI's P-2-F conversions. As a small plane, the B737 provides the flexibility and economy of flying cargo over short and medium distances.

In the past, IAI provided conversions for B737-300/400, but has now focused on the New Generation (NG) and currently provides P-2-F conversions for the 737 -700 and -800.

Since receiving the Supplemental Type Certificate (STC) to convert the B737-700 in 2017, IAI is the only provider of full cargo conversion for aircraft of this type, whereas others offer Combi configurations, carrying a mix of passenger and cargo. As with other conversions, IAI developed the BEDEK Special Freighter (BDSF) conversion and has Supplemental Type Certificates (STCs) from the FAA and EASA for the conversion of the B737-300/400/700 and /800. These BDSFs deliver excellent operational value with advanced avionics, improved performance, reduced fuel-burn, and reduced maintenance costs.

These conversions include a comprehensive modification of the aircraft, a new main deck cargo door, installation of Smoke and Fire Detection and Suppression Systems on the main deck, and floor drain system. In parallel to the conversion of B737-700, IAI developed a separate conversion for the longer B737-800, which has a much larger payload. In early 2020, IAI received the STC for its B737-800 conversion.

"IAI operates conversion lines for the B737 in Israel, Mexico and China, where aircraft undergo all the necessary inspections and heavy maintenance, as part of the conversion to the cargo configuration," Eran Cohen, Director of B737 Conversions Program at IAI's Aviation Group, said. "The conversion process takes between 90 – 100 days (depending on the specific model) and includes all the necessary modifications. Following the process, the aircraft is able to fulfil its new role of a cargo aircraft, for the rest of its operational life. IAI also offers full MRO services support for these aircraft.

Until 2020, the aftermarket price of B737-800 remained too high for economic conversions due to high demand and the grounding of the B737-MAX. "The situation has changed with the outbreak of the COVID-19 pandemic," Cohen said. "Today, with the drastically reduced passenger aircraft operations and grounding of fleets, airlines are phasing out relatively new aircraft, such as the Boeing 737-800."

Cargo operators are eager to introduce these aircraft into their fleets, while airlines are using them to carry packages in their cabins. With the full BDSF conversion, these aircraft can carry twice, and even three times the cargo, more efficiently, with faster loading and unloading. "Today, the B737-800 aircraft are available for cargo conversions at prices much lower than only four months ago. This trend has opened up the market, and we expect further growth in demand." Cohen concluded.

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14 | *The Safran-led SAGE 2 open-rotor tests were run in Istres, France, in 2017.*

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ON THE COVER

The world is close to celebrating the 20th anniversary of continuous human presence in space on the International Space Station, which has hosted 64 crews, including NASA astronauts Bob Behnken and Chris Cassidy, members of Expedition 63, who are pictured on a spacewalk in July to install hardware and upgrade the station. Our coverage, led by Space Editor Irene Klotz, begins on page 48. NASA photo by Doug Hurley.

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AVIATION WEEK
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FEEDBACK

'WHERE WE'VE BEEN, WHERE WE'RE GOING'

Space Editor Irene Klotz did a great job on the recent webinar "NASA Administrators Panel: Where We've Been, Where We're Going" with Dan Goldin, Sean O'Keefe and Charles Bolden. Dan, Sean and Charlie were great, and I so enjoyed their stories. I served in the Mission Operations Directorate at Johnson Space Center for 35 years, under all of them.

This kind of thing makes me enjoy my subscription to *Aviation Week* all the more!

James Clement, San Francisco

Access the webinar series at: **AviationWeek.com/webinar**

THE HYDROGEN DILEMMA

It is encouraging to see that Airbus is serious about hydrogen as a fuel for the future *(Sept. 28-Oct. 11, p. 16)*. This comes on top of other, smaller companies already actually flying demonstrators using hydrogen in one way or another. The big advantage of hydrogen is that it burns cleanly, and the exhaust is something you can drink rather than something that will kill you.

But to be environmentally green, the hydrogen has to be generated using sustainable electricity such as from solar, wind and hydro. Today 95% of hydrogen is generated from fossil fuels and is very far from being environmentally green.

In 2019, before the COVID-19 crisis struck, the global airline fleet used 300 billion kg (660 billion lb.) of jet fuel. Of this, about 25%, or 75 billion kg, was used for short-haul sectors (up to 1,000 nm), which is where green hydrogen is most likely to be used, initially at least. Because hydrogen has four times the energy content per kilogram of jet fuel, theoretically that jet fuel could be replaced by about 25 billion kg of hydrogen.

So where is all this green hydrogen going to come from? The obvious answer is electrolysis; but not so well-known is that it takes about 48 kWh to produce 1 kg of hydrogen. Scaling this up, the electrical energy needed to provide 25 billion kg of green hydrogen annually is 1,200,000 gigawatt-hr.

Currently, the world's biggest solar farms are rated at around 5 gigawatts, which would produce about 12,775 gigawatt/hr. annually. To fully meet the green hydrogen needs of the airlines, about 100 such plants across the globe would be needed. Similarly, the biggest wind farms today are around the 1.5-gigawatt capacity; it might take up to 200 such wind farms to produce the required amount of green hydrogen.

The need for 9 kg of clean drinking-quality water for every kilogram of green hydrogen is another issue not discussed here but which should not be overlooked. If sea water has to be desalinated before it can be used, it will have a substantial negative effect on the process.

These examples show the scale of the problem, bearing in mind this is just for short-haul aircraft and that there will be other industries competing with the airline industry for green hydrogen—such as the fertilizer, power, ground and sea transportation, and food production sectors.

The numbers are huge, and they can be tweaked by changing the assumptions. But they are accurate enough to illustrate the scale of the problem. Solar and wind farms are getting bigger and more efficient, and more are being built. But is this enough? The elephant in the room that nobody seems to see is: Where is all this green hydrogen going to come from in the time frames envisaged by the airline industry?

Robin Stanier, Torrens, Australia

'A DOUBLE WHAMMY'

As an ex-pat Brit who has much enjoyed living in the U.S. since retirement from the Royal Air Force in 1985, how sad and disappointed I was to read Antoine Gelain's commentary about Rolls-Royce in my latest copy of *AW&ST (Oct. 12-25, p. 10)*. Rolls represented the gold standard in British engineering for me until I read this article.

My logbooks count over 3,000 hr. in Canberras, Buccaneers and Tornados, all two-seat, twin engine jets powered by highly reliable Rolls-Royce engines (the Tornado with a little help from our pre-Brexit friends). Particularly in the Buccaneer, oftentimes many hundreds of miles from the closest shore (indeed sometimes thousands, during my time with 809 Naval Air Sqdn.), how glad we were to have those magnificent Spey engines keeping us aloft.

The last few paragraphs of Gelain's article identify two major causes for Rolls-Royce's present predicament: a preference for profit over product performance (no respect for customer satisfaction) coupled with senior leadership cronyism instead of merit (the Old Boy network). Recipes for disaster. Or, as I've learned to say here, "A double whammy"!

I offer a simple, vital solution to prevent the impending Rolls-Royce disaster before it's too late: Clear out the dead wood and recruit the very best person from a worldwide candidacy to take over the lead. Only the best will do.

Tim Price, Jefferson Hills, Pennsylvania

CORRECTION

The excerpt in "The Supply Chain After COVID-19" *(Oct. 12-25, p. 74)* should have read: "There will be more Tier 2s, fewer Tier 3s and slimmer Tier 1s and 4s."

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

WHO'S WHERE

Tom Jones has been promoted to *Northrop Grumman* corporate vice president and president of Aeronautics Systems effective Jan. 1, 2021. He was sector vice president and general manager of the Airborne Sensors & Networks division that produces C4ISR systems. Jones succeeds Janis Pamiljans, who will retire in February 2021.

Urban Aeronautics has promoted **Rafi Yoeli** to president from CEO and **Nimrod Golan-Yanay** to CEO from vice president of business development for producing manned vertical-take-off-and-landing (VTOL) vehicles for air taxi and air rescue roles and unmanned VTOL vehicles for military and civil uses.

Toray Advanced Composites has appointed **Toshiyuki Kondo** as CEO. He succeeds **Keisuke Ishii**, who was interim CEO since July 2018, when Toray Industries purchased TenCate's advanced composites division. Ishii will transition to assistant general manager of the Torayca division.

Boeing has appointed **Marc Allen** chief strategy officer and senior vice president of strategy and corporate development, and named **Chris Raymond** chief sustainability officer, a new position. Allen was president of Embraer Partnership and Group Operations and before that president of Boeing Capital Corp. Raymond had led integration efforts for the potential strategic partnership between Boeing and Embraer and before that was vice president and general manager of Boeing autonomous systems.

Serge Pons has been promoted to executive vice president and general manager of *Safran*'s Electrical and Power Interconnection Systems Eurasia; he was president of Safran's ventilation systems subsidiary. He succeeds **Sebastien Jaulerry**, who has been named Safran Helicopter Engines executive vice president of support and services.

Skydweller Aero has hired **Dale F. Jordan, Jr.**, as chief financial officer. Jordan held the same post at Oseberg oil-and-gas data analytics and at Acorn Growth, where he was also vice president of finance.

Drone avionics developer *Iris Automation* has appointed **Jon Damush** as CEO. Damush was Boeing NeXt senior director of new business ventures and before that Insitu chief growth officer. He succeeds co-founder **Alexander Harmsen**, who has been promoted to chairman of the board.

RBC Bearings has promoted **Daniel A. Bergeron** to vice president and chief operating officer from vice president and chief financial officer. **Robert M. Sullivan**, former corporate controller, succeeds him. **John J. Feeney** has been named vice president, general counsel and secretary.

The Civic Air Transport Association has named **Philip Butterworth-Hayes** director of strategy and communications. He is editor of Unmanned Airspace and Urban Air Mobility News.

Jaunt Air Mobility has promoted **Martin Peryea** to CEO from chief technology officer of the company, which is vying for a berth in the eVTOL mobility markets.

Glenn Bradley has been promoted to *UK Civil Aviation Authority* head of flight operations from flight operations manager. Bradley amassed more than 9,000 flight hours while a GB Airways pilot and flew the iconic Tornado during service in the Royal Air Force.

Launch Technical Workforce Solutions has hired **Michael Lorenzini** as president of services and chief strategic officer; he had worked at United Airlines and Gogo. **Mike Reporto** has been named president of staffing.

Nobu Okada has been elected a vice president of the *International Astronautical Federation*, whose aerospace members represent 71 countries. Okada is the founder and CEO of Astroscale.

Optical wireless communications support company *BridgeComm* has promoted **Ethan Becker** to director of engineering from senior research and development engineer. Becker had worked at United Launch Alliance and Siemens.

Mott MacDonald has hired **Joanne McCall** as transport sector leader for Canada. She brings a quarter-century of infrastructure management, design and delivery across Canadian, U.S. and international transportation sectors.

Former UK Minister for Science and Universities **David Willetts** is joining *Skyrora* as senior consultant to help foster development of the UK space industry at an international level and build UK orbital launch capability.

Woolpert, an industrial architecture and engineering consultancy, has hired **Jill Geboy** as strategic consultant and project manager. Geboy has worked for numerous aviation, health care and federal clients on the West Coast for most of the past decade.

HONORS & ELECTIONS

Recipients of the *National Aeronautic Association's 2020 Wesley L. McDonald Distinguished Statesman and Stateswoman of Aviation Award* are: U.S. Air Force Brig. Gen. (ret.) **John Allen**, for mutifaceted leadership and improving aviation safety; Capt. **Julie Clark**, for aerobatic airshow flying and blazing a trail for women in aviation; **Einar Enevoldson**, for researching and exploring the stratosphere in a glider; **David Franson**, for 40 years of service in advancing aviation; U.S. Air Force Col. (ret.) Dr. **Kathryn Hughes**, for pioneering accomplishments in aviation and aerospace medicine; and **Michael Quiello**, for devotion as a military aviator and industry leader.

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

FIRST TAKE

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COMMERCIAL AVIATION

Daily passenger throughput at U.S. airports reached 1 million people on Oct. 18 for the first time since mid-March, marking a symbolic turning point in the airline industry's recovery from the COVID-19 pandemic.

With plans to bring a zero-emissions airliner to market by 2035, Airbus has formed a joint company with German automotive fuel-cell supplier Elring-Klinger to develop technology for hydrogen-fueled aircraft.

AirAsia X is liquidating its Indonesian unit and has written down its 49% holding in Thai AirAsia X as the long-haul low-cost carrier struggles to pay for aircraft leases across its operations.

Satellite operators Inmarsat and Hughes Network Systems have announced a strategic collaboration to provide in-flight connectivity for commercial airlines in North America.

Lessor GE Capital Aviation Services and investment management firm PIMCO are partnering on a $3 billion aircraft investment platform focused initially on narrowbodies.

Switzerland's RUAG International is selling production of the 19-seat Dornier 228 twin-turboprop regional aircraft to General Atomics' European business.

Delta Air Lines will defer $5 billion in planned deliveries through 2022, reaching an agreement with Airbus to delay the arrival of 77 new airliners.

The European Union has been cleared by the World Trade Organization to apply almost $4 billion worth of punitive tariffs on imports from the U.S. in retaliation for illegal Boeing subsidies.

DEFENSE

Boeing has won a $30 million contract to demonstrate Spear, an F/A-18E/F-launched solid-fuel ramjet supersonic missile technology demonstrator, for the U.S. Navy in late 2022.

Sweden's Saab has taken a 1.1 billion krona ($130 million) charge for the impact on production of the Gripen combat aircraft due to the COVID-19 pandemic.

Turkey and Ukraine have signed agreements to strengthen long-term industrial cooperation on warships, unmanned aircraft and turbine engines.

Airbus Spain is proposing development of a single-engine transonic jet trainer to support pilots who will go on to fly the European Future Combat Air System (page 34).

TECHNOLOGY

UK startup Stratospheric Platforms and Northrop Grumman's Scaled Composites are developing a hydrogen-fuel-cell-powered high-altitude, long-endurance UAV for cellular connectivity to remote areas.

Market accelerator EmbraerX has spun off Eve Urban Air Mobility Solutions as an independent company to develop electric air taxis, air traffic management and support services.

The Sikorsky-Boeing SB-1 Defiant coaxial rigid-rotor compound helicopter demonstrator has reached 211 kt. in level flight and 232 kt. in a descent.

General Atomics Electromagnetic Systems and Boeing have teamed to compete for high-energy laser weapon programs in the 100-250-kW class.

SPACE

After a 10-month hiatus, Blue Origin on Oct. 13 resumed flight testing of its New Shepard suborbital space transportation system with the seventh flight of the reusable booster and capsule.

NASA and the European Space Agency have contracted with Nanoracks to use the private company's Bishop airlock, to be delivered to the International Space Station in November.

VIEW FROM WASHINGTON

The FAA's Commercial Space Boost

The FAA has pared down its launch and reentry licensing regulations, a move that is expected to fuel growth in the nation's commercial space industry.

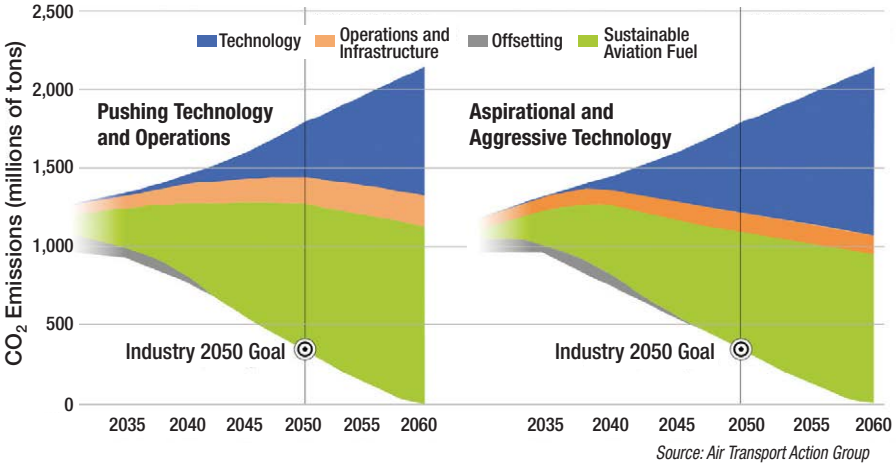
Heralded as a "historic milestone," the Streamlined Launch and Reentry Licensing Requirements (SLR2) final rule consolidates and revises four regulatory sections into a new Part 450 rule that allows commercial space operators to acquire a single license to conduct multiple launches from multiple sites. The rule is performance-based; it requires that launch and reentry vehicles comply with performance standards instead of specific, FAA-prescribed conditions.

"The goal is to simplify the licensing process and allow novel operations and reduced costs, and position both the industry and the FAA for the rapid increase in the number of launches that are coming, all without compromising safety," says Wayne Monteith, FAA associate administrator for commercial space transportation.

This year, the FAA expects to license around 35 space vehicle launches and reentries, increasing to 56 such operations in 2021. That tempo is expected to grow to 100 flights per year.

The final rule enters into force 90 days after its Oct. 15 publication in the *Federal Register*. Existing launch licenses can be used for up to five years after the rule's effective date.

Sustainable Fuels Key to Reduced Emissions



Source: Air Transport Action Group

Even with ambitious (left) and aggressive (right) scenarios for deployment of aircraft electrification, hybridization and hydrogen propulsion, low-carbon sustainable aviation fuels will play a major role in enabling aviation to achieve net-zero emissions by 2060, says the Air Transport Action Group's new "Waypoint 2050" report.

With the arrival of 60 more Starlink satellites on orbit on Oct. 18 and another 60 due for launch shortly, SpaceX plans public trials of its high-speed internet service before year-end.

India's space agency expects to resume launches in November. It has not staged a space mission in 2020 because of COVID-19.

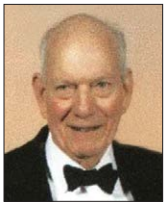
Sweden plans to establish a small-satellite launch capability at its Esrange Space Center, joining a growing list of European countries with launch ambitions.

Seven nations interested in collaborating with the U.S. on lunar exploration have signed the Artemis Accords, which establishes principles for cooperative space projects (page 48).

The robotic arm of NASA's Osiris-Rex probe briefly touched the surface of asteroid Bennu on Oct. 20, aiming to collect a few pounds of pebbles and soil for return to Earth (page 55).

OBITUARIES

Alan Boyd, the first U.S. transportation secretary, died Oct. 18, aged 98. Boyd helped bring together more than 30 federal agencies to create the Transportation Department in 1966 and, during his two years as secretary, led creation of the Airport and Airway Trust Fund to finance aviation programs. A former Army pilot who flew C-47s during the D-Day invasion, Boyd was chairman of Airbus North America in 1982-92. He received an Aviation Week Lifetime Achievement Award in 2009.



CHRIS ZIMMER

Key Dismukes, noted expert in human error in aviation, died of cancer on Oct. 14. A retired former chief scientist for human factors at NASA Ames Research Center and a passionate glider pilot, Dismukes in 2013 received the Flight Safety Foundation's Laura Taber Barbour Air Safety Award for advancing aviation safety.

30 YEARS AGO IN AVIATION WEEK

The cover of our Oct. 22, 1990, issue featured a McDonnell Douglas MD-11 taking off from Yuma International Airport in Arizona during a 5.8-hr. test flight by AW&ST's David Hughes. Appearing just nine months after the trijet's first flight, the issue included his 10-page pilot report that lauded the new aircraft's advanced automation. Coincidentally, that same issue also reported on a blockbuster development: Boeing's launch of the 777 family with a landmark $11 billion order from United Airlines.

The issue encapsulated seismic changes underway in the industry. Launched in 1986, the MD-11 was a DC-10 derivative targeted at the yawning gap between Boeing's 767 and 747. Airbus, too, was in the hunt, with the A330 and A340—both of which were launched in 1987. But it was the 777 that would eventually reign supreme and go on to become one of Boeing's most successful products.

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

The fuel efficiency of the twin-engine, long-range 777 helped drive the four-engine A340 and MD-11 trijet out of the market. In doing so, the 777 ultimately contributed to the downfall of McDonnell Douglas, which merged with Boeing only six years later. When finally paired exclusively with General Electric's GE90-115, the 777-300ER would go on to dominate the widebody, long-haul market for almost two decades.

Thirty years later, Boeing is at another strategic turning point. Consumed by crises external and internal, the company is again looking to a derivative of the 777—the new 777X stretch with bigger GE9X engines—to retain pole position in the long-haul market. But facing aggressive competition from Airbus, it must also somehow steady the ship as it transfers 787 production to South Carolina and—looking beyond the 737 MAX—begin its search for a new-generation narrowbody.

UP FRONT

P. BARRY BUTLER

A SILVER LINING GLINTS ON THE horizon for the aviation industry. In the commercial lull of the pandemic, investors and entrepreneurs are fixing their eyes on the future to seize opportunities to push aerospace technology forward. As industry leaders have pointed out in Aviation Week panels, defense and commercial space innovators are still hiring, and air mobility enterprises have attracted private equity investors. We also see smaller companies aggressively hiring to establish themselves as midtier providers.

In addition to producing the workforce of tomorrow, a university's contribution to our industry's recovery is to provide an environment where academia, industry and entrepreneurship can create mutual benefit that translates into new products, services and solutions. Smaller, streamlined companies have the advantage of agility. When they can reinforce their capacity for speed and adaptation by tapping the resources of partnerships, everyone can potentially win: students, entrepreneurs, researchers and customers/consumers/end users. Successful business clusters in places like Boston, Silicon Valley and Austin, Texas, all have entrepreneurial-focused universities nearby.

At many universities, resident entrepreneurs provide an invaluable learning lab for students planning startups as well as those who will apply their creative thinking and business savvy to "skunk works" at aviation and aerospace giants. A co-located research park can be a proving ground for possibilities, allowing the next wave of leaders to gain experience beyond solving technical challenges—learning to maneuver the demands of financing, managing intellectual property, reviews and approvals, marketing and establishing a supply chain.

One such innovator, VerdeGo Aero, recently moved to build market share and increase name recognition in a rapidly emerging aviation sector. Company CEO Eric Bartsch and Executive Chairman Erik Lindbergh teamed up with Embry-Riddle Aeronautical University to develop and commercialize patent-pending technology designed to mitigate electric aircraft noise.

Although electric aircraft promise reduced carbon emissions, fossil fuel use and operating costs, the propellers or rotors can be relatively noisy. Traditionally, electric aircraft rotors can spin faster to gain efficiency while also increasing noise levels, or spin slower and be less efficient but quieter. The technology now being commercialized by VerdeGo Aero would automatically adjust the pitch of rotating propeller blades while also adjusting motor torque to maintain constant thrust. This approach makes it possible to reduce noise or increase efficiency, while maintaining substantially constant thrust, altitude and airspeed. Using the new technology, electric aircraft could be designed to operate most efficiently once they are at cruising altitude, where noise abatement may be less of a concern, then switch over to a lower-noise mode as they descend over urban areas.

Opening Doors

Co-located research parks **boost innovation and entrepreneurs**

SENSATEK PROPULSION TECHNOLOGY

Reamonn Soto (right), Azryana Soto (second from left) and part of the Sensatek team.

Another entrepreneur, Reamonn Soto, a U.S. Marine Corps veteran, was wrapping up his master's degree when he had a big idea that could save gas turbine operators millions of dollars annually. To build his business, Sensatek Propulsion Technology, Soto took advantage of incubator space at Embry-Riddle's Research Park, which has forged partnerships with private industry as well as local, state and federal policymakers and agencies.

The Sensatek business model—licensing patented wireless sensor technology to increase the operational reliability and performance of jet engines and high-temperature process flow applications—proved appealing to an array of investors. Soto's funding from all sources now stands at more than $4.5 million. His innovation, based on entrepreneurial out-of-the-box thinking, created high-paying new jobs.

Universities rely on industry support to help entrepreneurs like Soto achieve liftoff. For example, Launch Your Venture incentivizes Florida university students to refine their best startup ideas for changing the future of aviation, aerospace and engineering. Another competition, the TREP Expo, puts would-be aerospace entrepreneurs on a ladder to success and greater support. In 2017, Soto qualified in the TREP Expo to compete in Launch Your Venture, which he won, garnering a much-needed $10,000 for his business.

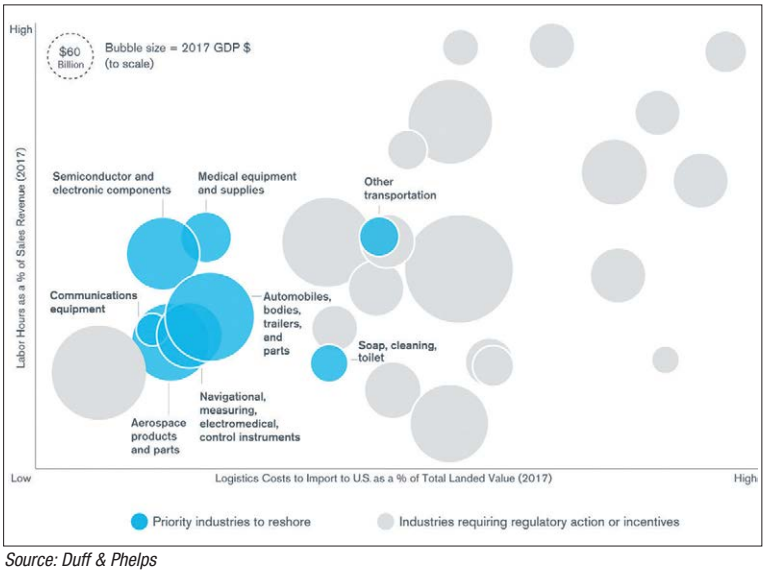
Businesses like Sensatek and VerdeGo Aero—encouraged by strong industry partnerships—also help add value to graduates as they enter the workforce. Just as engineering is applied science, entrepreneurship is applied talent, fusing technology and business to put ideas at our service.

P. Barry Butler is president of Embry-Riddle Aeronautical University.

GOING CONCERNS
MICHAEL BRUNO

WESTERN AIRLINES ARE BEGGING for more government aid, the International Air Transport Association does not expect the industry to see positive cash flow before 2022, and credit agency analysts forecast depressed aerospace and defense business activity for up to another 1.5 years.

Meanwhile, data continues to portray China as the lone bright spot in the aviation world. By August, Chinese domestic flights had recovered to about 90% of 2019 levels. "China has been effectively controlling the spread of COVID-19, limiting cases to less than 100 a day. Combined with a large domestic market, the recovery in commercial aviation is expected to outpace the rest of the world," Jefferies analysts Sheila Kahyaoglu and Greg Konrad noted in late September.



Source: Duff & Phelps

"Right now, really, the two areas of traffic that are close to normal are domestic China and the roughly 2,000 all-cargo aircraft out there today," echoes AeroDynamic Advisory Managing Director Kevin Michaels. Otherwise, "it's a bloodbath, and we're all aware of that," he told an Aviation Week SpeedNews conference in September.

For aerospace and defense (A&D) suppliers, the dichotomy sets up a critical decision: Should suppliers and servicers run toward China—or run away?

It is easy to understand why they are debating the question. Long before COVID-19 gutted commercial air traffic and kick-started what is expected to be the greatest makeover of aircraft manufacturing and the maintenance, repair and overhaul industries since the dawn of the jet age, there were already good reasons to debate being in China. Topping the list was the Trump administration's trade war with the world's second-largest economy. Ongoing questions lingered about intellectual property rights and the specter of inadvertently creating future competitors in Avic, Comac and other Chinese companies.

Proponents of reshoring industry to the U.S.—or "nearshoring" to Canada or Mexico—are certainly touting potential opportunity. "The logical thing is to fill longer-term and COVID-revealed supply chain gaps," Reshoring Initiative President Harry Moser told an Aerospace and Defense Forum audience on Oct. 6.

Others agree that conditions are ripe for reshoring, not least because automation and advanced technologies that replace humans can offset North American costs. Also, A&D has been deemed a critical part of U.S. infrastructure. And Chinese unit labor costs have risen fivefold in recent decades. This summer, site-selection consultant Duff & Phelps identified A&D as a top candidate for moving to America (see chart).

But siting decisions are complex, and supply chain moves are even more so. Not only is commercial aviation looking strongest in China now and in the near future, but it could accelerate a long-expected toppling of the U.S. as the world's leading aviation market, possibly as soon as 2025. Increasingly, Beijing officials talk about relying on domestic supply instead of imports.

Get In or Out?

China's aviation recovery compared with the depression everywhere else **sets up a dilemma**

Indeed, the "Sleeping Giant" could boast a future estimated aviation market value of more than $1 trillion, according to Yi Zhang, general manager of OCO Global China.

That catches suppliers' attention. Zhang spoke in June to a well-attended webinar hosted by Washington state economic development officials about aerospace opportunities in China, and that was a month before Boeing revealed it was even thinking about scrapping 787 production in Puget Sound, Washington.

Now China's opportunities beckon brighter with no snapback in Western air traffic.

Still, in his Sept. 24 report titled "Caveat Venditor," or "seller beware," Vertical Research Partners analyst Rob Stallard cautions Western A&D companies against rushing toward China. "We see the Chinese government leveraging its position of relative post-COVID strength in coming years, and no doubt aerospace will see some of the fallout," Stallard says. "As the biggest show in town, we would expect to see more quid pro quo in China's relationship with what is still very much a Western aerospace industry. Price, supply chain and technology transfer could be on the table, as could politics.

"Aviation could conceivably suffer collateral damage as part of a broader trade war," Stallard writes. "So while investors will probably see good news in a Chinese-led aero recovery, we would be looking for any strings attached."

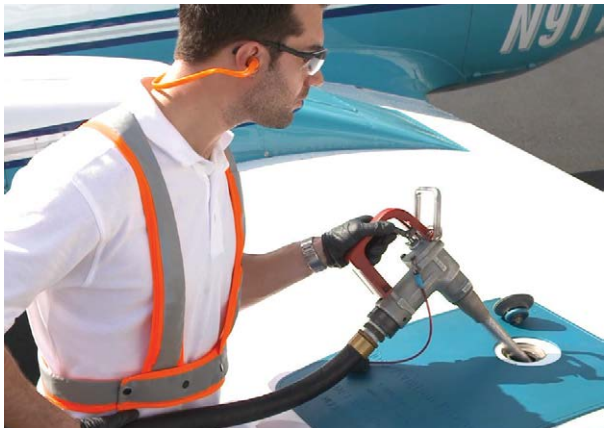
INSIDE BUSINESS AVIATION
WILLIAM GARVEY

GO AHEAD, BLAME JIMMY DOOLITTLE. After all, it was his idea, his crusade and now, his fault. But know this: It helped the Allies win World War II, which put an end to global conflict for 75 years. And counting. Now the questions:

Was it his surprise bombing of Japan four months after the Pearl Harbor attack? No, that boosted U.S. morale and rattled the Japanese. But that wasn't it.

Was it his directing the U.S. Army's Eighth Air Force to pound Nazi Germany into submission? No, but that helped end the war in Europe.

Was it his earlier experience in air racing? Well, that along with his Ph.D. in aeronautics and background as a military aviator were certainly factors.



AVFUEL

Combined, that knowledge raised an alarm while he was touring Germany's aircraft and engine facilities as a private citizen in the 1930s. Upon returning home, he became an advocate within the Shell Oil Co., where he was an executive, for developing a high-octane aviation gasoline. Doing so would help boost the performance of that era's aircraft. Convinced a war was coming, Doolittle had his country's fighters, bombers and transports in mind.

After much urging by Doolittle, Shell leadership agreed to invest. TEL-infused aviation gasoline (avgas) was the result. For those, like me, not steeped in the science of chemistry, TEL is tetraethyl lead, a fuel additive that somehow increases octane level and thus engine performance.

TEL-boosted avgas helped Hurricanes and Spitfires prevail in the Battle of Britain and continued to help Allied aircraft triumph in the air war that followed. German warplanes were fueled by synthetic gasoline, whose energy properties were inferior.

Post-1945, the additive boosted performance of the Buicks, Fords and Plymouths that carried their drivers through the booming peacetime economy. However, over time, advanced auto engine technology—specifically, better liquid cooling and electronic ignition systems—combined with environmental concerns resulted in the removal of TEL from motor gasoline.

However, avgas fueled air-cooled, piston aircraft engines that powered lightplanes then, which needed the TEL-boosted octane to keep from overheating and failing. And that dependency has become a serious concern.

Absent the auto market, TEL production declined dramatically. Today, according to the General Aviation Manufacturers Association (GAMA), there is but a single manufacturer that still produces the compound. Industry's reliance on a sole-source supplier is especially worrisome since its market exit would ground the fleet.

Why would any company abandon a monopoly? First, the market is tiny, maybe 230,000 aircraft worldwide, and a considerable percentage of those sit on the ground most of the time consuming nothing. Accordingly, avgas production has declined by roughly 50% in the past 30 years.

Second, there's that letter "L." Lead in the atmosphere is harmful to humans. Today, the only transportation segment emitting it is lightplane aviation burning 100-octane low-lead (100LL) avgas. Environmentalists are well aware and want to see those emitters choked and possibly TEL's manufacture halted. Were they to prevail, the fleet would be permanently chocked and essentially worthless.

Get the Lead Out

No success yet in pursuit of lead-free avgas

So getting lead out of avgas is a goal shared by the U.S. Environmental Protection Agency, U.S. Congress, FAA and the lightplane industry. To help, federal legislators allocated $5.4 million to the aviation agency to set standards and evaluate unleaded replacement fuels through a government-industry Piston Aviation Fuels Initiative (PAFI). The FAA has been doing that for six years, but it has yet to identify an acceptable replacement.

Walter Desrosier, vice president of engineering and maintenance at GAMA, a PAFI participant, explains that the effort has produced high-octane unleaded fuels.

However, the initiative's goal is to find a "drop-in" fuel requiring no alterations throughout the entire fuel chain—from its refinement to its in-engine combustion. And so far, every fuel tested has failed in some way—corrupting filters, fittings, piping, generating excessive heat, toxicity, emissions and so on.

Desrosier is among those who believe a solution will be found, but others are not so optimistic.

Meanwhile, the FAA has exhausted the initial PAFI funding, and one of the original pair of new fuel providers selected for testing has given up the quest. Still, the other company has continued to experiment in its search for a lead-free fix. That company? Shell Oil.

I think Gen. Doolittle would salute.

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

AIRLINE INTEL
JENS FLOTTAU

The BER Nightmare Ends

Berlin Brandenburg Airport prepares to open after **nine-year delay**

WHEN THE NEW BERLIN AIRPORT was originally planned to open in the spring of 2012, the world of aviation looked quite different, even discounting the coronavirus pandemic.

Air Berlin had just joined the Oneworld alliance and celebrated the occasion in a large tent on the airport apron. It announced its plans to turn Berlin into a substantial European hub, complemented by a growing number of long-haul routes and betting on the support of its new partner carriers. The opening date of the airport had already shifted by a few months from late 2011.

Almost nine years later, Air Berlin is history, along with any plans for its hub. But Berlin Brandenburg Airport (BER) is finally ready to open. On Oct. 31, EasyJet will fly an aircraft from the old airport Berlin-Tegel (TXL) to the new facility south of Germany's capital, while Lufthansa will have dispatched one of its aircraft from Munich to BER around 30 min. earlier.

GUENTER WICKER/FLUGHAFEN BERLIN BRANDENBURG GMBH

The idea is to have both aircraft make the first two official landings simultaneously on the two parallel runways, showcasing Berlin and the country's two biggest airlines. All flights will be transitioned from Tegel to BER the following week. Air France was the first airline to land an aircraft, a Lockheed Super Constellation, at Tegel on Jan. 2, 1960. It will be also be the last to leave, on Nov. 8 at 3 p.m. local time, bound for Paris.

The nine-year delay in opening BER has been deeply embarrassing for German engineering and infrastructure planning, as an endless cycle of studies, parliamentary investigations and disputes has shown. That new airports are not ready on time is a common enough occurrence, and a one- or two-year delay is practically normal. But nine years?

There are a myriad of reasons for the catastrophe, some particularly devastating. Construction began in late 2006. But less than a year later the airport decided to drop the original consortium that was to build the main terminal, instead distributing the work in seven lots. Airport operator Berlin Airports also assumed oversight of the massive project rather than delegating it to companies specializing in infrastructure development. Clearly, knowing how to run an airport does not carry over into building one.

Construction continued, but with a huge lack of transparency and consistency. The various companies knew little or nothing about what the others were doing, the standards they were following or what assumptions they were making. Integrated planning fell apart, and oversight by the airport was lacking. Oversight by the airport's owners—Berlin, the state of Brandenburg and the federal government—was also insufficient.

Sure enough, a few weeks before the 2011 opening date, rumors emerged about serious flaws in the fire suppression system: Air ventilation planning was deficient, and fireproof doors were not working, to name but a few of the problems. To make matters worse, regional authorities tasked with regulatory oversight were overwhelmed, unaccustomed to checking sites as big as a new airport.

Over time, the extent of the defects became clear, as the opening date shifted again and again. At some point it might have been easier to tear down the main terminal and start over from scratch than to remedy tens of thousands of mistakes. Politically, that was not doable, however.

With all regulatory approvals in hand and process testing completed, Berlin will finally have a new airport by the end of October. It is of course ironic that right now no one really needs an airport. A fraction of the old Tegel airport would suffice for the time being.

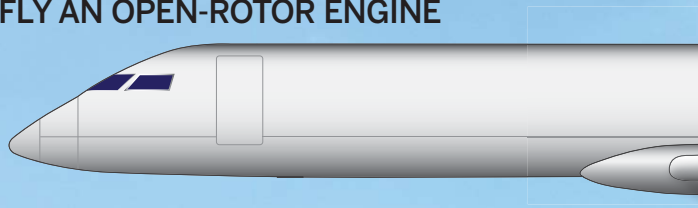
The industry hopes this will only be a short-term phenomenon, but some fundamentals have changed. Before COVID-19, the new airport looked too small. Terminal 1 (the main building) has space for 27 million passengers; low-cost facility Terminal 2 can handle another 6 million; combined with the old, adjacent Schoenefeld Airport, capacity exceeds 40 million. In 2019, Berlin's airports handled 36 million passengers. Now traffic is down 70%, and capacity constraints are not an issue for the foreseeable future.

The new airport is facing other challenges, too. Munich and Frankfurt continue to dominate hub traffic. Unlike in 2012, there is no airline willing to make BER its hub. EasyJet was the largest airline in Berlin before COVID-19, buoyed by strong inbound tourist demand, but the extent and pace of rebuilding traffic remains uncertain. And low-cost travel is expected to recover faster than legacy business travel, meaning Berlin Brandenburg's legacy-type facilities and costs will be even more misplaced than they were nine years ago.

SHAPING UP

> SAFRAN AND GE AVIO AERO LEAD BID TO FLY AN OPEN-ROTOR ENGINE

> EUROPE'S CLEAN AVIATION PROGRAM WILL FOCUS ON SUSTAINABILITY



Guy Norris Los Angeles

With sustainability front and center on the aerospace industry agenda, plans are firming up on both sides of the Atlantic for a new wave of ambitious large-scale technology demonstrators to pave the way for ultraefficient next-generation commercial airliners.

Ranging from advanced propulsion and airframe concepts to new systems, structures and fuels, the main demonstrators will form part of the proposed Clean Aviation initiative in Europe and the next round of NASA X-plane projects in the U.S. Clean Aviation, which is expected to succeed Europe's long-running Clean Sky program, supports the European Union's broader Horizon Europe research and innovation framework effort for 2021-27 and will feed technology into new civil aviation projects later this decade and into the 2030s.

Projects under Clean Aviation are expected to target disruptive technologies for hybrid-electric regional aircraft, ultraefficient short- and medium-range airliners and hydrogen-powered transport. All will support the longer-term goals of the proposed European Green Deal, which calls for zero net greenhouse gas emissions by 2050.

In the U. S., the upcoming demon-

NASA Prepares for Next Generation of Single-Aisles

Graham Warwick Washington

NASA HAS BEGUN PLANNING FOR A FLIGHT DEMONSTRATION of the Transonic Truss-Braced Wing ultraefficient airliner configuration. The experimental aircraft would be one of a suite of demonstration projects to mature key technologies for a next-generation subsonic commercial transport by the mid-2020s.

"We have a preformulation planning team looking at the potential for [a fiscal 2022] start for a Transonic Truss-Braced Wing [TTBW] flight demonstration," Bob Pearce, NASA associate administrator for aeronautics, told an Oct. 14 virtual meeting of the National Academies' Aerospace and Space Engineering Board.

The other planned demonstration projects in support of development of ultraefficient subsonic airliners cover electrified propulsion, small cores for turbofan engines and high-rate composites manufacturing.

"NASA, in partnership with industry and universities, has been working for the last 10-15 years on what are the right technologies to enable the next generation of transports," Pearce said. "We've got it down to a handful of what we think are game-changing technologies that could be available for this next generation. And for them to be available that means we need to get these to [technology readiness level (TRL)] 6 in the mid-2020s."

All will depend on funding, and NASA has entered fiscal 2021 with the U.S. government operating under a continuing resolution. This keeps funding at 2020 levels and prevents the start of new programs, but Pearce's comments make clear where NASA wants to go as funding does become available.

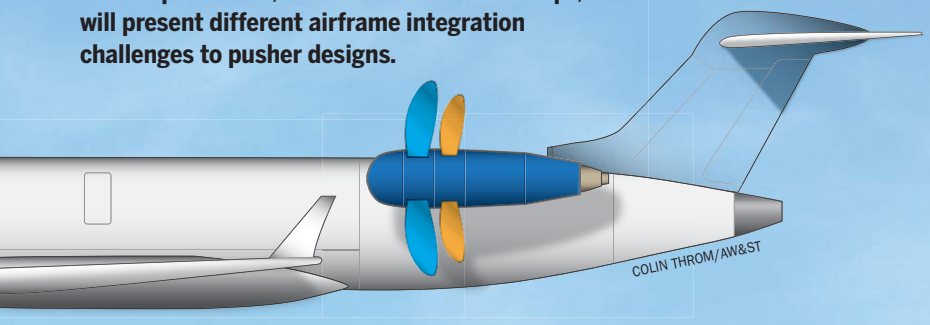
NASA is already developing the request for proposals for the Electrified Power Train Flight Demonstration project, with costs planned to be shared with industry. "We've had several risk-reduction contracts that will support getting to flight with a megawatt electric power train demonstration," Pearce said.

"Based on the resources and schedule we have, we should be able to get to flight in the fiscal 2023-24 time frame, at least for the first demonstration, and then looking hopefully to have a second demonstration in the fiscal 2024-25 time frame and to finish that up by fiscal 2026," he added.

The compact high-power-density core project is now in formulation, aiming for a fiscal 2022 start. The goal is a ground demonstration, in partnership with industry, of the key technologies, materials and component advances required to develop smaller cores enabling higher-bypass-ratio turbofans.

The electrified power train and small core demonstrations are "pretty synergistic," Pearce said. "Because what we're looking at relative to electric propulsion is a mild parallel hybrid system that would supplement the turbine power in key phases of flight."

Puller open rotors, as in this Avio Aero concept, will present different airframe integration challenges to pusher designs.



COLIN THROM/AW&ST

strator efforts form part of NASA's updated Strategic Implementation Plan for aeronautics and include four main projects aimed at maturing technologies for a next-generation subsonic airliner for service entry in the 2030s. Headlined by a flight demonstration of the Transonic Truss-Braced Wing configuration, they will also include electrified propulsion, small high-density cores for turbofan engines and high-rate composites manufacturing (see sidebar below).

Although teams bidding for Clean Aviation demonstrators have until the end of November to submit proposals, Safran Aircraft Engines and GE Aviation-owned Avio Aero have revealed plans to flight-test an open-rotor engine, with the aim of reducing fuel burn up to 20% from current turbofans. The initiative, if approved, will build on the Safran-led Counter-Rotating Open Rotor (CROR) project conducted under Clean Sky's €200 million ($240 million) SAGE 2 (Sustainable and Green Engines) program that ended in 2017.

Open rotors, also known as unducted fans or propfans, were initially developed in the U.S. in the 1970s and 1980s amid concerns over rising fuel costs. Although two concepts—GE's GE36 and the Pratt & Whitney/Allison 578 DX—were flight-tested, both were shelved by the early 1990s after oil prices fell. Although development of propfans continued in Russia, it was not until greenhouse gas emissions became a legislative factor in the 2000s that Western interest in the concept was revived.

In the U.S. NASA, GE and the FAA collaborated between 2009 and 2012 on wind tunnel tests of an open rotor with blades developed using modern computer-based design methods. The tests showed up to a 3% improvement in net efficiency relative to the best 1980s design, while nominally achieving a 15-17-EPNdB noise margin to Chapter 4 limits.

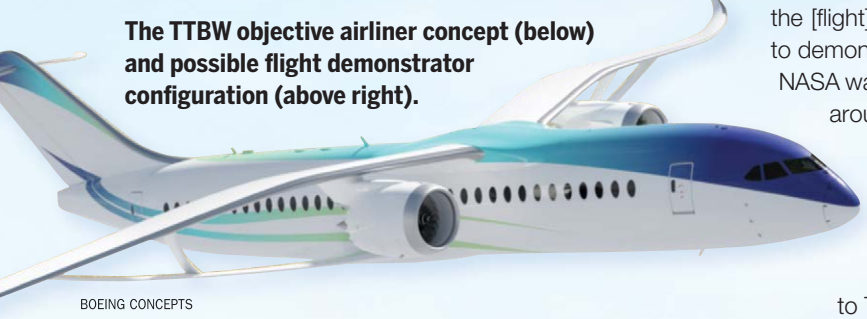
Around the same time, two open-rotor concepts were evaluated in Europe under the SAGE effort, with

Mounting a motor/generator on the engine shaft would allow the turbine to be augmented electrically on takeoff and climb, when power demand is highest, and reduce design requirements on the turbofan, which could then be made more fuel-efficient in the cruise.

Also now in formulation is the Hi-Rate Composites Aircraft Manufacturing project, a follow-on to NASA's completed Advanced Composites Project. "One of the characteristics of the single-aisle market is the need to produce a relatively large number per month, up to potentially 100 aircraft. With largely composite aircraft, we have not proven the ability to do that," said Pearce.

The TTBW flight demonstration would be the culmination of work begun in 2010 when Boeing revived the truss-braced wing concept and applied it to an advanced transonic airliner. NASA has conducted a series of wind tunnel tests of the configuration since 2013, exploring its low- and high-speed behavior.

The TTBW objective airliner concept (below) and possible flight demonstrator configuration (above right).



BOEING CONCEPTS

Thanks to the lower induced drag of the 170-ft.-span wing, which has an aspect ratio twice that of the 737-800, Boeing estimates the TTBW will have a 9% fuel-burn advantage over an equivalent-technology conventional cantilever-wing airliner on ranges up to 3,500 nm.

"We've got some additional tests coming up this year," Pearce said. These include transonic buffet testing of the TTBW in the 11-ft. tunnel at NASA Ames Research Center and additional low-speed testing in the 14 X 22-ft. tunnel at NASA Langley Research Center.

"We've already had one entry in the 14 X 22 [tunnel], and we're going back in to do some additional high-lift stability and control testing," he said. "So we will have bounded the [flight] envelope pretty well and be ready to take that to demonstration."

NASA wants to bring U.S. industry and academia together around these four demonstration projects in support of developing a new generation of ultraefficient aircraft. "The notion of this whole thing is to look at how we create a national partnership that is wrapped around this, since all the pieces come together looking at how to get these technologies to TRL 6 by the mid-'20s," said Pearce.

a Rolls-Royce-led team evaluating a direct-drive propulsor system while a Safran-led group developed the geared pusher CROR. The Rolls project was later rescoped to focus on lean-burn combustion, while Safran developed a CROR ground demonstrator using its M88 military engine as a gas generator.

Unlike the CROR program, which aimed primarily to demonstrate the improved propulsive efficiency of the open rotor, the proposed next phase will also boost the thermodynamic efficiency of the core engine. In recognition of the drive toward electrical power extraction, both for aircraft systems and to augment propulsion, the engine will also be adapted for hybrid-electric systems.

The original CROR team, which included Avio, GKN Aerospace and Leonardo, have remained enthusiastic supporters of the open- rotor concept since the completion of the program. Safran maintains that open rotors are "so far the only known architecture with a double-digit fuel-burn reduction potential while still matching future community noise standards."

After more than 70 hr. of ground runs from May to December 2017 on a test stand in Istres, France, Safran said the demonstrator validated key technologies and answers to the challenges of overall system integration and "confirmed the great potential of this architecture."

Although demonstrating that the pusher-configured CROR was compliant with existing Chapter 14 certification noise standards, Safran has acknowledged further work will be required to make the concept less noisy. "That work would be done at the propeller, engine and aircraft level," Safran says.

Another area of potential concern, engine dynamic behavior and the potential transmission of vibration into the airframe and cabin, was mitigated by careful balancing of the test engine's 13.1- and 12.5-ft.-dia. rotor sets and the use of soft engine mounts.

The new technology demonstrator plan was outlined for the first time during an International Civil Aviation Organization virtual seminar in September. Speaking on behalf of the European-based team, GE Aviation's Greg Steinmetz, said the engine's 20% fuel-burn improvement will be achieved by using three major technology "baskets." Steinmetz is a consulting engineer in the company's Advanced Systems and Preliminary/New Engine Design unit.

The Safran-led SAGE 2 open-rotor tests were run in Istres, France, in 2017.

SAFRAN

"The first basket of technology is improved, or what we call entitlement, propulsive efficiency. That entitlement, or best level of propulsive efficiency, is achieved by utilizing an open fan system. Recent breakthroughs in the areas of acoustics and engine integration have convinced us that now's the right time to finish up this technology maturation and have it ready for the marketplace," said Steinmetz.

The second basket is improved thermal efficiency from higher operating temperatures and pressures, while the third is better system-level efficiency. "One example is a hybrid-electric system," he said.

"GE is working in three building-block areas to make this hybrid-electric a reality," he added. "The first building block is developing lighter-weight and more compact generators and motors. A second building block is demonstrating very high power extraction from gas turbine technology. It's likely that at least the initial embodiments of hybrid-electric will require power from gas turbines. And finally, we're investing in facilities that allow us to model the very complex environment for an integrated hybrid-electric system, in terms of its aircraft-engine environment, so that it can enter into service successfully."

Although no details of the proposed concept will be unveiled until bids are submitted, it is possible that a puller open-rotor configuration may be considered. With forward-mounted blades—unlike the pusher-configured CROR, GE38 and Pratt/Allison 578 DX—such a concept might enable flight testing on some existing aircraft testbeds without the need for major modification.

Plans to flight-test the CROR on an Airbus A340 were shelved in 2017 due to concerns over airframe strengthening and weight gain around the tail to counter potential blade separation events. "We've talked about a flying testbed and a demonstrator, and we use that word 'demonstration' very intentionally. We understand at GE Aviation that, at the end of the day, you've got to prove it in flight," said Steinmetz.

Safran studied at least two puller open-rotor configurations before settling on the pusher CROR for reasons of easier mechanical feasibility and could revisit the earlier designs for the new demonstrator. The studies included a puller version of the CROR with the propeller sets driven by a low-pressure (LP) transmission system. In this configuration, the LP shaft passed through the gas generator and drove the props via a differential power gearbox.

However, a more likely option could be the second puller configuration, to be studied, in which a second blade row made up of active variable-pitch stators acts as flow recovery vanes. The design increases overall fan pressure ratio while simultaneously reducing rotor loading—thus enabling a higher maximum flight Mach number. This configuration incorporates a high-speed power turbine and an LP-shaft-driven front epicyclic gearbox.

Boeing's Rare Forecast Reductions Underscore the Pandemic's Reach

> THE LATEST FORECAST EXPECTS THE WIDEBODY MARKET TO REMAIN SOFT

> TRAFFIC NOT PROJECTED TO RETURN TO 2019 LEVELS BEFORE 2023

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

Boeing's latest commercial airplane outlook calls for rare reductions in deliveries and total fleet size compared with its last forecast, underscoring the depth of the novel coronavirus' reach on the airline business and, by extension, its supply chain.

The figures, released as part of Boeing's annual 20-year Commercial Market Outlook (CMO), paint a difficult picture for the airline industry, which the aircraft manufacturer believes will not recover to prepandemic traffic levels until at least 2023.

Widebody deliveries have been revised sharply downward in Boeing's latest forecast compared with the year-ago outlook. The company sees increased emphasis on fleet flexibility, including smaller widebodies and long-range narrowbodies, coming out of the pandemic. Despite the shift, the company remains upbeat on the 777X family's prospects.

Boeing also predicts it may take as long as five years for the airlines to resume the industry's long-term trajectory of 4-5% annual growth, established in the 1980s.

The demand shock forced Boeing to make rare reductions to key parts of its detailed, annual two-decade look ahead. Boeing's forecast of 43,110 deliveries through 2039 is 2% lower than the figures outlined in its 2019 20-year outlook. Most of the drop will come in the first half of the forecast, reflecting the ramifications of the current pandemic. Deliveries through 2029 are projected to be 11% lower than comparable 2019 forecast figures. Its total projected fleet of 48,400 commercial passenger and freighter jets at the end of 2039 is 2,260 lower than last year's comparable figure—a 4% reduction.

Successive forecasted drops in Boeing's total fleet-size deliveries are rare. The 2020 version is only the second this century that presented a gloomier outlook than its predecessor; the first was the 2009 forecast. That year, at the tail end of a multiyear global financial crisis, Boeing expected small declines in deliveries and resulting fleet sizes; in each case, dip was less than 1%.

The year-over-year drop in global revenue passenger kilometers—current figures have them down about 75%—and little hope of a fast recovery will prompt significant systemic changes in the makeup of the world fleet, says Darren Hulst, Boeing's vice president of commercial marketing.

"I don't think anybody has given a commercial market outlook briefing when passenger flights are hovering right around 50% of normal, which is where we are today as an industry, and about 25% of normal passenger travel," Hulst says. "So the industry clearly has been dramatically impacted and remains dramatically impacted by the pandemic worldwide."

Outlining a two-phase recovery scenario, Hulst says the early retirement of older aircraft will be a key driver of near-term fleet strategy. Although more than 70% of the active fleet has returned from temporary storage, many aircraft will never come back. As a result, 56% of the 18,350 aircraft Boeing now forecasts to be delivered by 2029 will be replacement aircraft, which is 12% more than Boeing's 2019 projection.

The effect is also expected to continue into the second decade of the forecast, with a slightly lower emphasis on replacements as airlines regroup and growth resumes to prepandemic levels. The forecast predicts that 48% of the total 43,100 new aircraft to be delivered by 2039 will be replacements.

Boeing's forecast details a changing global fleet mix with a greater focus on single-aisle market growth than before the pandemic, and a shift away from the trend toward narrowbody upscaling that dominated much of the 2010s. Overall, Boeing forecasts that 32,270 single-aisle aircraft will be delivered during the next two decades, including 13,570 through 2029.

BOEING

The 4% overall fleet decline in the next 20 years, compared with the previous forecast, includes an 11% drop in projected widebody deliveries. The widebody sector is now forecast to account for 7,480 deliveries, against last year's estimate of 8,340.

The freighter forecast is lower, to a net gain of 930 new-production freighters, versus more than 1,000 in the 2019 forecast. Boeing also sees another 1,500 converted freighters joining the fleet.

The only growth sector in the forecast is the regional jet market: Boeing now believes it will see deliveries of about 2,430 aircraft over the next two decades, compared with 2,240 in last year's forecast. Boeing defines regional aircraft as aircraft with fewer than 90 seats.

Boeing's latest forecast assumes an average passenger traffic growth rate of 4% annually. This should be higher in 2021, as 2020's historic decline presents an easy year-over-year figure to beat. If a COVID-19 vaccine is not developed and widely distributed in the next year or so, however, growth could stagnate because traveler confidence would remain low. But that would be temporary, Boeing believes. Post-pandemic, a return to the previous pace of growth is envisioned, similar to the aftermath of recent global slumps, including 9/11 and the Great Recession of 2007-09.

"Commercial aviation is facing historic challenges this year," Hulst says. "Yet history has also proven air travel to be resilient time and again. The current disruption will inform airline fleet strategies long into the future, as airlines focus on building versatile fleets, networks and business model innovations that deliver the most capability and greatest efficiency at the lowest risk for sustainable growth."

The updated CMO has annual global economic growth averaging 2.5%, down from 2.7% in the 2019 forecast. Boeing now sees airline traffic averaging 4% growth per year, down from the 4.6% envisioned last year.

Boeing's forecast focuses on the link between traffic demand and deliveries within general aircraft categories. Because the public data Boeing releases does not get into model-by-model breakdowns, Hulst offered little color on most Boeing-specific topics, such as the company's outlook on delivery timing of the 470 737 MAXs it has in storage or the grounded model's general demand outlook once it returns to service.

Hulst offered an upbeat assessment of the company's 777X, however. While acknowledging the pandemic will hurt widebody demand in general for years, the rapid retirement of the largest models, notably Airbus A380s and Boeing 747s, will leave a gap at the top end of the market once traffic begins to rebound. Mix in projected scheduled retirements of 777-300ERs later this decade—the highly successful model entered service in 1998—and the newest 777s should be on solid ground.

"I don't see a meaningful change in demand for the 777X in the long term," Hulst says.

Planned production rates align with Boeing's near-term outlook, a Jefferies analysis suggests. Boeing's forecast of 3,060 widebody deliveries through 2029 translates to 25.5 per month. Current Airbus and Boeing passenger model rates total 15 per month—six 787s, two 777s, two A330s and five A350s, including some 777 freighters. Before the pandemic, comparable rates totaled 34 per month, "pointing to a long recovery to peak," Jefferies says.

Boeing's narrowbody outlook for the next decade is 13,570 deliveries, or 113 per month. Current production plans assume about 32 MAXs per month, translating to 75 aircraft per month, Jefferies says.

The Boeing forecast assumes the current slack demand for new aircraft will tighten soon. Based on official production rate and delivery numbers, Jefferies estimates that 2020 build rates have produced about 260 excess aircraft, not counting 737 MAXs being built and stored while the model remains grounded.

"Production rates have largely been chosen for stability, rather than perfectly matching demand, so we would expect these aircraft in inventory to be worked off as demand recovers," Jefferies says.

A slower-growing fleet reset with a wave of retirements will cut into aftermarket services as well. The anticipated changes led Boeing to cut 10%, or about $100 billion, from its 20-year forecast for commercial-aviation services spending.

Boeing's updated services outlook, released alongside its CMO, projects a $9.04 trillion market through 2039 for its broadly defined services segment. The figure is down from September 2019's projection of a $9.1 trillion market through 2038.

Paralleling the CMO's delivery and fleet growth path, most of the reduction in services demand will come in the next 10 years, as airlines look to stabilize their operations with a smaller, younger fleet in the wake of the historic drop in traffic demand.

Among the main factors that will slow spending on services is the overall reduction in projected fleet growth, which has been exacerbated by rising retirements. Boeing's projection that 48% of new deliveries will replace aircraft instead of adding to a growing fleet stands in sharp contrast to last decade's actual figure of 35%, the company says.

During periods of growth and little market disruption, airlines collectively remove 2-3% of the global fleet annually for retirement in order to bring in new, more efficient aircraft. Using Boeing's numbers for the current fleet, that translates to 500-750 aircraft per year in the near term.

When the demand environment gets challenging, this removal rate can double, while new aircraft orders usually slow down.

"Our view is that we'll see something very similar" to a doubling of the fleet retirement percentage, Hulst says. "It may be even more pronounced in the near term because of the impact to the industry and [the industry's] significance on a global basis."

The Pandemic's Reach

Reductions in Boeing's 2020 Commercial Market 20-Year Outlook

Deliveries in Next 20 Years			Fleet Composition			
			2019 Forecast		2020 Forecast	
	2019 Forecast	2020 Forecast	2018 Fleet	2038 Fleet Forecast	2019 Fleet	2039 Fleet Forecast
REGIONAL JET	2,240	2,430	2,710	2,500	2,710	2,650
SINGLE-AISLE	32,420	32,270	16,630	35,200	16,520	33,850
WIDEBODY	8,340	7,480	4,520	9,560	4,660	8,640
FREIGHTER	1,040	930	1,970	3,400	2,010	3,260
TOTAL	**44,040**	**43,110**	**25,830**	**50,660**	**25,900**	**48,400**

Note: Regional jets are defined as having fewer than 90 seats.

Source: Boeing

Tough Winter Ahead for Airlines Burning Cash

> EASYJET EXPECTS TO FLY 25% OF NORMAL CAPACITY IN OCTOBER-DECEMBER

> IATA FORECASTS $77 BILLION CASH BURN IN SECOND HALF OF 2020

PATRICIA DE MELO MOREIRA/AFP/GETTY IMAGES

Helen Massy-Beresford Paris

With cash reserves running out fast, traffic levels declining and more capacity cuts on the horizon, the outlook for airlines looks increasingly pessimistic as they gear up for a difficult winter season.

The International Air Transport Association (IATA) warned on Oct. 6 that airlines worldwide would burn through $77 billion in cash in the second half of 2020—almost $13 billion per month, or $300,000 per minute—and that the slow recovery in air travel will compel the industry to continue its cash burn at an average rate of $5-6 billion per month in 2021.

IATA does not expect the industry to turn cash positive again until 2022.

Against this grim backdrop, the airline industry has been lobbying hard for weeks for a coordinated system of widespread COVID-19 testing to replace the current fragmented and frequently changing travel restrictions that are hampering their recovery efforts.

Some signs indicate that governments are responding to the calls for more coordination. In the UK, the formation of a government task force to look into alternatives to quarantine measures received a cautious welcome from the industry. And a European-wide harmonized "traffic light" system put forward by the European Commission has been approved by member states: The idea is that a simple map based on regional infection data analyzed by the European Center for Disease Prevention and Control (ECDC) will provide some much-needed clarity and predictability for would-be travelers.

But airlines hamstrung by a patchwork of individual restrictions, say the move does not go nearly far enough.

UBS analyst Jarrod Castle wrote in an Oct. 7 research note that as of Sept. 21, 67% of intra-European routes were subject to travel restrictions. This figure was down just 4 percentage points from the 71% seen in June, when many European countries were still in lockdown.

"With the onset of the winter season, we see a tougher trading environment, although the benefits from restructuring should start to gather pace," Castle wrote. "We think, given the levels of travel restrictions and unlikely material return of the business traveler, airlines will continue to reduce fourth-quarter capacity."

IATA has also called for more government aid for struggling airlines, now that the initial coronavirus pandemic support provided by many countries—totaling $160 billion worldwide—is beginning to dwindle and the industry is facing a longer crisis than many expected at the start of the year.

"The crisis is deeper and longer than any of us could have imagined. And the initial support programs are running out," IATA Director General and CEO Alexandre de Juniac said. "Today, we must ring the alarm bell again. If these support programs are not replaced or extended, the consequences for an already hobbled industry will be dire.

"Historically, cash generated during the peak summer season helps to support airlines through the leaner winter months," de Juniac added. "Unfortunately, this year's disastrous spring and summer provided no cushion."

UK budget carrier EasyJet warned on Oct. 8 that it will suffer its first-ever full-year loss of up to £834 million ($1.09 billion). Due to travel restrictions, the airline has set out plans to fly only about a quarter of its prepandemic planned capacity in October, November and December.

EasyJet is set to suffer its first-ever full-year loss.

EasyJet's cash burn rate was better than expected during the quarter to the end of September, thanks to its "prudent and conservative" approach to capacity, the airline said.

For the full year, passenger numbers dropped 50%, to 48 million. Meanwhile, capacity stood at 38% of previously planned levels in the three months from July through September.

"Flying peaked in August and then tapered significantly during September, when customer demand was materially affected by changes in government travel guidance and quarantine rules," EasyJet said. "Customers are booking at a very late stage, and visibility remains limited."

The number of flights operating grew to 30,849 in August from 13,992 in July but dropped to 21,692 in September. The ebb and flow of EasyJet's traffic mirrors a broader trend in European air transport, as uncertainty about the evolution of COVID-19 and travel restrictions has put off travelers since a summer peak.

Eurocontrol said on Oct. 12 that flights in its network during the week ended Oct. 11 numbered fewer than 100,000 for the first time since mid-July.

Traffic saw a 3.8% week-on-week downtick to 99,271 total flights, or 14,182 on average per day, Eurocontrol said. That figure represented 44.1% of 2019 levels, the organization added.

Amid warnings about the industry's cash situation, EasyJet said its own total cash burn for the fourth quarter is expected to be less than £700 million, compared with £774 million in the third quarter.

"Along with other airlines, EasyJet now has to look to summer 2021 for at least a partial recovery in demand," Bernstein analyst Daniel Roeska wrote in a research note. "Absent this, the industry will face an existential threat."

VoltAero Cassio Offers 'A La Carte' Hybrid-Electric Propulsion

> THREE-MEMBER FAMILY AIMED AT REGIONAL FLYING

> AIRPORT OPERATOR, NETWORK APP ALREADY ON BOARD

Graham Warwick Washington

Moving a step closer to its dream of developing a clean-sheet family of hybrid-electric aircraft for general and regional aviation, France's VoltAero has flown the 800-hp power train intended for the largest 10-seat member of the series.

The startup plans to stage a 2,300-km (1,240-nm) "Tour de France" with its Cassio 1 propulsion testbed on Oct. 26-31, visiting 11 midsize regional airports to demonstrate the travel convenience, reduced operating costs and lower noise promised by its production Cassio 2 family.

Whereas the Cassio 1 is a modified Cessna 337 Skymaster being used to develop and test the propulsion system incrementally, the Cassio 2 is a new, aerodynamically efficient design optimized around a power train that offers pilot-selectable "a la carte" operation: pure electric, mild hybrid or heavy hybrid.

"You can run like a series hybrid, you can run like a parallel hybrid, and you can have a disconnection—so pure thermal or pure electric," CEO Jean Botti says, adding that the system operates at 500 volts.

After competing 50 hr. of flight testing with earlier iterations of the power train, the Cassio 1 began flying with the most powerful version on Oct. 11 at Royan-Medis Aerodrome in France. The testbed is now fitted with two 45-kW Safran electric motors on the wing driving three-blade tractor propellers, and a VoltAero-developed hybrid power module in the aft fuselage driving a five-blade pusher propeller.

The "barrel" power module comprises three 60-kW Emrax electric motors and a 400-hp (300-kW) combustion engine supplied by Solution F and based on a Nissan V6 racing engine. The motors and engine all drive the propeller shaft via belts, and each can be disconnected independently if there is a failure.

The wing motors are powered by lithium-ion battery packs installed in the wingboxes outboard of the tail booms, and fuel for the thermal engine is housed in the inboard wing tanks. The hybrid-module motors are powered by three battery packs in the nose of the Cassio 1, replacing the Cessna's forward engine.

VoltAero developed the air-cooled battery system in-house using commercially available cells. Total battery capacity is 60 kWh, and system-level energy density is close to 190 Wh/kg,

VOLTAERO PHOTOS

VoltAero's Cassio 1 testbed has been fitted with the 800-hp hybrid-electric propulsion system planned for the production Cassio 2.

says former Airbus Chief Technical Officer Botti. "On short legs, we can fly pure electric with the range extender for safety," he adds.

The Cassio 1's cockpit has been retrofitted with Garmin avionics and displays, plus new information screens supplied by MGL Avionics for the hybrid power train. The cabin has been modified to accommodate the propulsion system electronics as well as two pilots and a flight engineer. Levers on the cockpit ceiling allow the pilot to disconnect individual motors.

All three members of the planned Cassio 2 production family—the four-seat Cassio 330, six-seat Cassio 480 and 10-seat Cassio 600—offer the same basic performance: 200-kt. cruise speed, 1,290-km (700-nm) maximum range and a takeoff and landing distance less than 1,800 ft.

The propulsion-system operating mode depends on range: pure-electric flight over distances up to 200 km, with the thermal engine as a backup for safety; mild hybrid over 200-600 km, with minimum recharging in flight; and heavy hybrid beyond 600 km, with more inflight recharging.

VoltAero plans to certify the family under European Union Aviation Safety Agency CS-23 regulations, beginning with the Cassio 330. The COVID-19 pandemic has delayed the program by 3-4 months, but the startup is aiming for certification of the four-seater by the end of 2022, to be followed at six-month intervals by approval of the six- and 10-seaters, Botti says.

The four-seater has a 330-kW power train and a design maximum takeoff weight (MTOW) of less than 2,000 kg (4,400 lb.); the six-seater, 480 kW of power and an MTOW of less than 2,500 kg. The 10-seater has a 600-kW power train and is expected to weigh in at less than 2,700 kg, he says.

The drivetrain in the initial Cassio 330 comprises a power module with three 60-kW Safran electric motors plus a 150-kW certified biofuel-compatible aircraft piston engine as the range extender.

The startup calculates the four-seater will have an average 35% lower cost of ownership than the competing Cirrus SR22 and 20% lower emissions in full-hybrid mode. Noise will be reduced by 8 dBA because the propeller is stopped during taxiing, and only electric propulsion is used for takeoff.

The power train for the six-seat Cassio 480 comprises the three 60-kW motors coupled to two 150-kW thermal range extenders, all driving the single pusher propeller, although VoltAero plans to switch to Solution F's high-power-density 300-kW combustion engine if it is certified, he says.

The Cassio 600 has a 300-kW motor-generator coupled to a range extender with 300 kW of electric and 300 kW of thermal power. The 10-seater may have wing-mounted propellers, as on the Cassio 1, but Botti says the pusher propeller is being designed to absorb all 600 kW and avoid the need for wing props.

Having raised the money to complete the first phase of Cassio development—propulsion system testing—VoltAero in May was selected to receive both grant funding and equity financing from the EU's European Innovation Council Accelerator. The startup is one of 64 companies chosen from 2,500 applications to receive a total of €307 million ($361 million) in funding and the only aeronautical project among the 38 of those chosen to share €182.6 million in equity investments.

As it looks toward operation of the Cassio 2, VoltAero has formed two key partnerships. One is with French infrastructure company Edeis, which operates 20 of the country's regional airports. The two companies plan to work together to develop an ecosystem for short- and medium-haul regional air services, including training schools and maintenance centers at these smaller airports.

"That's where we're going to do the 'Tour de France,' at their airports," Botti says. "[With Edeis], we have been thinking about how to better use midsize airports to develop regional air transportation. In France, Air France has been asked not to develop any more flights under 2.5 hr., so that creates an opportunity for us because sometimes the train, even if it's the TGV high-speed rail, does not serve some city-to-city routes well."

The second partnership is with U.S. startup KinectAir, which is developing an on-demand flight network built around an Uber-like smartphone booking app. "I want to integrate this into my cockpit," Botti says.

"That means, not only is the pilot going to type in where he wants to go, who he's going to pick up and so forth," he says. "But at the same time, the software is going to tell him, this is the route you have to take, these are the modes you have to run in: 30% electric, 50% hybrid at 50:50—it depends on the distance, altitude and everything. We want to make the cockpit of the Cassio smart."

When it enters the market, VoltAero plans to offer operators not only the aircraft but also access to infrastructure with Edeis and the "Uber in the air" app with KinectAir, Botti says.

VoltAero conducted the first flight with a 800-hp hybrid-electric propulsion system on Oct. 21.

Private Property

- AFTER A SPRINGTIME PAUSE, PRIVATE EQUITY INVESTORS RETURN WITH A VENGEANCE
- THE PUSH INTO A&D COULD HERALD SEVERAL CHANGES FOR INDUSTRY

Michael Bruno Washington

The stark reality of losing two years' worth of commercial aircraft production over the next half-decade continues to weigh on industry as it becomes clear there will be no snapback to prepandemic air traffic levels.

Shares of publicly traded aerospace and defense (A&D) companies worldwide lag their stock market indices by 26% year to date, Vertical Research Partners said Oct. 16. The laggardly public performance shows how few outsiders—except for people who love to fly—want to be involved with the industry right now.

Few, that is, except for a growing cadre of private equity (PE) investors.

"There are a lot of private equity players that are very interested in what is going on and see an opportunity to buy into the aerospace supply chain," Scott Thompson, PwC's U.S. aerospace and defense leader, tells Aviation Week. "There's a ton of interest. I've got quite a few reach-outs from PE saying, 'Hey, if you can help us identify companies looking for capital, we are eager investors.'"

Thompson is far from alone; headhunters, lawyers, acquisition deal-makers, investment bankers and industry advisors all report noticeable jumps in PE interest in A&D as the pandemic and its economic fallout rolls through industry. "Private equity group percentages have been increasing over the years, and I suspect they will continue increasing," says Stephen Perry, managing director at Janes Capital Partners.

Some recent deals punctuate the observation. In late September, Blackstone Group's Draken International bought 13 aviation service businesses of Cobham Group, which Advent International had taken private just last year and now is breaking up. In another deal unveiled in late September, Delta Tucker's DynCorp International, a provider of military logistics and aviation services to federal agencies, will be acquired by Amentum Holdings in a deal expected to close by year-end.

AE Industrial Partners is one of the leading PE groups active in A&D over the last 3-4 years. AE partner Kirk Konert says now that industry has entered a down cycle, his firm sees an opportunity to look at companies with more limited competition in the middle-market space.

"This is an industry that we have a lot of passion for, passion for the longevity of the sector," Konert says. The long-term business case remains intact, and veteran A&D PE investors such as AE have tried to stay disciplined with the prices they pay for acquisitions. "I don't think we're going to get better deals—we're going to continue to pay the same prices we were paying—but maybe have more opportunities and more assets" to consider, he said in late July.

Many observers predict private equity's growing presence in A&D could bring many changes to the industrial base. From consolidation of the supply chain to moving production to new locations to accelerating automation, robotics and other digital technology adoption, PE owners are expected to alter the slow-changing A&D industrial base. But PE may not be satisfied with just the midtier and below: Speculation over PE involvement with OEMs and Tier 1 providers—whether on individual programs such as a new midmarket aircraft or new aero engines—remains a staple of industry water-cooler talk.

"They're probably going to move more from a sector participant to a strategic partner," says Alex Krutz, managing director of consultancy Patriot Industrial Partners. "They typically haven't been viewed by the OEMs, or Boeing for that matter, as partners, and I think that with their liquidity and financial capabilities, we're going to start to see them move into design."

"We're being contacted on a consistent basis by investors looking for resiliency in A&D investments, and military for now looks like the place getting the most attention," says Paul Weisbrich, managing director of the investment banking group at D.A. Davidson. Foreign military sales, which saw a record government-approved $83.5 billion value in

Highly Acquisitive A&D Buyers

Company	A&D Acquisitions Since 2017
Top Private Equity Buyers	
AE Industrial Partners	26
ACP	21
The Carlyle Group	16
The Jordan Co.	9
Acorn Growth Cos.	7
Veritas Capital	7
Enlightenment Capital	7
J.F. Lehman & Co.	7
Warburg Pincus	6
KKR	6
Liberty Hall Capital Partners	6
Audax Group	5
Platinum Equity	5
Tinicum	5
Odyssey Investment Partners	5
Top Strategic Buyers	
Heico	14
Mercury Systems	8
L3 Technologies	8
Ametek	7
General Dynamics	7
Transdigm Group Inc.	6
Boeing	5
Other*	4

*CAE, Cubic, Elbit Systems, Hexcel, Qinetiq, Accenture, BAE Systems, ParkOhio, FLIR, TT Electronics, Astronics, Saab

Sources: Janes Capital Partners and Robinson+Cole

fiscal 2020, is one trend to ride. But he says buyers need to be discriminating within defense investments and focus on 2022-23, for instance, looking beyond 2021 for which the defense budget is already set.

Others concur. "I do really continue to see opportunity," says Chris Celtruda, managing principal of Destiny Equity Partners. He cites Pentagon mandates around hypersonics, unmanned aircraft, microelectronics and space driving long-term value in related assets, as well as for modernization and sustainment of aging but critical military systems such as aircraft. Privatization of pilot training is another opportunity as the armed services consider outsourcing the task for cost savings and readiness reasons.

But while the military field is attractive, seasoned investors note the need for diversification across A&D and avoidance of getting caught up in one niche that has performed well over the last six months. "This cycle is a reminder of why platform and market diversity has always been a cornerstone of investing in aerospace and defense," said Paul Teske, a co-founder and partner at ATL Partners, at an A&D Forum event on PE investing in October. "The growth of commercial in the last five years has made some people forget about that."

Weisbrich also recommends space-related opportunities, including supply chain. "That's really the hot topic zone for us today: space," he says. But again, Celtruda and Teske urge discrimination. Celtruda says space is a tale of two cities: the commercial side of space, while it receives lots of news coverage, is driven by billionaires, and the business models remain to be proven. But government-based work in launch, low-Earth-orbit (LEO) satellites, clandestine intercept and other projects shows genuine opportunity.

Teske noted that among three space sectors—military, civil government and commercial—defense looks the best long term. Others agree.

"Today we see a combination of the two, and really it's a question of the sustainability of one over the other," agrees Tracy Glende, CEO of Valence Surface Technologies. His company does commercial launch vehicle work for SpaceX, Blue Origin and others, but it is satellites for government use that he believes will be higher-margin, more sophisticated and sustainable work. "A lot of these small LEO satellites have cheaper components. We've already seen OneWeb go bust," he notes. "Yes, you can provide internet service to Central Africa, but who's going to pay for it?"

In commercial aviation, many observers advocate more of a wait-and-see approach. Several participants at the A&D Forum event said they expect commercial aviation activity to truly bottom out between now and February. "You are not going to get rewarded for going too early in a cycle if things are still declining," said Teske. "We have a lot of debate [as to] where the dust will settle first, aftermarket or OEMs."

Bryan Perkins, founder and CEO of Novaria Group, suspects there are leading indicators of business activity of which commercial aircraft and engine OEMs are aware but that are not as visible to suppliers. The list begins with the amount of backed-up inventory in commercial aerospace and its consequences.

"I think OEMs are struggling to understand what a supplier sitting on two years' worth of inventory in their own business, coupled with maybe three years of inventory at the OEM, is going to be faced with and how that is going to impact the supply chain in total," Perkins says.

There are also challenges with how cost curves have to change as work volumes drop so much for so long, bringing concurrent pressure on suppliers' working capital accounts. "We're in the second inning of a nine-inning ballgame," Perkins says. "The supply chain is in an every-man-for-himself situation because the OEMs are exhausted."

Glende echoes Perkins and notes how OEM and upper-tier supply chain squeezes of recent years, including should-cost contracting, were predicated on production volumes increasing. "There's a whole set of assumptions behind those programs that all arrows pointing north, and they point north with a rapid acceleration," he says. "They are no longer true."

With Airbus seen as generally better positioned than Boeing, insiders acknowledge the attractiveness of boosting business with the European OEM. Weisbrich predicts more cross-fertilization of suppliers to Airbus and Boeing within five years. But Perkins thinks U.S. PE investors may have to become more active in Europe if they want to play into Airbus' supply chain because protectionist economic policies may make transatlantic trade harder, and others concur.

"It's going to be more challenging to be a part of that supply chain unless you're physically on the ground in Europe, with a management team in Europe that can help drive that growth and take advantage" of Airbus' A220 and A321XLR, Glende says.

PEs fall within a category of merger and acquisition (M&A) deal-makers known as financial sponsors. The other side, "strategics," are A&D companies, although since late last year their deals predominantly have been divestitures—e.g., OEMs, primes and "Super Tier 1s" shedding noncore businesses.

After an unprecedented pause in March-May due to the COVID-19 outbreak, deal-makers report a return to record activity and eye even more opportunities, especially if Democrat Joe Biden wins the White House and pursues certain tax increases, spurring a stampede to get in before they take effect.

"We've probably never seen such an abundance of deals," says Craig Chason, leader of law firm Pillsbury's Northern Virginia office corporate practice.

"The floodgates really opened in September," agrees Jean Stack, managing director in Baird's Global Investment Banking group and co-head of its government and defense practice.

Pillsbury hosted a webinar series on M&A in aerospace in October where Chason, Stack and other deal-makers talked about how "weird" 2020 has been, with a near-freezing of activity in the spring followed by today's rush. But even as PE investors held off at the time—to deal with the pandemic crisis within their own portfolio companies—strategic buyers still were hunting for targets, they say. Both sponsors and strategics are positioning for 2-3 years out, and the current Goldilocks atmosphere both reaffirms the sector's resilience while also providing a unique opportunity.

Looking ahead, many deal-makers see activity reaching new heights. "I expect the next 12 months to be an extremely busy time for this sector," says Bob Kipps, founder of KippsDeSanto & Co., an A&D and government services advisory firm.

Stack says the transformation within the sectors will be "awe-inspiring," including divestitures and new owner entrants. "Nothing is off the table," she says.

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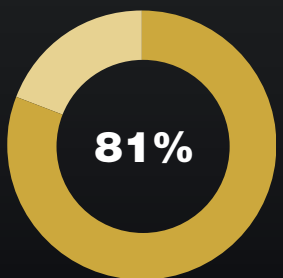

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1:00-1:05 PM	**INTRODUCTIONS** **Joanna Speed**, Managing Director, A&D and SpeedNews Conferences, Aviation Week Network
1:05-1:15	**WELCOME ADDRESS** **Michael J. Richter**, Managing Director, Global Head of A&D Group, Lazard **Dr. Brad M. Meslin**, Senior Managing Director, CSP Associates
KEY ISSUES DRIVING THE INDUSTRY	
1:15-1:45	**OPENING ADDRESS** SPIRIT AEROSYSTEMS – **Thomas "Tom" Gentile**, President & CEO *Moderated by **Michael Richter**, Managing Director, Global Head of A&D Group, Lazard* **Questions & Discussions**
1:45-2:35	**PANEL: THE STATE OF THE AEROSPACE & DEFENSE INDUSTRY: IMPLICATIONS FOR M&A** *Moderated by **Dr. Brad M. Meslin**, Senior Managing Director, CSP Associates* AE INDUSTRIAL PARTNERS – **John Nemo**, Senior Partner AERODYNAMIC ADVISORY – **Dr. Kevin Michaels**, Managing Director LOAR GROUP – **Dirkson R. Charles**, Chief Executive Officer & Co-Chairman **Questions & Discussions**
2:35-2:40	**REFRESHER AND NETWORKING BREAK** Sponsored by **Moss Adams**
2:40-3:10	**INTERACTIVE VIRTUAL CHAT** *Moderated by **Jens Flottau**, Executive Editor, Commercial Aviation, Aviation Week Network* AIRBUS – **Michael Schöllhorn**, Chief Operating Officer
3:10-3:45	**PANEL: HOT SPOTS FOR M&A IN THE SUPPLY CHAIN** *Moderated by **Kenneth "Ken" Herbert**, Managing Director, Canaccord Genuity* LIBERTY CAPITAL – **Rowan G.P. Taylor**, Managing Partner PARKER AEROSPACE – **Peter Collins**, Group Vice President, Strategy & Business Development **Questions & Discussions**
3:45-3:50	**REFRESHER AND NETWORKING BREAK** Sponsored by **Moss Adams**
3:50-4:45	**PANEL: INVESTMENT TRENDS AND OUTLOOKS: WHERE ARE THE OPPORTUNITIES?** *Moderated by **Michael J. Richter**, Managing Director, Global Head of A&D Group, Lazard* AGENCY PARTNERS – **Sash Tusa**, Partner, Aerospace & Defense Partners HEICO CORPORATION – **Eric A. Mendelson**, Co-President **Questions & Discussions**
4:45-4:55	**CLOSING COMMENTS** **Michael J. Richter** **Joanna Speed**
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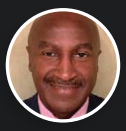

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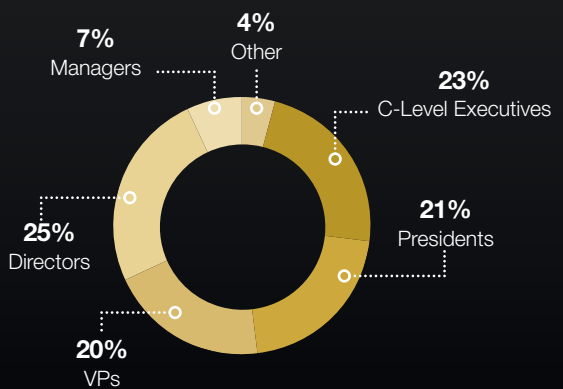

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DARPA-Funded Study Proposes Vision for Hypersonic Production Facility

> HPAF SHIFTS START-UP COSTS TO NONFEDERAL SOURCES

> FACILITIES, MACHINES COULD BE REFRESHED EVERY THREE YEARS

Steve Trimble Washington

A future factory called the Hypersonic Production Accelerator Facility—for building potentially thousands of scramjet propulsion systems for hypersonic cruise missiles—may not need the U.S. Defense Department or the defense industry to pay the up-front costs for facilities and equipment.

With no or few capitalized investments demanding a lengthy return on investment, the additive manufacturing machines needed to produce the high-temperature materials required for scramjet propulsion could be refreshed or replaced in three-year cycles.

The entire supply chain—from the feedstock suppliers for the electron-beam welders to the prime contractors—could be co-located within the Hypersonic Production Accelerator Facility (HPAF). The vertically integrated process would be capable of producing, testing and qualifying materials for new designs in almost half the time and for about one-fourth the cost of a traditional distributed supply chain.

That vision for mass production of scramjet-powered vehicles has emerged from a two-year DARPA-funded study by the Applied Science & Technology Research Organization (ASTRO).

An unclassified summary of the study published by ASTRO in September proposes a new business model for producing scramjet-powered missiles, but defense officials say it could be applied to a wide range of advanced weapons.

"This effort was intended to inform us as we develop the concepts for [producing] affordable systems in large numbers where high-temperature materials and advanced thermal-management techniques will drive designs that have unique production requirements," a Pentagon spokesman says. For example, the carbon-carbon material applied to rocket-boosted hypersonic glide vehicles also could benefit from the same approach, according to the study's authors.

ASTRO

The HPAF facility would use dedicated bays for separate supply chains to protect intellectual property and defense security as well as common areas to leverage other machines for metrology, inspection, subtractive manufacturing, welding, and other pre- and post-processing needs.

The ASTRO study seeks to answer questions that have hung over the Pentagon's three-year-old rush to play catch-up with advances by Russia and China in hypersonic weapons: Who would pay the up-front costs to build an infrastructure of production and test facilities necessary to support U.S. weapon production? And would that infrastructure accommodate the rapid pace of change in the nascent hypersonic field, allowing quickly obsolete manufacturing processes and tools to be affordably replaced with state-of-the-art equipment in cycles of a few years?

According to ASTRO, a consultancy founded by a former DARPA manager, the answer would be to seek a dramatic split from the conventional model for producing advanced weapons. To start, the study proposes a new level of participation by state and local governments in defense production.

"A number of regions have talked about local and state support for having the [hypersonic production] facility located there," Mick Maher, chief technology officer for ASTRO, says in an interview.

The published summary of the ASTRO study identifies nine potential sites for the HPAF: Seattle; Long Beach, California; San Antonio; Wichita; College Station, Texas; West Lafayette, Indiana; Huntsville, Alabama; Daytona, Florida; and Hampton, Virginia. The locations share a common trait: local access to existing hypersonic infrastructure.

"If you look at all of those places, there's probably a wind tunnel nearby or an OEM," Maher says.

The ASTRO study recommends that the Defense Department hold a competition in which the potential cities would offer bids of financial support to offset the up-front cost of establishing the HPAF. As part of each proposal, the competitive bidding could include offers to finance the capital infrastructure costs for the facility, production machines and tooling.

By their nature, scramjet propulsion systems make ideal candidates for additive manufacturing. Such processes can "grow" a part made of high-temperature materials, along with intricately designed internal passages to enable active cooling systems.

Thomas Bussing, former vice president of advanced missile systems for Raytheon, confirmed that additive manufacturing will play a key role in the production of the company's scramjet design. "You could not build [scramjets] using conventional methods the way cooling systems are structured," Bussing said in a June 2019 interview. "Also, the larger segments—the inlets and bypass ducts—all of those things are basically done via additive manufacturing."

Additive manufacturing makes the new generation of scramjet designs possible to build but creates certain financial pressures.

The ASTRO study proposes an HPAF financed largely by nonfederal sources, such as local and region-

Japan's electromagnetic warfare aircraft **p. 35**

al governments or public-private partnerships between governments and academia.

Those entities would own the HPAF, then lease access to the facility and the machines to the Defense Department to support production for a program of record. The Pentagon would then turn over the machines and the facility to the supply chain to build the scramjets.

"We're saying the government doesn't even need to get into the ownership piece," Maher says. "It can provide the money to set the facility up and get it running. And then we can even provide project money on top of that."

The concept bears faint echoes of an early description in late 2018 of the Pentagon's vision for future hypersonic production by Patrick Shanahan, who was then the deputy defense secretary spearheading a review of industrial base policy. In remarks at a National Defense Industrial Association event on hypersonic manufacturing, Shanahan, a former Boeing executive, was keen to shift the cost burden of manufacturing infrastructure from industry to government.

"I'd love to build the right facilities and then turn the keys over to someone to manage," Shanahan said in 2018.

The ASTRO study builds on that approach but suggests using local and regional governments to supplement or assume the Pentagon's up-front costs to build a hypersonic manufacturing infrastructure within a few years.

The goal of using that approach is twofold. After nearly four decades of start-stop cycles in hypersonic technology development, businesses would not have to convince skeptical boards to spend heavily on up-front production equipment. The same burden upon the Pentagon's budget also would be relieved. In addition, the industry and the military would not be disincentivized to invest in new additive machines and processes as they become available.

"If you buy equipment, that locks you into that time frame [to earn a return on investment]," Maher says. "Leasing it allows you to be much more flexible."

The ASTRO study anticipates a regular cycle of manufacturing updates. The OEMs could "refresh" the additive machines to adapt to new technology. Alternatively, if a new manufacturing process emerges, the HPAF could be "reset" with different production tooling altogether. The refresh-reset cycle assumed in the study is set at three-year intervals, although Maher says the industry is still debating the ideal time period.

"If you change it too fast, you never qualify the process, so you never get to use it," Maher says. "If you go too slow, you don't get to take the advantage of what's out there. So three years is somewhat controversial. It came down to what we thought made the most sense."

When the Pentagon moves to establish a new base or production site, the location decision often reflects political considerations as much as operational needs. Those same political interests also usually drive defense contractors to disperse the supply chain to as many congressional districts as feasible.

The ASTRO study seeks basically the opposite for the HPAF. The entire supply chain for design, test and manufacturing would be co-located inside the facility. Each tier of the supply chain would be on-site, including the material feedstock supplier, factory equipment supplier, Tier 1 suppliers, contract manufacturer, lead system integrator and the Air Force program manager.

The concept for the vertically integrated campus emerged from a workshop of more than 100 industry representatives summoned by ASTRO in November 2019.

"You look at a traditional manufacturing path, and you're back and forth across the country several times between heat treatments and machining places," Maher says. "There's a tremendous amount of time just lost in queue."

The HPAF also would be sized to support multiple prime contractors working on different vehicles.

In August, the Air Force selected Boeing, Lockheed and Raytheon to compete for the Future Hypersonic Program, a planned follow-on to DARPA's Hypersonic Air-Breathing Weapon Concept. Lockheed and Raytheon are participating in the latter; the first flight tests of each company's design are scheduled for later this year. The Air Force has not defined an acquisition strategy for the operational prototyping program, but it may not lead to a traditional winner-takes-all contract award. Senior Pentagon officials have previously said they would prefer to maintain competition beyond development, with multiple designs competing for annual production orders.

To facilitate long-term competition, the HPAF would be designed with up to four bays, allowing for three OEMs and their supply chains to occupy one area each. The fourth bay would be set aside as a demonstration site, where new production technologies could be showcased and used for experiments, Maher says.

MIKE CASSIDY/U.S. AIR FORCE

A new production system is envisioned for the next generation of scramjets rather than the small, fragmented industrial base that built experimental systems such as the Boeing X-51.

Digitalization—A Trademark of 2020 Program Excellence

> 2020 PROGRAM EXCELLENCE NOMINEES SPAN ALL SECTORS OF INDUSTRY

> ALL THINGS DIGITAL A COMMON THEME AMONG FINALISTS, WINNERS

Carole Rickard Hedden Washington, DC

While recognizing excellence in program execution is the most visible outcome of Aviation Week's annual Program Excellence Awards, the foundation of the initiative is a desire by program executives to share lessons learned and best practices. Since 2004 the goal of the initiative has been to improve the performance of all programs and thus assure the health of the aerospace and defense industry overall.

The push in 2004 to create the initiative coincided with the 2003-04 President's Commission on Moon, Mars and Beyond. Led by then-Hewlett Packard CEO Carly Fiorina, the commission delivered its results to the George W. Bush administration in early 2004, finding that the top issue to renewing a commitment to space exploration had one foundational need–program performance within NASA and the space industry had to improve and achieve excellence.

Working together, NASA, Aviation Week, industry leaders, representatives from Sandia National Lab and from academia created the foundation of the Aviation Week Program Excellence initiative.

The 2020 Aviation Week Program Excellence Awards winnowed down the thousands of industry programs and projects to 23 programs that submitted applications and agreed to share their lessons learned and best practices with the industry. This year's entries were broad-ranging, from component production using additive manufacturing to the long-term value delivered by a 40-year-old spacesuit.

Among the most common factors were two items indicative of the current era and its evolving priorities—reliance on data and its analysis to drive improvement, and the use of digital design/build/sustain environments to reduce the time required to develop and field new products and capabilities. Program teams developing new products used Agile software development processes not just for software but also to design, model and test highly complex aerospace systems.

Program Excellence Awards are made in seven categories: Special Projects, Supply Chain Design and Development, Supply Chain Production, Supply Chain Sustainment, Original Equipment Manufacturer (OEM) System Design and Development, OEM Production and OEM Sustainment. This year, for the first time, there was no finalist or winner in one category—Supply Chain Production.

More than 200 people participated in the evaluation process, providing a professional development opportunity for the judges as they scored the entries across four dimensions: value creation, managing complexity, organizational leadership and excellence, and use of leading-edge metrics to drive improvement.

2020

SPECIAL PROJECTS

> **Lockheed Martin Orion Ascent Abort Two-Launch Abort System**

> **Roger McNamara, Director, Orion Launch Abort System**

Roger McNamara

The Launch Abort System (LAS) team manufactured, delivered, tested and verified the system in a flawless test flight proving its ability to successfully rescue the crew capsule and astronauts in an abort situation during ascent. Hardware was delivered on an accelerated timeline, delivering seven months in advance of the contract date and launching six months in advance of the baseline date.

The successful integration of the LAS with the boost vehicle became the basis for future Orion vehicle- integration processes, both for the development and production programs. The strong technical background and collaborative approach of the LAS team ensured efficient resolution of schedule and critical technical issues during final assembly, resulting in 100% mission success of the AA-2 flight test. This test, combined with subsystem qualification and the Pad Abort-1 flight test, has successfully produced a LAS that is now certified to fly on the Artemis missions with astronauts on board.

Lockheed Martin completes the test for the Orion Ascent Abort Two-Launch Abort System as part of the preparations for crewed flight. Photo Credit: NASA

PROGRAM EXCELLENCE AWARD WINNERS

Agile development practices yield innovation, time savings

SUPPLY CHAIN DESIGN AND DEVELOPMENT

> **Honeywell Aerospace Micro Power Unit**

> **Laurel Huffman, Senior Program Manager**

Laurel Huffman

This year's winner in the Supply Chain Design and Development category is Honeywell Aerospace's Micro Power Unit development team. This team developed a new certified hardware product using agile methods to accomplish FAA certification in half the time compared to the norm.

Honeywell Aerospace's Micro Power Unit team used agile methods to reduce certification cycle time by half. Photo Credit: Honeywell Aerospace

Two-week sprints allowed the team to design and quickly resolve issues, including the financial and scope impacts of their changes. Team members started from a baseline that questioned traditional methods and instead looked to drive speed to market with a certificated level of quality.

SUPPLY CHAIN SUSTAINMENT

> **Collins Aerospace Extravehicular Mobility Unit for NASA**

> **Greg Stonesifer, Program Director, EVA Space Operations**

Greg Stonesifer

Collins Aerospace has maintained this critical equipment for use by astronauts as they venture into the vacuum of space for more than 200 space walks, flawlessly, over the past 40 years. The program includes the maintenance, refurbishment, hardware development, logistics and mission expertise for the EMU flight and training hardware, and the team has extended the anticipated 10-year life of the spacesuit to 40 years, saving NASA and taxpayers more than $56 million over the last three years alone as well as collecting data and experience that are critical in informing spacesuit development for the future.

The Collins Aerospace Extravehicular Mobility Unit has recorded more than 200 space walks and has set the stage for a new generation of space suits as astronauts return to the Moon. Photo Credit: NASA

OEM SYSTEM DESIGN AND DEVELOPMENT

> **Lockheed Martin Space Fence**

> **Robert Condren, Senior Program Manager**

Robert Condren

From this strong field of candidates, the winner is the Space Fence from Lockheed Martin. This team took on the seriously complex task of developing new technology but also building the infrastructure on the ground and then putting the system into operation— for an all-new radar capability for the newly formed U.S. Space Force. This truly is a program of excellence as exhibited by numerous lessons learned and best practices that have been spread across not only Lockheed Martin but also the industry, as part of this year's Lessons Learned/Best Practices Report.

Protecting the U.S. from space-based threats involves more than interceptors. Lockheed Martin's Space Fence program involved beam direction and other technologies, but also the building of structures and infrastructure for what amounts to a city in the Marshall Islands. Photo Credit: Lockheed Martin

As indicated by the customer at Space Command, "Space Fence is revolutionizing the way we view space" — indicating that this team also mastered the technology of focusing literally thousands of beams to further America's efforts in space.

OEM PRODUCTION

> **Raytheon Missiles and Defense Standard Missile-3 1B Production**

> **Sharon A. Walk, Program Director**

Sharon A. Walk

In 2019, the Standard Missile-3 (SM-3) Block 1B Production Team delivered 56 missiles to the Missile Defense Agency, the highest number ever delivered in a single year in the history of the program, overcoming technical and supplier challenges.

The team recognized the need to improve across the board, from how it partnered with suppliers to the overall culture and philosophy used on the factory floor, a new state-of-the-art facility in Huntsville, Alabama. The Missile Defense Agency recognized the performance by this team, making the first-ever multi-year contract award in the history of the agency.

Among the team's accomplishments are:

- Accelerated deliveries by as much as 50%
- Cycle time reduced by half
- Reduced test equipment downtime
- Helped key suppliers increase their yield
- Implemented lean manufacturing
- And developed a stronger partnership with the MDA customer, Navy technical representatives, and the Defense Contract Management Agency

Raytheon's Standard Missile-3 1B program made record deliveries, worked with suppliers to increase yield and reduced cycle time by half. Photo Credit: Raytheon Missiles & Defense

OEM SUSTAINMENT

> **General Atomics Aeronautical Systems Gray Eagle UAS Sustainment**

> **TJ Nagle, Program Director**

TJ Nagle

With more than 100,000 Gray Eagle flight hours operated annually, GA-ASI's Performance Based Logistics program is tasked with maximizing the UAS's operational readiness to ensure mission success when and where it is needed. From January 2017 to December 2019, General Atomics led initiatives and techniques that improved its mission-capable rate by 15 percentage points, from 82% to 97%.

The Gray Eagle Sustainment program team from General Atomics Aeronautical Systems developed a proprietary logistics tracking system and used modeling to deliver readiness beyond the standards set by its customer, the U.S. Army. Photo Credit: General Atomics Aeronautical Systems

Evaluators noted, in particular, that this team provided best practices and lessons learned in the areas of Organizational and Leadership Excellence for the use of processes and motivation, resulting in:

- Constant focus on potential and emerging issues
- Sensitivity analysis applied to reduce costs
- A proprietary logistics tracking system to track the 105,000- ft.^{2} warehouse, and
- Procurement modeling and simulation to deliver results beyond the Army's operational readiness standards.

2020 PROGRAM FINALISTS

SPECIAL PROJECTS

> **Get to Gold Program to Eliminate Quality Escapes**

- Jason Casebolt, Program Director

  Aerospace Composites Malaysia, a Boeing Joint Venture

> **Integrated Digital Shipbuilding**

- Tim Sweitzer, Director Digital Shipbuilding

  Huntington Ingalls – Newport News Shipbuilding

> **Additive Manufacturing for Space**

- Bill Massaro, Director of Advanced Manufacturing

  Moog Inc., Space and Defense Group

> **Ground-Based Detect and Avoid (GBDAA) – The SkyVision Project**

- Jack McAuley, Director Program Management

  Raytheon Technologies

SUPPLY CHAIN DESIGN AND DEVELOPMENT

> **Litening L3.1 Software Enhancements**

- Cliff Pearce, Program Manager

  Northrop Grumman

> **Exoatmospheric Kill Vehicle (EKV) FTG-11 Flight Test**

- Roy Donelson, Senior Program Director

  Raytheon Technologies

EXCELLENCE

SUPPLY CHAIN SUSTAINMENT

> **F-35 Display Management Computer/Helmet Sustainment (DMC/H)**
- John Murphy, Director Sustainment & Support
- Ken Brooks, Program Director
- Amy Bobo, Program Manager

Elbit Systems of America

> **131-9 Block II Engine Development Program**
- Rasa Fuller, Director Development Programs

Honeywell Aerospace

OEM SYSTEM DESIGN AND DEVELOPMENT

> **Lower Tier Air and Missile Defense Sensor (LTAMDS)**
- William Patterson, Director II Program Management

Raytheon Technologies

OEM SYSTEM PRODUCTION

> **Common Infrared Countermeasures (CIRCM)**
- Anthony Obering, Program Manager

Northrop Grumman

OEM SYSTEM SUSTAINMENT

> **Fixed-Wing Sniper Advanced Targeting Pod**
- Kenen Nelson, Fixed-Wing Program Director
- Valerie Potthoff, Sniper Advanced Targeting Pod Program Director
- Bill Spangenberg, Sniper Advanced Targeting Pod Program Manager

Lockheed Martin Missiles and Fire Control

2020 PROGRAM EXCELLENCE EVALUATION TEAM

2020 PROGRAM EXCELLENCE EVALUATION TEAM MEMBERS

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Chris Seat
Senior Vice President Program Management, General Atomics Aeronautical Systems

James Steffan
Director Program Management and Contracts, Moog Space & Defense Systems

Wendy VanWickle
Executive Vice President, Parsons

U.S. Army Flexes New Land-Based Anti-Ship Capabilities

- PROJECT CONVERGENCE 2021 TO INCLUDE ANTI-SHIP TEST
- PRECISION STRIKE MISSILE TO RECEIVE ANTI-SHIP ROLE IN 2025

An artist's rendering of a Precision Strike Missile offers a preview of a new weapon entering service in fiscal 2023. An advanced seeker with a maritime targeting capability has entered flight testing for delivery two years later.

U.S. ARMY

Steve Trimble and **Lee Hudson** Washington

Finding ever new and efficient ways to sink enemy ships is usually assigned to the U.S. Navy and, to a lesser extent, the Air Force—but not anymore.

Though still focused on its primary role of maneuvering against land forces and shooting down air and missile threats, the Army is quietly developing an arsenal of long-range maritime strike options.

As the Army carves out an offensive role in the Pentagon's preparations for a mainly naval and air war with China, service officials now seek to develop a capacity for targeting and coordinating strikes on maritime targets with helicopter gunships in the near term and with long-range ballistic missiles by 2025.

The Project Convergence 2020 event in September focused the Army on learning how to solve the command-and-control challenge for a slew of new land-attack capabilities scheduled to enter service by fiscal 2023. The follow-on event next year will expand to include experiments with the Army's command-and-control tasks in the unfamiliar maritime domain.

"I think we have a long way to go in terms of partnering with the Navy for some of the maritime targeting [capabilities]," says Brig. Gen. John Rafferty, the Army's cross-functional team leader for Long-Range Precision Fires.

"And I think that'll be a natural evolution into Project Convergence 2021," Rafferty said during the Association of the U.S. Army's virtual annual meeting on Oct. 15.

The Army operates a small, modest fleet of watercraft, including logistics-support vessels and Runnymede-class large landing craft, but service officials have been content to respond to attacks from enemy ships at sea with the Navy's surface combatants and carrier-based fighter squadrons. Last year, the Air Force also revived a maritime strike role by activating the Lockheed Martin AGM-158C Long-Range Anti-Ship Missile on the B-1B fleet.

But the Army's position has changed. The AH-64E Capability Version 6, which Boeing started developing in 2018, includes a modernized radar frequency interferometer. The receiver can identify maritime radars, allowing the AH-64E to target watercraft at long range for the first time.

Meanwhile, the Defense Department's Strategic Capabilities Office started working in 2016 to integrate an existing seeker for targeting ships into the Army Tactical Missile System (Atacms), which is currently the Army's longest-range surface-to-surface missile at 300 km (162 nm). Beginning in fiscal 2023, the Lockheed Martin Precision Strike Missile (PrSM) is scheduled to begin replacing the Atacms. The Increment 1 version will extend the range of the Army's missiles to 500 km. A follow-on Increment 2 version of PrSM is scheduled to enter service in fiscal 2025, featuring a new maritime seeker now in flight testing by the Army Research Laboratory.

"As we begin to develop the PrSM [Increment 2] with the cross-domain capability against maritime and emitting [integrated air defense system] targets, obviously we'll be partnering with the Navy on that," Rafferty says.

Targeting ships using land-based artillery systems is not unique to the Army. The U.S. Marine Corps plans to introduce the Raytheon-Kongsberg Naval Strike Missile, firing the ground-based anti-ship cruise missile from a remotely operated Joint Light Tactical Vehicle.

To strike a moving target at ranges beyond the horizon, the Army needs more than an innovative new seeker. A targeting complex linking over-the-horizon sensors with the Atacms and PrSM batteries is necessary. Moreover, the Army will need to adapt command-and-control procedures to an unfamiliar maritime domain.

The annual Project Convergence events offer a laboratory for the Army to prepare the targeting and command-and-control complex before new weapons enter service. With the Long-Range Hypersonic Weapon, a medium-range ballistic missile and PrSM also set to enter service in the

next three years, the Army is seeking to adapt quickly.

In September, the Army used the first prototype of the Tactical Intelligence Targeting Access Node ground station. An artificial intelligence (AI) program named Prometheus sifted through intelligence information to identify targets. Another AI algorithm called SHOT matched those targets to particular weapons with the appropriate range and destructive power. An underlying fire-control network, called the Advanced Field Artillery Data System, provided SHOT with the location and magazine status of each friendly weapon system. A process that would otherwise take minutes or even hours dwindled—in an experimental setting—to a few seconds.

The first Project Convergence event in September focused on the Army's traditional mission against targets on land. The next event will seek to replicate that streamlined targeting process against ships possibly hundreds of miles away. These experiments are intended to help the Army familiarize itself with new tools in the command-and-control loop, such as automated target-recognition systems and targeting assignments. The event also helps the Army dramatically adapt, in a few years, institutional practices that have endured for decades.

If a bureaucracy is to change, it must "understand the need, and we have to create the use case in order for [that] bureaucracy to change," says Gen. Mike Murray, the head of the Army Futures Command. "I think in Project Convergence, what we're able to demonstrate to the senior leaders in the Army will further help drive that change."

In a way, the Army is seeking to achieve in the maritime domain a networked sensor and command-and-control system that the Navy introduced to its fleet nearly two decades ago. To improve the fleet air-defense mission substantially, the Navy's Cooperative Engagement Capability (CEC) generally develops a common, shared database of tracks from the multiple airborne, surface and subsurface sensors available to a carrier battle group.

But the Navy also is building on the CEC standard. In 2016, a Lockheed F-35B demonstrated the ability to develop a target track of an over-the-horizon enemy warship. The track information was sent via the CEC to a launcher for a Raytheon SM-6. Although primarily an air- and missile-defense interceptor, in this case the SM-6 demonstrated an anti-ship role. A follow-on development SM-6 Block 1B is expected to optimize the weapon system as a long-range anti-ship ballistic missile with hypersonic speed.

More recently, the Navy has been quietly experimenting with its own series of Project Convergence-like experiments. Known as the Navy Tactical Grid experiments, the Navy and Marine Corps organized a series of demonstrations in fiscal 2019, according to the latest budget justification documents. Building on the common operating picture provided by the CEC, the Navy Tactical Grid is possibly experimenting with similar automation and machine-learning algorithms to streamline and amplify the targeting cycle markedly.

A new initiative is now replacing the Navy Tactical Grid experiments. Chief of Naval Operations Adm. Michael Gilday tapped Rear Adm. Douglas Small, the head of Naval Information Warfare Systems Command, to lead the effort known as Project Overmatch.

Small must provide a strategy, no later than early December, that outlines how the Navy will develop the networks, infrastructure, data architecture, tools and analytics to support the operational force. This includes linking hundreds of ships, submarines, unmanned systems and aircraft.

"Beyond recapitalizing our undersea nuclear deterrent, there is no higher developmental priority in the U.S. Navy," Gilday wrote in an Oct. 1 memo that revealed the existence of Project Overmatch. Aviation Week obtained a copy of the document. "I am confident that closing this risk is dependent on enhancing Distributed Maritime Operations through a teamed manned-unmanned force that exploits artificial intelligence and machine learning."

While Small is tasked with creating the "connective tissue," Gilday has directed Vice Adm. James Kilby, deputy chief of naval operations for warfighting requirements and capabilities (N9), to accelerate development of unmanned capabilities and long-range fires, Gilday wrote in a separate Oct. 1 memo outlining the details of Project Overmatch.

Kilby's assessment must include a metric for the Navy to measure progress and a strategy that appropriately funds each component. His initial plan is also due to Gilday in early December.

"Drive coherence to our plans with a long-term, sustainable [and] affordable view that extends far beyond the [Future Years Defense Program]," Gilday instructs.

The Army conducted the first experiment of a land-based anti-ship missile during a 2018 international maritime exercise at the Pacific Missile Range in Hawaii. The Raytheon-Kongsberg Naval Strike Missile struck a decommissioned ship 63 mi. north of Kauai.

U.S. ARMY

Team Tempest Seeks Path to Approval for Technology

> THE PROGRAM COULD GENERATE £25 BILLION FOR THE UK ECONOMY

> BAE SYSTEMS HAS BEGUN WORK ON REPRESENTATIVE TEMPEST FRONT FUSELAGE

Tony Osborne London

Advanced multifunction arrays that can be distributed around the fuselage of future combat aircraft are envisioned for the UK's Tempest Future Combat Air System.

Development of Leonardo's Multifunction Radio Frequency System (MFRFS) would likely complement—or could even replace—the traditional fire control radar in the nose of the fighter. Multiple high-power arrays are capable of performing passive tasks, such as electronic support measures, and active tasks, such as electronic attack as well as detection and imaging. The system would lean on the company's experience in developing active, electronically scanned arrays for the Eurofighter and Saab Gripen and distributed search radars, such as its Osprey sensor.

The radar and electronic warfare functions would be integrated into one system capable of collecting and making use of data from other platforms instead of being siloed into separate systems.

Details of the MFRFS sensor, subsystems of which Leonardo is testing at its Edinburgh, Scotland, facility, emerged as the main industry members of the Team Tempest consortium—BAE Systems, Leonardo, MBDA and Rolls-Royce—lifted the lid on some of the technology-maturation activities funded by the UK Defense Ministry's £2 billion ($2.6 billion) Future Combat Air System Technology Initiative (FCAS TI).

RAY TROLL/BAE SYSTEMS

These maturation activities will help support the business case for an acquisition program to be submitted in December.

But that is not the only hurdle. The initiative's supporters will also need to fight for its place in the government's upcoming Integrated Review of the nation's future foreign policy and defense posture.

The review, due to be published in November, is expected to call on the Defense Ministry to lean more heavily on the UK's industrial capacity, both to ensure supply security and to invest in new technology. Such initiatives would also support the British government's so-called leveling up agenda to create more jobs in regions such as Northern England (*AW&ST* Sept. 28-Oct. 11, p. 51).

The Team Tempest consortium hopes the initiative can tick all those boxes as it aims to retain the skills and capabilities to develop future combat aircraft and a range of additive capabilities to support them, including advanced weapons, sensors and unmanned systems.

Findings from an independent review of the program by auditors PwC suggest Tempest could inject £25 billion into the UK economy during the first 30 years and secure 20,000 jobs in 2026-50.

Those figures apply to the period of program development, production, entry into service and early support but do not include export opportunities, research and development investment or the value of the program beyond 2050.

Work on combat aircraft has provided a boost to UK prosperity. The UK's 15% share in the Lockheed Martin F-35 program is expected to net £35 billion over the life of the program, while its share in Typhoon has brought in another £28.2 billion.

BAE's factory of the future has begun producing a representative front fuselage based on the public Tempest design.

"The combat air sector has contributed on average 80% of defense exports, so it has been a very successful sector. . . . We intend to keep it that way," says Michael Christie, director of the future combat air systems acquisition program for BAE Systems.

FCAS TI work has already generated nearly 2,000 jobs, which will increase to 2,500 during the next 12 months and now involves about 600 companies nationwide.

Development of the MFRFS could enable a different approach to the Tempest platform's design. It would also appear to be scalable to the capability or budget of the customer. Leonardo says the system will produce gigabytes of data, requiring significant processing power and potentially artificial intelligence to help the pilot make the best use of that data. Flight trials of the sensor system are planned for 2023 using a Boeing 757 testbed platform to be provided by 2Excel Aviation.

Leonardo has already identified challenges with cooling associated with the onboard systems and sensors and is working with Rolls-Royce on a thermal management system that will take heat generated from them and pass it

LEONARDO UK

Leonardo's Multifunction Radio Frequency System would integrate radar, electronic warfare and electronic support systems, scooping up and processing electromagnetic data about the battlespace.

through to the engine, using it as a heat sink, recycling the waste thermal energy and removing the need for overboard venting, which could increase the platform's infrared signature.

Additionally, Rolls-Royce is exploring the use of additive manufacturing to enhance the combustion system of a future fighter engine, allowing it to operate at a higher temperature and increasing the powerplant's efficiency.

"This gives them choice to design into the combat air system," says Phillip Townley, director of future programs at Rolls-Royce. "You can go for greater range, greater time on station, or you can have a smaller design of your vehicle."

BAE Systems, having advanced the development of an augmented-reality cockpit, is now exploring a virtual assistant or co-pilot that will be able to take over elements of the pilot's responsibilities. How the assistant will be presented is yet to be determined, either through an avatar or via a social media-like information feed. But it could perform a variety of functions, including piloting the aircraft or controlling the additive capabilities.

One area of study is to monitor the pilot with psycho-physiological systems to detect when a pilot is being overloaded with tasks, then lessening that workload through the virtual assistant. BAE has also pressed its Warton, England, factory of the future facility into operation to build a representative front fuselage section based on the current public Tempest design. The process will use additive manufacturing, robotics and its cobotics systems, in which employees work hand in hand with robots (*AW&ST* Aug. 17-30, p. 31).

Tempest's business case—to be examined by the Defense Ministry's financial committee—will likely be buoyed by support from Sweden, which has proposed legislation to fund support of the UK FCAS efforts, following agreements the two countries signed in July 2019.

The legislation, part of a buildup of the Nordic country's defense posture, still requires parliamentary approval, with a vote planned in December. The Swedish efforts would initially support the development of upgrades for the Gripen before a future system is considered. The business case will inform whether the program can move into its next phase, with the aim of delivering a full business case submission in 2025 and then leading to full-scale development. The UK hopes to put the platform into service in 2035, replacing the Eurofighter.

Airbus Spain Pursues Jet Trainer Concept

- THE AFJT IS BEING PROPOSED TO REPLACE SPAIN'S SF-5 FLEET IN 2027-28
- THE PLATFORM COULD USE EUROJET'S EJ200 ENGINE OR SAFRAN'S M88

Tony Osborne London

Airbus in Spain has proposed a new advanced jet trainer that it hopes will be the European answer to the Boeing-Saab T-7 Red Hawk.

Although the company designed its Airbus Future Jet Trainer (AFJT) around Spanish requirements, it believes the AFJT could also meet an expected need for Europe's air forces, which continue to be largely reliant on platforms developed and built in the 1960s and 1970s—including the BAE Systems Hawk and Dassault Alpha Jet—and on the Northrop T-38 Talon while training in the U.S.

Airbus has been quietly developing the AFJT for three years. The original concepts looked at how to replace Spain's fleet of CASA C-101 Aviojets with an aircraft similar in performance to the Hawk. But when Madrid opted to replace the Aviojets with the Pilatus PC-21 turboprop last year, the focus shifted to replacing Spain's fleet of Northrop SF-5 Freedom Fighters, currently used for lead-in fighter training.

The AFJT features a configuration similar to the KAI T-50 and the Boeing-Saab T-7 Red Hawk.

The result is a clean-sheet, transonic-capable, single-engine design similar in configuration and size to both the T-7 and the Korea Aerospace Industries (KAI) T-50 Golden Eagle. Taking into consideration the AFJT's maximum take-off weight of about 7 metric tons, the development team is looking at either the Eurofighter's Eurojet EJ200 engine or the Dassault Rafale's Safran M88 as potential powerplants. Both would retain their afterburner modules.

The proposals easily could be written off as yet another jet trainer in an already crowded market. After all, along with the T-7, Turkish Aerospace Industries is developing its own T-50 look-alike in the form of the Hurjet, and Leonardo in Italy is advancing its M-345 and M-346 platforms. There also are questions about whether such platforms are really needed as synthetic technologies advance.

But the AFJT has already received Madrid's backing. The proposals are part of an agreement the government signed with Airbus at the end of July to maintain and, ultimately, strengthen the company's presence. Along with purchasing new tankers and maritime patrol aircraft, the Spanish government has agreed to fund studies for the AFJT (*AW&ST* Aug. 17-30, p. 32).

"Taking into account the return on investment for the money that Spain would put into this program and the money that is coming back, we think it is more cost-effective than going out to the market," says Abel Nin, head of the AFJT program at Airbus.

Airbus says the program would return a large part of the investment in the aircraft back into the Spanish economy through taxes and fiscal contributions. The company adds that the AFJT's development would help maintain skills and capabilities needed to support development of the Future Combat Air System (FCAS), in which Spain has an equal share with France and Germany. Madrid's support for the AFJT has yet to be budgeted, but Airbus believes it can meet the Spanish Air Force's target of replacing the SF-5 by 2028. The company plans to fly an AFJT prototype around 2025 and begin deliveries in 2027.

"This funding needs to be put into black and white," Nin says. "We have people working with the government to establish what will be the next steps. . . . We are preparing everything in advance to be ready for development."

Spanish requirements are for about 50 aircraft, says Raul Tena Martin, Airbus sales director for combat aircraft in Spain. But the potential is "far beyond Spain," he notes, with a market for 500-800 aircraft. France continues to use the Alpha Jet, while Finland is flying early-model Hawks. Germany owns its own fleet of T-38 Talons based in the U.S. but has yet to decide whether to replace them with the T-7.

Along with the advanced training mission, the aircraft, Nin says, could also perform as a red-air aggressor and even in the light attack role, with engineers leaving a space in the nose for the fitment of a radar.

Airbus sees the AFJT forming part of a wider training system that also includes training devices; support for live, virtual and constructive training; and the ability to download advanced training from frontline types currently in Spanish service such as the Eurofighter Typhoon and the McDonnell Douglas EF-18 Hornet. The aircraft could someday prepare crews for flying the FCAS, too.

"We are trying to be cost-conscious by thinking holistically," Nin says. "If you can create a well-connected aircraft, then you can also do more operations in the flight simulator."

Development of the AFJT would lean heavily on the Spanish supply chain: Compania Espanola de Sistemas Aeronauticos S.A. (CESA) could provide the landing gear and actuators, GMV would develop the flight control systems and software, Indra would supply the ground-based simulators, and Technobit would develop the communications and cockpit interface. Engine support could be provided through ITP Aero if the EJ200 is selected, since the company is a member of the Eurojet consortium that developed it.

Airbus envisions the use of a fly-by-wire flight control system as well as a wide-area display in the cockpit that could be adapted to show the cockpit layouts of other types to support training.

Japan Moves Ahead With Electromagnetic Warfare Aircraft

- THE FIRST RC-2 IS WITH A TACTICS-DEVELOPMENT UNIT
- REPLACEMENTS FOR C-1 JAMMERS AND EP-3s ARE ALSO WANTED

Bradley Perrett Sydney

The RC-2 is festooned with antenna fairings.

Simultaneous progress in three Japanese electromagnetic warfare aircraft programs does not look like a coincidence. They are moving together now that the navy and air force finally have access to two new types as replacements for models dating from the 1970s or earlier.

The most advanced of the three programs has produced a signals intelligence (sigint) version of a Kawasaki Heavy Industries (KHI) C-2 airlifter. Meanwhile, the defense ministry is asking for money to develop a standoff jammer, based on the C-2, and sigint equipment for what will almost certainly be the other type to be employed electromagnetically, the KHI P-1 maritime patroller.

KHI developed the P-1 and C-2 in parallel programs, and they share major structural elements. Deliveries of the P-2 began in 2013, and the C-2 in 2017. With both models in service in their original roles late last decade, the ministry moved to acquire their electromagnetic warfare versions—though it has sought information on alternatives.

The first sigint C-2, designated an RC-2 and converted from an airlifter prototype, moved to a tactics development unit on Oct. 1, bringing its new but undisclosed capabilities closer to operation. The jet will operate from Iruma Air Base near Tokyo.

It is probably not yet fully operational, since the Japan Air Self-Defense Force, announcing the handover, said the receiving unit is the Air Tactics Development Wing, which will test the aircraft and train on it. The RC-2 has already been subject to two years of testing, or evaluation, following its delivery by KHI to the air force's Air Development and Test Wing in 2018.

The aircraft features new "radio-wave measuring" equipment developed by Toshiba, the defense ministry told the Jiji news agency. As is usual in signals intelligence, no details were provided. Eight antenna fairings appear on the RC-2 (see illustration).

More RC-2s are evidently planned, because the defense ministry has asked for ¥7.1 billion ($67 million) for the acquisition of RC-2 electronic intelligence equipment in its budget request for the fiscal year beginning April 2021. There is no request for building another RC-2, however.

A total of four may be planned, since that is the number of YS-11EB electronic intelligence aircraft in air force service. The Japanese armed forces have a strong tendency to maintain numbers when replacing small groups of aircraft.

The new sigint aircraft, with the tail number 202, was the second C-2 prototype.

This program began long before a C-2 was available for conversion, maybe even before the C-2 type was chosen to carry the new system. Equipment development ran from fiscal 2004 to 2012, the ministry has previously said. Aircraft 202 was modified from fiscal 2013 to 2017.

Whatever the performance of the electronic systems on the RC-2, a step-up in performance is obvious from its ability to fly higher and accommodate more equipment and workstations. The C-2 has a service ceiling of 12,200 m (40,000 ft.), and the YS-11 turboprop airliner, on which the YS-11EB is based, 6,100 m. In both cases, drag from radomes would reduce heights somewhat. Greater height improves radio-frequency signal reception.

Whereas the YS-11 has a fuselage sized for two-plus-two seating, the C-2's is 4 m wide internally.

The difference in size is also expressed by the maximum takeoff weights: 120 metric tons for the C-2 and 24.5 metric tons for the YS-11. That makes the C-2 unusually large for a modern sigint aircraft—but quite comparable to the 133.6-metric-ton Boeing RC-135 Rivet Joint of the U.S. Air Force.

For the standoff jammer based on the C-2, the ministry is requesting ¥15.3 billion in development funding for the year beginning April 2021. This will also replace a much smaller aircraft, one based on the 39-metric-ton KHI C-1 airlifter. The C-2 is replacing the C-1 in the airlift role.

The P-1—smaller, higher-flying and already configured for workstations—may seem to be a more obvious basis for sigint or jamming aircraft than the C-2, but it is a navy type. The air force operates C-2s.

That is also one reason to expect the navy to choose the P-1 as the replacement for four Lockheed Martin EP-3 sigint aircraft. The ministry is requesting ¥5 billion to develop equipment for a new naval sigint aircraft. The ministry has previously investigated replacing five OP-3C optical observation aircraft; again, the P-1 would be the obvious candidate.

The defense ministry has ordered 15 C-2 airlifters since 2011, not counting the two prototypes. A total purchase of 22 is planned, according to the *Asahi* newspaper. Orders for P-1s have reached 36, against a requirement for 65.

Cargo Conversion Specialists See Strong Demand Despite COVID-19

- GROWING E-COMMERCE IS DRIVING AIR CARGO DEMAND
- AIR CARGO CAPACITY SQUEEZE IS SET TO UNDERPIN DEMAND FOR NEW FREIGHTERS AND CONVERSIONS

BOEING

Helen Massy-Beresford Paris

The COVID-19 pandemic has turned the air transport industry on its head. Travel restrictions are hampering recovery efforts on the passenger side, while demand is outstripping supply in the cargo sector. In this context, strong interest in converting passenger aircraft to freighters is set to continue.

Amid major upheaval for all operators, air cargo is faring better than the passenger category: In August, according to figures from the International Air Transport Association (IATA), global cargo demand was down 12.6% compared with a year earlier, a slight improvement on the 14.4% drop recorded in July.

The real problem for cargo operators is a lack of capacity. Global capacity measured in available cargo ton-kilometers was down 29.4% in August, and the 67% drop in belly capacity for international operations was only partially offset by a 28.1% increase in dedicated freighter capacity, according to IATA.

Daily widebody freighter utilization was close to 11 hr. per day, the highest levels since tracking of those figures began in 2012.

In its 2019 commercial market forecast, published pre-COVID-19, Boeing had predicted demand for 1,040 new widebody deliveries and 1,780 conversions over 20 years. In its latest update at the beginning of October, it scaled those numbers back—although it is still predicting a need for 930 production freighters and 1,500 passenger-to-freighter conversions during the 2020-39 period.

"Despite recent challenges, air cargo is forecasted to grow at an average annual compound rate of 4% in the next 20 years, led by the robust markets in East Asia and acceleration of e-commerce," the manufacturer said. "Acceleration of passenger-airplane retirements as a result of the pandemic will provide additional feedstock opportunities for freighter conversions. The freighter fleet will increase by more than half: from 2,010 airplanes in 2019 to 3,260 by 2039, representing 62% fleet growth over 20 years."

Michael Doellefeld, vice president of commercial services programs at Boeing Global Services, says demand for freighter conversions is still strong. "Even during COVID, we continue to see strong demand for both our 737-800 converted freighter as well as the widebody 767-300 converted freighter," he notes. "That demand has not subsided during COVID, and in fact we are taking steps even now to open up some new conversion lines to react to that growing customer demand."

Doellefeld says the company is seeing an uptick with orders from existing customers as well as interest from emerging customers.

The manufacturer is opening additional passenger-to-freighter conversion lines at Gameco in China for the 737-800BCF and at ST Aerospace Services Co. for the 767-300BCF.

"Those are [maintenance, repair and overhaul sites where] we have conversion production at today, but we are opening up additional capacity

Boeing still forecasts strong demand for freighter conversions, the coronavirus crisis notwithstanding.

for the growing demand we're seeing across our passenger-to-freighter offerings," Doellefeld says.

In September, Boeing secured another two 737-800 freighter conversions for an undisclosed customer, taking its total to 134 orders and commitments for the type. It has 51 orders and commitments for the 767.

"Both pre-COVID activity late last year and more recent orders and commitments this year were factored into those decisions as well as the longer-term outlook," Doellefeld says, referring to the additional capacity moves in China and Singapore. "We have confidence that growth will remain strong over a long-term of forecasted operation.

"We do expect demand for dedicated freighters to continue to grow," he adds. "And it's really being driven by increasing demand and expansions of express cargo markets and further developments in e-commerce, as well as the inherent demand of cargo itself."

According to the Aviation Week Network Fleet Discovery database, by Sept. 15, 221 passenger aircraft had been converted to freighters since the beginning of 2018.

In Europe, the Airbus passenger-to-freighter conversion specialist EFW says demand for the A320/A321 passenger-to-freighter conversion is "very strong" with conversion capacity booked out until the second quarter of 2022.

The company obtained FAA validation for the type back in February, based on existing approval from the European Union Aviation Safety Agency.

"As part of the regular plan, we will ramp up our production and have

started to qualify more and more conversion lines to satisfy this demand," says Thomas Centner, EFW's sales director of aircraft conversions.

EFW—based in Dresden, Germany—is focusing on ramping up its A321 and A330 passenger-to-freighter production capacity. Its secondary goal is to start A320 passenger-to-freighter prototype installations, a plan that was pushed back slightly in favor of escalating the A321 passenger-to-freighter activity more quickly than originally planned, Centner says.

According to Fleet Discovery data, EFW has converted two A330-300s so far this year.

EFW also attributes some of that demand growth to the growing e-commerce segment. While the COVID-19 pandemic has hit economies hard, with repercussions on spending power, on the flip side, lockdowns have also shifted retail behavior patterns toward increased online purchasing.

"COVID-19 has quickly accelerated online retail, and express demand grew in parallel," Centner says. "In addition, the corona crisis kicked a huge portion of belly hold capacity out of the market, and today freighter aircraft are much more in demand."

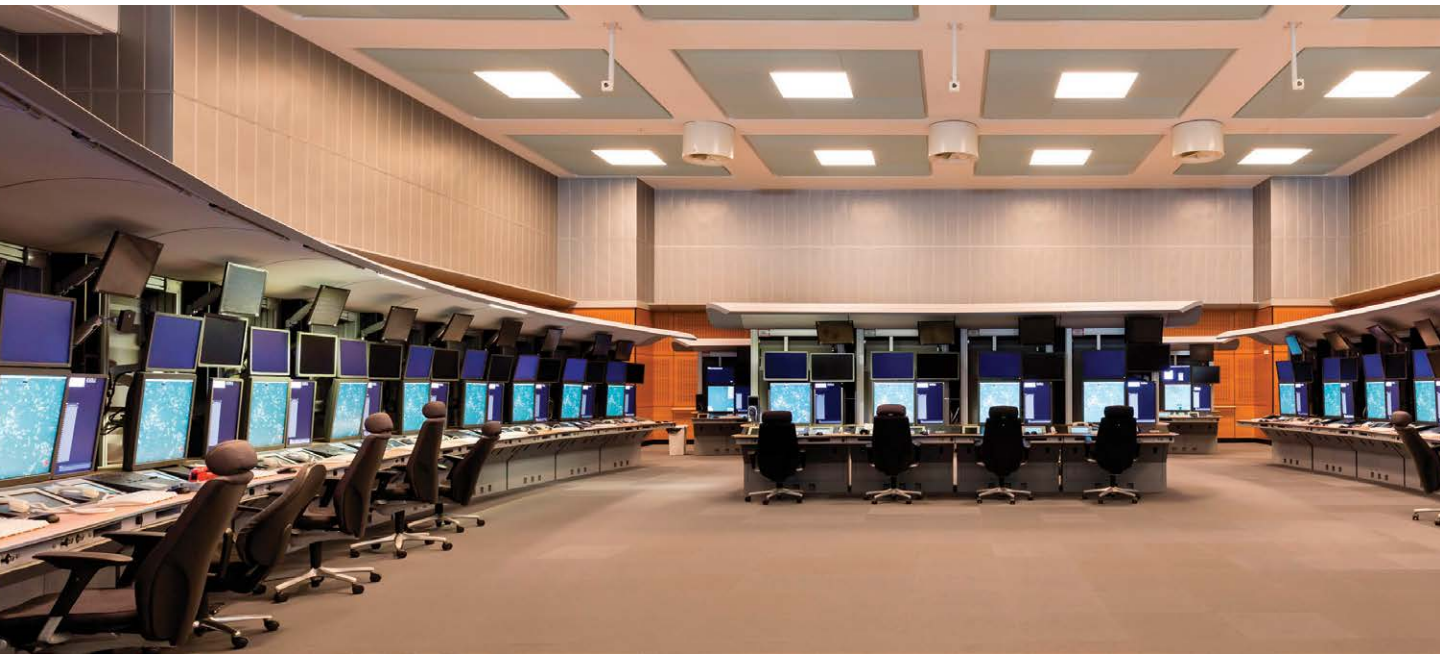
Israel Aerospace Industries (IAI) points to Chinese demand for freighters to fulfill the growing appetite for e-commerce. It delivered its first Boeing 737-700 passenger-to-freighter conversion to Tianjin Cargo Airlines in early October. The conversion took place at its Tianjin maintenance site through a partnership with the Haite Groupe. "With the rise of e-commerce and the resulting higher demand for cargo aircraft, together with the effects of the COVID-19 pandemic, cargo aircraft have become the lifeblood of the Chinese economy," IAI says.

"The corona crisis kicked a huge portion of belly hold capacity out of the market, and today freighter aircraft are much more in demand"

In addition to affecting day-to-day air cargo operations and demand for freighter aircraft, the COVID-19 crisis shows signs of creating a shift toward younger aircraft on average entering conversion programs, given the historically large numbers of parked passenger aircraft around the world, Centner believes.

"Lessors and combination carriers have started to rethink their strategies, and many will return to invest in conversions to balance their businesses better," Centner says. "Lower residual aircraft values make passenger-to-freighter conversion even more attractive as a sound investment opportunity."

Centner adds: "I'm convinced that one of the lessons learned from this crisis will be that operating freighters is essential for global logistics chains as well as essential for revenue balancing of airlines and asset management of lessors and investors."



Europe Presses Ahead With Modernizing Air Traffic Management

> INVESTMENT PLANS REMAIN STABLE DESPITE PANDEMIC CRISIS

> ENVIRONMENTAL PROGRESS TAKES PRIORITY OVER AIRSPACE CAPACITY

Thierry Dubois Lyon

The renovation of European air traffic management is progressing steadily—but with shifted priorities. The promoters of the Single European Sky Air Traffic Management Research project, supported by air navigation service providers, have managed to maintain budgets despite the COVID-19 crisis.

"Long-term plans are still there; a positive mindset has survived the crisis to keep the ball rolling," says Nicolas Warinsko, general manager of the Single European Sky Research (SESAR) Deployment Manager organization, which is in charge of implementing air traffic management (ATM) improvement plans.

When the crisis hit, 144 projects under SESAR's deployment framework—such as streamlining approach trajectories at a given major hub airport—had been put in place. That number then stopped increasing. "Late in August, we restarted counting—the total of 151 projects completed as of Sept. 30 was a good signal," Warinsko says.

SESAR includes 343 deployment projects, worth €2.9 billion ($3.4 billion). To keep up the momentum, faster distribution of the European Commission's €1.3 billion financial support is being discussed. After that, the next phase of the "Connecting Europe Facility" funding instrument will fill out new budgets for 2021-27.

The goal is to maintain stakeholder motivation. "We operate in a regulated environment; European law requires from stakeholders that they make a certain level of investment by a certain date," Warinsko says. "But the best way to incentivize them is to demonstrate their investment will bring end users and themselves benefits."

To that end, the SESAR Deployment Manager has created a performance database showing the rewards from completed projects, quantifying the results and accompanying forecasts.

Airspace capacity will be needed again at some point. But increasing capacity will not be an issue for the next 2-3 years, predicts Warinsko. Until 2023-24, depending on estimates, air traffic will be nowhere near 2019 levels.

The greening of aviation is taking priority. "If people resume flying, they will be more careful about their environmental footprint," Warinsko says.

When the coronavirus crisis started, the SESAR Deployment Manager was completing a revision of the Pilot Common Project, its regulatory framework. "We took the chance to fine-tune the final phase of the revision. We emphasized the goal of greener air transport," Warinsko says. In addition, more time was provided for project implementation, to keep programs in line with funding capacities.

Making commercial aviation more environmentally friendly also has been a growing concern recently at France's air navigation service provider, the Air Navigation Services Directorate (DSNA).

One of the first consequences of the pandemic was the urgent need for business continuity and recovery plans, says Philippe Barnola, the DSNA's deputy director for strategic planning. Air traffic control towers and en route centers still needed to be staffed, even with slower traffic, and the crisis also entailed health and safety measures.

Cash flow was another important consideration. Airlines were allowed to suspend navigation service fee payments. The DSNA had to request parliamentary approval to raise a loan. But critical system maintenance must be secured, Barnola points out. Nevertheless, the priority of creating greener aviation has been reinforced, he says: "There is a strong expecta-

THALES

New equipment in control centers should help implement concepts such as data link and free-route airspace.

tion that the recovery should be green."

In the DSNA's jurisdiction, free-route airspace, a concept under which flight crews choose their preferred routes in a relaxed framework, was to be first deployed at the Brest en route control center in 2022. "We are trying to bring this forward to 2021 to meet the demand for environmental performance," Barnola says.

Most of the DSNA's modernization plan takes place within SESAR's framework, he notes.

Moving in the same direction as free routes, toward more streamlined traffic, is the "PBN-to-ILS" project. Already in use—with further enhancements planned—at Paris Charles de Gaulle (CDG) Airport, it takes advantage of satellite guidance, also known as performance-based navigation (PBN), in lieu of the less accurate radar vectoring. The aircraft relies on satellite-aided positioning until it catches the instrument landing system's (ILS) guidance to the runway.

As a result, continuous descent approaches should become the norm at CDG by 2023. Live trials, involving real traffic, will begin early next year, Barnola says. PBN-to-ILS enables simultaneous approaches on a pair of runways, even if they are close to each other, which is the case at CDG. "Thanks to the greater accuracy of flightpaths, you no longer have to maintain a 1,000-ft. vertical separation," Barnola stresses.

Continuous descent approaches have a reduced noise footprint and also result in lower aircraft fuel burn.

Two other key technologies that can improve ATM at the Europe-wide level are data link (the transmission of data instead of voice communications between the crew and controllers) and automatic dependent surveillance-broadcast (ADS-B), where aircraft broadcast their position.

Data link, which connects aircraft to the ground, is a crucial piece of the full SESAR concept. "The use of data link is growing," Warinsko says. He credits his organization as having played a major role in accelerating data link system deployment since 2017, when the program was "in a bad shape."

However, neither the air nor the ground segments have reached full implementation. Some 75% of the target fleet has been equipped with data link systems, although the deadline was February 2020, Warinsko says. The target fleet excludes aircraft that fly below the affected airspace as well as those being phased out.

On the ground, at air traffic control centers, the data link implementation deadline was February 2018. Some countries, such as France, are lagging. That country poses a double problem because of its relatively large size and geographical position.

Of the five information regions covering France, three are not providing full data link service, Warinsko says. The delay is a consequence of the slow implementation of the 4-Flight information system for en route control centers, because data link is embedded in that system, he notes.

Supplied by Thales to the DSNA, 4-Flight is described as a new-generation stripless control system for high-density airspace. It is said to incorporate advanced flight data processing, an augmented user interface and an advanced simulation environment.

Barnola contends that 4-Flight and data link are independent but acknowledges the delay. Data link will be deployed in the remaining three centers next year, as per a catch-up plan agreed on in 2018 with the European Commission, he says.

Warinsko was happy to see the DSNA's positive reaction to that plan. He says the SESAR Deployment Manager is supporting the DSNA but insists full data link capability is needed by the summer of 2021. The difference of opinion is real but small and seems to be resolving, a common situation in EU projects the past few years.

As for ADS-B, 80% of the target fleet is now equipped. "Airlines were reluctant to invest because they were uncertain about the ground segment," Warinsko says. Just as with data link, he believes the SESAR Deployment Manager has successfully put the process back on track.

Warinsko's team has also discovered a wider issue. A number of air navigation service providers continue to invest in older technologies, typically mode-S radars. Such expenses may be detrimental to ADS-B expansion. But ADS-B brings more benefits than a mode-S radar network, at a lower cost and with a greater population of aircraft served, Warinsko contends.

If older ground equipment has to be maintained for particular users such as the military or light aviation, the question of whether they should pay for it is relevant, he says.

A positive effect of the slow traffic due to the pandemic is that it frees up time for controller training. The DSNA has cleverly seized the opportunity for SESAR and national-level projects, says Michel Coz Elleouet, a board member at French air traffic controller union SNCTA. "4-Flight and PBN-to-ILS each require 10 days of instruction per controller," he says.

The DSNA seems to be avoiding the recruitment mistakes it made in the late 2000s, when it cut hiring plans. At the time, a downturn translated into a need for fewer air traffic controllers over the coming years, and the DSNA accordingly reduced its training capacities.

That approach proved shortsighted. "In 2016-18, we found ourselves with a dearth of controllers," Coz Elleouet says. France's ATM capacity could not keep up with air traffic growth, causing flight delays and therefore carrier and passenger exasperation.

This time, the DSNA is betting on traffic recovery and is well aware it will have to offer enough capacity to airlines, Coz Elleouet says. Hiring plans for 2020 have not been changed, so an annual budget to start a five-year training program for 100 controllers is pivotal.

The investment is all the more important as a wave of retirements is to begin in 2028, Coz Elleouet says.

FAA Envisions Interwoven, Distinct Airspace Layers

> UAM OPERATIONAL ASSUMPTIONS DESCRIBED

> THIRD-PARTY COMPANIES WILL PROVIDE SERVICES

Bill Carey Washington

The traffic management constructs forming around small drones and future urban air mobility vehicles are coming into clearer focus, but they reside at slightly different stages of development that point to distinct but interwoven layers of airspace.

In the ever-growing lexicon of aviation acronyms, constructs for unmanned aircraft systems (UAS), UAS traffic management (UTM) and urban air mobility (UAM)—which is now commonly wrapped into the broader definition of advanced air mobility (AAM)—share common attributes.

This artist's rendering depicts an Advanced Air Mobility airspace environment, with drone traffic below.

NASA

Both rely on the digitalization of processes and platforms, data sharing and automated flight planning and execution.

Both constructs are federated systems involving multiple actors. The traditional arbiters of air traffic management (ATM)—air navigation service providers (ANSP) that are either owned by a government, shared by a government or act on its behalf—will likely delegate to third-party, corporate technology providers the responsibility for delivering flight planning services and authorizations to pilots and operators.

The assumed line of demarcation between UTM and UAM/AAM is 400 ft. above ground level (AGL). Below that altitude, UAS service suppliers (USS) will interact with drone operators to provide flight planning, airspace authorization, traffic deconfliction and other services. Above that altitude, providers of services for UAM (PSU) will engage with larger manned, and eventually unmanned, aircraft flying in defined corridors between airports, vertiports and short runways.

Given that a cohort of drone-software platform, ATM and telecommunications companies has emerged to support the development of UTM, the older of the two constructs, the question arises: Could a USS also be a PSU, and vice versa? "Yes," FAA Chief Scientist Steve Bradford said at a recent conference. "But we named them differently because we believe that the information requirements and the performance may vary between operations below 400 ft. and operations in corridors or UAM/AAM airspace."

The FAA released the first version of a UAM concept of operations (conops) document in June. Bradford briefed viewers on the notional architecture during the Association of Unmanned Vehicle Systems International's Xponential conference, held virtually in early October.

Similar to UTM, UAM will be a "community-based," federated system populated by vehicle operators and PSUs, with the FAA providing regulatory oversight. Unlike UTM, passenger- and cargo-carrying UAM/AAM vehicles will stay within airspace corridors; these initially will build on customary general aviation and helicopter routes.

Based on industry projections, Bradford assumes a 10-year transition period that begins with UAM vehicles controlled by pilots, who remain capable of communicating with traditional air traffic control (ATC) while flying within corridors, and evolves to autonomous vehicles.

"There will have to be demand-capacity balancing applied where necessary," he said. "We would expect that to be a product of community-based rules, which we will approve. But for this to work, the FAA can't be directly involved operationally."

Access to UAM corridors will be based on the aircraft

meeting performance requirements that may change based on the tempo of operations and demand for the airspace. Operators will stay safely separated through "shared flight intent for strategic deconfliction, shared situational awareness" and consensus procedures, Bradford noted.

"We reserve the right to increase individual aircraft operational performance requirements in order to optimize the capacity utilization of the airspace structure," he said. "If the demand goes up, we may require only those vehicles that can meet a certain level of navigation performance or intent-sharing to be able to fly in those corridors at a certain time of day. It's not equitable to have the lowest-common-denominator vehicle taking up a lot of airspace and moving very slowly in a place of high demand."

Bradford added: "If UAM operations reach a peak where the community-based demand/capacity balancing no longer works, then we always reserve the right to get back into the picture. That's a promise, not a threat."

Participation in the UAM corridors will be voluntary, but departing from them will subject operators to the requirements of the ATC system, said Bradford. "The difference between continuous access and on-demand access is [that] for those vehicles operating within the UAM construct, within the corridors, we don't need to have constant [position] updates because we are not providing services," he said. "We will need information if you depart the corridor and go into ATC."

PSUs will be able to obtain flight information on drones operating below the corridors by connecting to the USS network and vice versa.

The FAA released the first version of a UTM conops document in 2018, followed by a 2.0 version this March. During a World ATM Congress virtual panel discussion Oct. 13, Jay Merkle, executive director of the FAA's UAS integration office, described the agency's next planned steps to implement the low-altitude construct.

The UTM effort is focused now on introducing flights beyond visual line of sight of a drone operator, below 400 ft. AGL, said Merkle. Airspace designers will also flesh out the role of public-safety operators in the construct and the need to protect sensitive military and homeland security facilities from unauthorized drones.

"We're closing the concept time," he said. "We're moving toward the details of implementation that we need to start putting in place."

A common theme that unites UTM and UAM is that the FAA does not want to be directly involved in managing flights.

"We in the United States do expect a federated approach where the ANSP will not be providing the majority of the services directly to the aircraft owner-operator," said Merkle. "We want to govern as little as possible, to encourage as much innovation as we can while maintaining aviation safety and airspace security."

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READY TO ROC

> STRATOLAUNCH AIMS TO RESTART FLIGHT TESTS IN EARLY 2021

> MODULAR HYPERSONIC PAYLOAD PYLON DEVELOPMENT IS UNDERWAY

Guy Norris Los Angeles

Despite its enormous size, the six-engine Stratolaunch carrier aircraft has remained largely hidden from sight since its debut flight in April 2019. But that's about to change as its Mojave, California-based developers prepare to roll the behemoth back into the open in readiness for an intense flight test and operational clearance campaign targeting service entry in 2022.

Distinguished by its twin fuselages and enormous 385-ft. wingspan, the carrier aircraft—nicknamed the Roc—is being developed as a rapid response, cost-effective launch platform for testing hypersonic vehicles and missile systems. Originally designed as a mothership for air-launching space-launch vehicles, the project's pivot in 2018 toward a high-speed test role has put the Roc in the right place at the right time for the emerging revolution in hypersonics.

"We really do think of the carrier aircraft as a national asset, and we've had a wide variety of interest in it, whether it's government or commercial customers, because we can provide a capability that really is unique," says Stratolaunch Chief Operating Officer Zachary Krevor. "No one can match the combination of payload, volume and overall performance of this carrier aircraft. Not only are we going to be using the carrier aircraft for our missions, but the aircraft is something that will be used for our country's national needs."

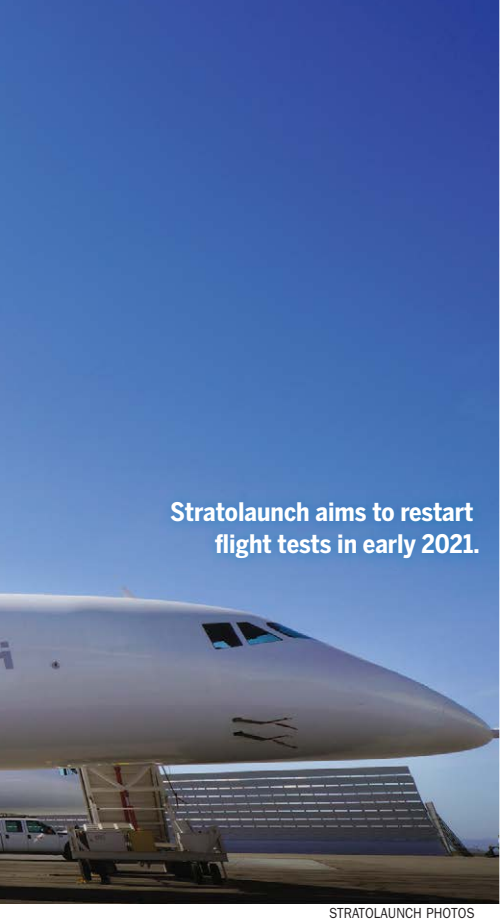
The accelerating test effort marks a major rebound for Stratolaunch, which only last year was facing an uncertain future in the months following the death in October 2018 of the project's original co-founder, billionaire philanthropist Paul Allen. Reinvigorated following its acquisition by Cerberus Capital Management in late 2019, the company is on track to restart the flight-test campaign early next year.

"The goal is to get back into the air in the first quarter of 2021 with our initial set of flight tests," Krevor says, speaking exclusively to Aviation Week about the test plan and ongoing modifications to the Roc prior to resuming flights. "Then we'll analyze the data and make some refinements based on what we learned from the flight tests. Then we'll just continue to increase the pace and cadence to get through our flight testing, leading to operational missions in the first quarter of 2022."

Envelope expansion will continue from where it left off in 2019, when the aircraft reached a speed of 165 kt. and a maximum altitude of 17,000 ft. over the course of its 2.5-hr. first flight over the Mojave Desert. "We'll go through a typical flight-test approach in terms of expanding altitudes and speed and continue to add in more complexity," Krevor says.

For the moment Stratolaunch remains coy about some aspects of the expected limits of the flight envelope, particularly the operational altitudes for launching payloads. However, given the aircraft's maximum payload limit of around 545,000 lb. and the performance of its six Pratt & Whitney PW4056 engines, the operational ceiling for most missions is widely expected to be in the 30,000-35,000-ft.-altitude range. "We can't provide the exact release altitudes due to the proprietary nature of our customers. But we can say the carrier aircraft can reach altitudes and fly generally just like a [Boeing] 747-400, as we are using the same engines," Krevor says.

Early test flights will also include gear retraction. "On our first flight, the gear was pinned [fixed in extended position]," Krevor says. The aircraft



Stratolaunch aims to restart flight tests in early 2021.

STRATOLAUNCH PHOTOS

has 28 wheels, all of which are recycled from a pair of 747-400s cannibalized for the construction of the Roc. The bulk of these are arranged longitudinally in three main landing gear bays built into the midsection of each of the aircraft's 238-ft.-long fuselage booms. Each boom has three sets of four-wheel 747 main-body gear assemblies and a two-wheel 747 nose gear, for a total of 14 wheels per fuselage.

Other changes for the upcoming flight-test campaign are principally minor changes to areas such as the cabin pressurization, flight control and fuel systems, says Stratolaunch Chief Engineer Scott Schultz. "We flew with an unpressurized cabin for the first flight and had the crew on oxygen as a mitigation for safety. We didn't have the pressurization system ready at the time, so recently we have had the aircraft outside for cabin pressure tests," he says. "That's a step to get it into its final long-term configuration for mission operations."

Although the forward section of both fuselages will be pressurized, only the right boom contains the crew, which occupy a cockpit with places for two pilots and a flight engineer. A composite pressure bulkhead separates the cockpit from the remainder of the vehicle, which is unpressurized. The forward section of the opposite fuselage, which will not be occupied, will house systems related to the test payload. As these include the option for both solid- and liquid-fueled rocket-boosted vehicles, they will include cryogenic, compressed air, avionics and other systems. Storage space for up to 2,500 lb. of mission-specific support equipment is available in each fuselage.

"We're also making a fair amount of modifications to the flight control system," Schultz says. "Obviously, the flight controls were fine for first flight, but we're doing a lot of fine-tuning for flight control 'feel' and for crew displays that will set us up for the operational airplane. During the flight, we learned it handled significantly better in a couple aspects than we thought and close to where we thought it was going to handle in other aspects."

Although declining to offer more specifics, Schultz says: "We have done a lot of simulator work and really paid a lot of attention to large-aircraft handling qualities. And one of the factors was how the airplane feels to the pilots. So in a couple of the axes, we found that the feel was better than expected in flight. It's just another reason why we really valued [doing] that flight test."

Flight controls consist of 12 cable-driven ailerons powered by 747 hydraulic actuators, plus split rudders and conventionally configured horizontal stabilizers on the twin tail units. The wing trailing edge supports 14 electrically signaled, hydraulically actuated split flaps that also pivot down to act as air brakes. Like the engines and landing gear, the hydraulic system and actuators, along with the electrical system, avionics, pilot controls and flight deck, are also from the donor 747s. Stratolaunch says around 250,000 lb. of the aircraft's full-up takeoff weight of 1.3 million lb. consists of 747 components.

"One thing that's really important about our design philosophy is to make sure that we are applying the appropriate margins to our vehicle. In terms of the flight controls, we found that those margins were actually pretty conservative, and in those large handling maneuvers we were able to maneuver the aircraft a little bit better than our conservative approach," Krevor says.

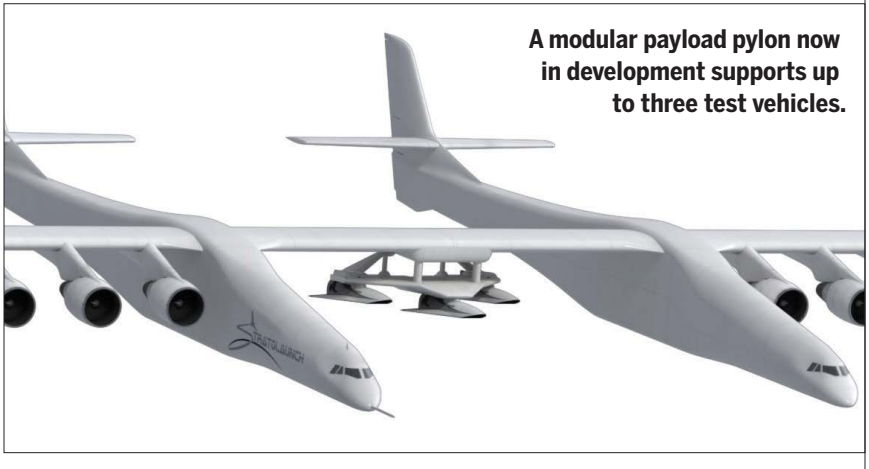
"Right now, it's a conventionally boosted system, but those are some of the upgrades that we're working through," he adds. "It's really all about getting ready for the operational mission such that we can get a little more precision and be ready to release hypersonic vehicles for their flight test. It's really important to our customers that we're hitting their conditions with some pretty tight tolerances.

"You'll see us out again in the future for some fuel system testing," Schultz adds. "We've made a laundry list of fuel system upgrades. The system actually worked really well on the first flight, but we're making a few updates

An orange ball on the 747-derived flight deck aids quick visual situational awareness for the ground control room.

to let, us get into missions a little bit better." The composite wing incorporates six main and two auxiliary fuel tanks, with each of the main tanks located in the inboard section adjacent to an engine. The auxiliary tanks are housed in the outer section of the inboard wing where the load-carrying structure meets the fuselage.

"One of the major things that we're also working on right now is the pylon adapter to hold our launch vehicles," Schultz says. "The team is relishing getting into some detail design of a new clean-sheet pylon design for hypersonic vehicle missions." The modular pylon is designed to mount up to the primary hardpoints in the main center section, which is made up of four continuous primary composite spars supported by four secondary spars.



STRATOLAUNCH

A modular payload pylon now in development supports up to three test vehicles.

"It's a universal-mount wing, if you will. So that means this significant structure in the carrier center wing enables you to bolt pylons on and off," Schultz says. "You can roll the aircraft into the hangar and spend a few days to swap a pylon onto a completely different vehicle with different shapes and features and go fly a different mission with fairly quick turnaround."

The pylon will connect to the wing at five primary titanium attachment points: two each forward and aft, and a fifth centrally located to handle lateral loads. The flexible pylon design enables testing of either Stratolaunch's purpose-developed Talon-A hypersonic testbed or flight systems—both hypersonic or nonhypersonic—provided by other suppliers.

Up to three Talon-A vehicles can be carried on one flight with the current pylon design, says Stratolaunch, which announced new details of the testbed in April. Derived from the Hyper-A concept unveiled two years ago, the Talon-A is a fully reusable, autonomous, liquid-rocket-powered vehicle targeted at flight speeds up to Mach 6. Measuring 28 ft. in length with an 11.3-ft.-span delta wing, the Talon-A is configured with a single vertical tail fin and will have a launch weight of around 6,000 lb. The vehicle will be capable of recovering for an autonomous horizontal landing as well as taking off horizontally under its own power.

A follow-on Talon-Z version is also in design; it will target faster test conditions up to Mach 10. Weighing up to 65,000 lb., the larger vehicle will offer longer-duration flights that could see the vehicle boost to 500,000 ft. altitude and cover ranges up to about 800 nm. Both vehicles will carry both internal and external payloads. Talon-A, for which Stratolaunch has contracted engineering company Draper for flight software, will support bolt-on propulsion or flow-path experiments as well fin-like structures for boundary layer transition experiments. Beyond the Talon testbeds, Stratolaunch ultimately aims to develop its longer-term Black Ice spaceplane project, which could provide an air-launched reusable space shuttle-like capability to orbit.

Flight testing will be based largely in the R2508 restricted airspace block around Mojave, Edwards AFB and the nearby Naval Air Weapons Station China Lake range. Buildup work will include captive-carriage flights of simulated vehicles, plus release of payloads in the hangar to test launch mechanisms as well as air drops of inert loads.

Krevor says the Roc may be operationally more flexible than first thought. "We see already that, based on the first flight and how the vehicle performed, we'll be able to remove some of the constraints," he says. "We want to make sure that this aircraft can turn around and complete the operational missions quickly. So we're trying to be able to turn around missions and complete missions at least on a weekly basis, and certainly we want to fly the aircraft on a daily basis."

Could some of this high tempo be linked to supporting the U.S. Air Force's planned hypersonic weapons flight-test campaign, based at nearby Edwards AFB? "We don't want to necessarily try to encroach on any of the great capabilities of [the Air Force] B-52, but we want to augment it because we see the same thing. The Defense Department's budget, specifically for hypersonic flight testing, is going out tremendously," Krevor says. "So we just want Stratolaunch to be seen as a national asset, as we do, and for it to augment the B-52 as that schedule starts to become constrained." The Pentagon plans to conduct 40 flight tests over the next four years on several prototypes of hypersonic missiles now in development.

Stratolaunch has also responded to the Air Force Research Laboratory's (AFRL) recent request for information on a proposed Mayhem demonstrator vehicle for a hypersonic, air-breathing propulsion system.

"We think we can provide a lot of interesting capability to AFRL, and we actually think it's right up our alley," Krevor says. "The AFRL has asked for a vehicle at about the Talon-A's size and has asked to bring aboard air-breathing capability, which fits perfectly under the belly of our vehicle. We look forward to working with the AFRL to try to provide them a solution that we think aligns with our path already.

"We are trying to get to market quickly with our operational product, which involves both the Talon and the carrier aircraft," Krevor says. "So we've been trying to optimize the schedules of the carrier aircraft and the Talon and when those will be ready together in concert." Although he acknowledges that the COVID-19 pandemic has caused delays, he adds: "I wouldn't say it has upset our overall schedule, which is getting an operational product to market in 2022."

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Chinese Moonshot Proposal Relies on New Rocket

- SCHEME INCLUDES A SPACE STATION AND MOBILE LABORATORY
- NGMLV ADVANTAGES INCLUDE RELIABILITY AND SAFETY

Bradley Perrett Sydney

China is developing a multishot plan for a manned Moon landing that would feature docking in lunar orbit and a low-risk launcher based on current technology. The rocket, previously revealed as a concept but now confirmed as the focus of a contemplated mission plan, would have half the launch capability of the full-scale Moon rocket that the country also is working on.

A vague description of the mission plan in state media implies that a landing will require flights by several launchers of the new type, provisionally called the New-Generation Manned Launch Vehicle (NGMLV). The spacecraft and other equipment they hurl toward the Moon would join up in orbit there. Not spelled out is the role of the bigger rocket, the Long March 9, which would be comparable to the Apollo program's Saturn V.

BRADLEY PERRETT/AW&ST

A 63%-scale test specimen of the capsule of China's new manned spacecraft.

Although Chinese engineers have for years been studying and accumulating technology for a manned mission to the Moon, the government has not yet authorized the program. And there is no confirmation that the multishot mission configuration is the one that will be finally recommended.

"During studies, China has proposed a lunar-orbit docking mode that would be based on the NGMLV," Zhou Yanfei, deputy chief designer of the manned space program, said at a conference. "The studies of this flight mode include the NGMLV, a new-generation manned spacecraft, a lunar lander, a space station in lunar orbit and a manned mobile laboratory on the Moon's surface."

Zhou's remarks, made at the China Space Conference in Fuzhou on Sept. 18, were carried by the government's China News Service.

He divided the technological objectives into these categories: landing, traveling between the Earth and the Moon, living on the Moon, and exploration integrating people and machines. The program also aims to build a lunar science station and to carry out continuous investigations and experiments in exploring the development and utilization of resources.

An intention to use several launches to set up a landing is implied by Zhou's reference to docking in lunar orbit and, decisively, by the limited capability of the NGMLV.

The launcher first appeared at Airshow China in Zhuhai in 2018 in the form of a large model displayed by its intended developer and manufacturer, state space contractor Casc. The concept was obviously serious but, like many others, could have soon been dropped, replaced by a new idea. Instead, it is now a key part of a published mission configuration.

Zhou told the China Space Conference that the NGMLV's liftoff weight would be 2,000 metric tons and the height 90 m (300 ft.). It could be launched from the Wenchang base on Hainan, he added. There is no mention of recovering and reusing the core first stage and the boosters.

He also confirmed details that Casc officials gave to Aviation Week at the 2018 show: a modular design using 5-m-dia. elements and an ability to throw 25 metric tons to translunar injection (TLI) or 70 metric tons to a low-altitude, low-inclination Earth orbit (LEO) (*AW&ST* Nov. 12-25, 2018, p. 20).

That capability is not enough for a single-shot Moon landing, as demonstrated by the specifications for the Saturn V: The Apollo launcher eventually could push 49 metric tons to TLI. The Long March 9, as outlined in 2018, will be similarly capable, hurling 50 tons to TLI.

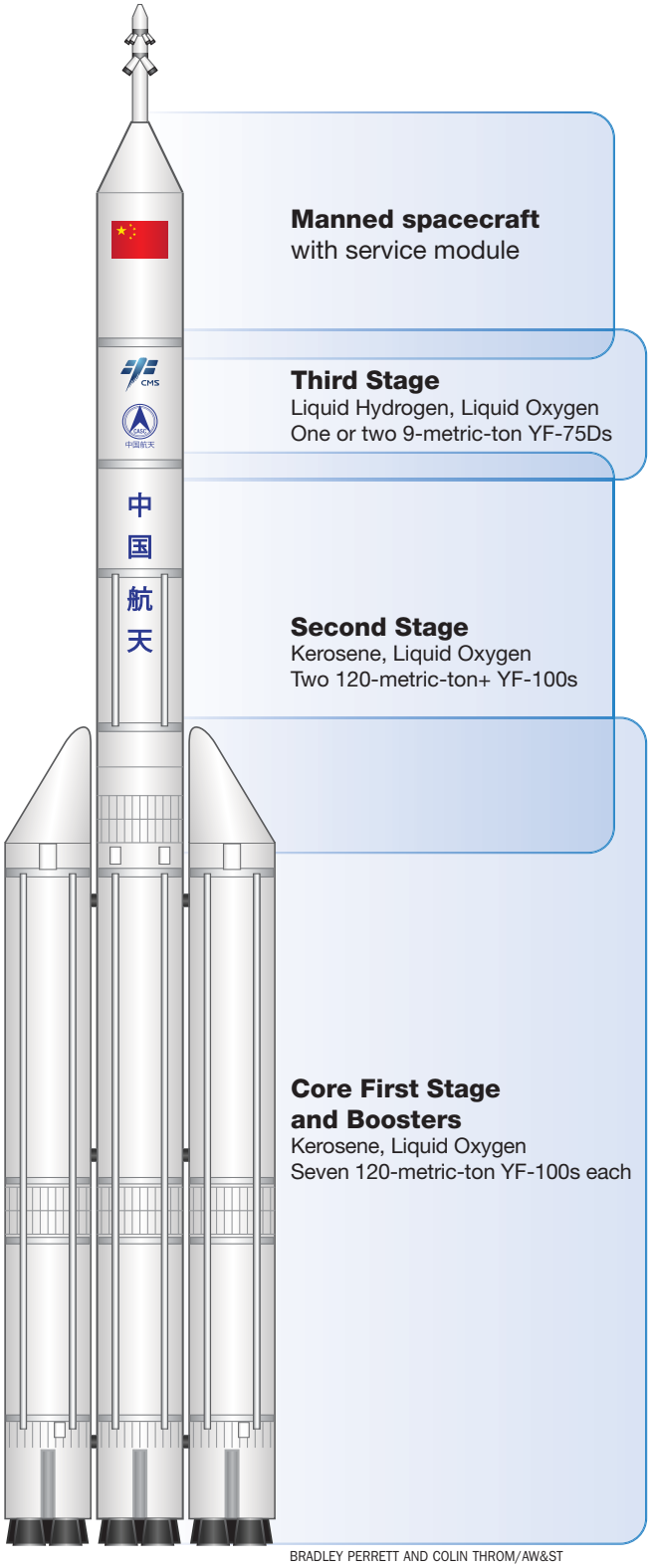
Zhou said the new launcher will be able to carry a manned spacecraft and a lander—though China News Service did not quote him saying the rocket could carry both at the same time.

A new Chinese manned spacecraft will have a mass of 20 metric tons when fitted with a large service model for lunar missions, Chinese media have reported. In addition, the Chinese manned-lunar plan includes a space station in lunar orbit and the lander. Details about them are lacking, but the two-person lander of the Apollo program had a loaded weight of around 15 metric tons. All that totals too much for just one NGMLV.

Furthermore, China may be planning a larger lander than Apollo's. A Chinese lander engine described at a conference in 2017 had a maximum thrust of 80 kN (18,000 lb.), compared with the 45 kN available to the Apollo lander, implying greater mass. This year, sources said China had approached engineers in Ukraine for help in developing an 80-kN lander engine (*AW&ST* March 9-22, p. 36). For comparison, the abortive NASA Altair lander was to have had an 83-kN engine and a 37-metric-ton mass on descent.

But the big Chinese engine may be needed only to land the laboratory—and for moving it about the lunar surface, since Zhou said it will be mobile. Astronauts could use a simpler craft for traveling between the laboratory and the

New-Generation Manned Launch Vehicle



BRADLEY PERRETT AND COLIN THROM/AW&ST

space station. Also at the 2017 conference, Casc's spacecraft subsidiary, Cast, showed a concept for a 5-metric-ton lander that would be unsuitable for habitation but would be reusable; in effect, it was a simple shuttle, its passengers wearing space-walk gear during the ride. Notably, the mass of that little lander plus the new Chinese spacecraft would be just right for the NGMLV.

Still, a second NGMLV launch would be needed for the space station. If its design is based on the modules to be assembled for China's planned space station for LEO, its weight would approximately match the NGMLV's TLI capability.

This leaves the question of what the Long March 9 would be used for. A likely answer is that it would be needed to deploy the surface laboratory if that element of the program has a mass exceeding 25 metric tons—as indeed the lander-engine research suggests.

Plans for this 4,000-metric-ton monster rocket have not been dropped. Eminent Chinese rocket designer Long Lehao mentioned at the same September conference that it would be developed. Its first flight, subject to approval for full-scale development, has been scheduled for around 2030.

In 2017, Casc outlined a multishot scheme for a more modest lunar mission. The first two launches would be performed by an unidentified rocket type, bigger than any that China then had or now has; one would send a conventionally large lander straight to lunar orbit, and the other would place its upper stage with unexpended fuel in Earth orbit. A Long March 7 would be used for the third shot, lifting a manned spacecraft to dock in LEO with the unexhausted upper stage, which would push it to the Moon. This scheme did not include a space station or surface laboratory.

As for the NGMLV, Zhou emphasized the reliability and safety offered by its use of established technology. Its design amalgamates features from the Long March 5, 6 and 7, a family of launchers that China began putting into service in 2015. Established technology and a modular design should also make the NGMLV more economical than the Long March 9 and probably available earlier.

The diameter of the NGMLV's three core stages and two side-mounted boosters is 5 m, which is the dimension of the core of the Long March 5. So fabrication equipment for that earlier rocket could be used. As described in 2018, the NGMLV's first stage and boosters would be powered by YF-100 kerosene-burning engines; thrust at liftoff would be 2,520 metric tons (see graphic). The YF-100 is used for liftoff by the Long March 5, 6 and 7. The NGMLV's second stage would use the same engine model, and the third would mount engines of the hydrogen-burning YF-75 type, which also is used by the Long March 5.

Use of kerosene in the second stage of the NGMLV varies from the formula of the Saturn V and, according to a 2017 presentation, the Long March 9. The second and third stages of those unidentified rocket types burn hydrogen, which offers high energy per unit of mass.

The NGMLV is in the class of the SpaceX Falcon Heavy, a reusable, all-kerosene launcher with only two stages plus boosters that can hurl 64 metric tons to LEO in fully expendable mode.

—With Anatoly Zak in New York

ISS TURNS 20

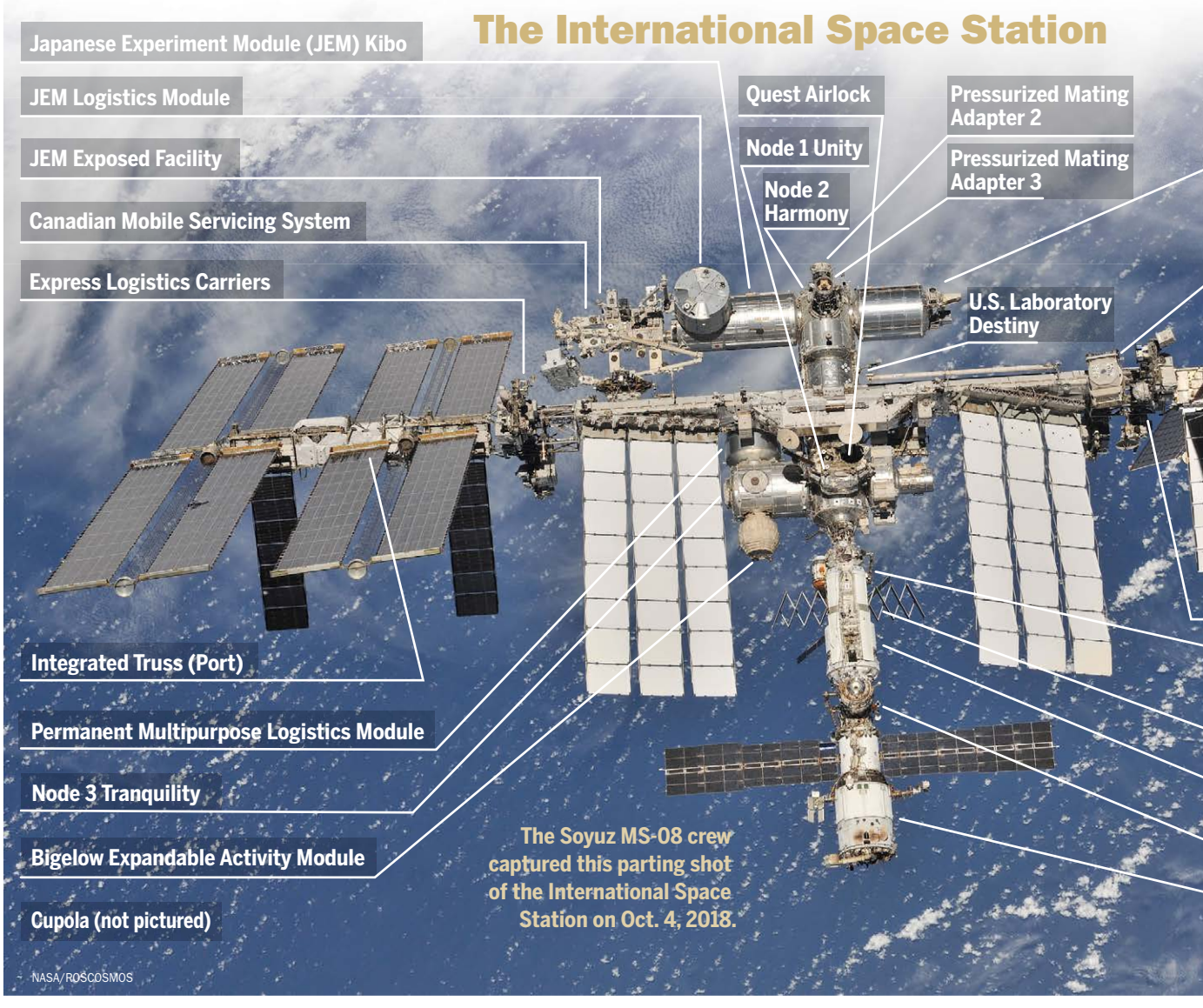
- BUSINESSES ARE TESTING LEO WATERS
- ISS IS THE MODEL FOR FUTURE JOINT MISSIONS

Irene Klotz Cape Canaveral

It is not just the length of time that humans have been continuously living and working in space that is impressive, though 20 years is a milestone in and of itself, but also how the 15 nations in the International Space Station program have maintained a partnership that thrives despite national and international strife.

It began with technical and operational standards, allowing hardware that had never been in contact on Earth to connect and function together upon reaching low Earth orbit (LEO). NASA is now looking to extend those standards for programs and partnerships beyond LEO under the Artemis program, which aims to return astronauts to the Moon as a precursor to human missions to Mars (*AW&ST* Nov. 12-25, 2018, p. 30).

"In the early days of ISS design and assembly, everyone was just incredibly nervous," recalls John Mulholland, who



now serves as ISS program manager for lead contractor Boeing. "One of the biggest risks was: 'Are we going to be able to assemble all of these [modules] on orbit and have everything work the first time successfully?'

"The space shuttle program had put a lot of plans in place to be able to return a module and then fly it back. We never had to do that," he adds. "Looking back, [the ISS] was just an incredible engineering achievement, probably the most incredible engineering achievement of our lifetime."

The station's base block, a Russian-built, U.S.-owned propellant module named Zarya—Russian for "dawn"—was launched into orbit on Nov. 20, 1998. The first of what would become 37 U.S. space shuttle assembly missions followed in December to attach connecting Node 1, Unity.

Delays building the third component, Russia's Zvezda service module, which was needed for early crew habitation, put construction of the outpost on hold for two years. Zvezda (Russian for "star") finally reached orbit on July 12, 2000, and docked with Zarya on July 25, kicking off a decade of assembly and outfitting missions by the U.S. and Russia.

The first crew, Expedition 1—NASA astronaut William Shepherd and Russian cosmonauts Sergei Krikalev and Yuri Gidzenko—lifted off aboard a Russian Soyuz rocket on Oct. 31, 2000, and reached the fledgling station two days later. The orbital outpost, now about the size of a six-bedroom house, has been permanently staffed by rotating crews of astronauts and cosmonauts ever since.

"The demonstration that nations can come together and pull off something magnificent and sustain it for 20 years is probably the most significant achievement of the International Space Station," NASA Administrator Jim Bridenstine tells Aviation Week. "It is definitely a marvel of technology, but I think it's also a marvel of diplomatic power, not just for the United States but for all of the partners that are involved in it. It really shows that when we all collaborate we can do things that have sustainability and durability."

After a 10-year hiatus, the U.S. and Russia are again preparing to add modules to the ISS, though the U.S. facilities will be owned and operated not by NASA but by private companies. Nanoracks, which broke into the LEO services business by integrating experiments and launching cubesats from the ISS, is preparing for the November launch of its Bishop Airlock, which will become the first U.S. commercial module permanently attached to the station. (The Bigelow Aerospace-owned Bigelow Expandable Activity Module, known as BEAM, joined the ISS in 2016 as a technology demonstration, not a commercially operated facility.)

Bishop is to be followed in 2024 by a module owned by Axiom Space, which intends to parlay a $140 million contract with NASA for docking rights at the Harmony Node 2 forward port into a privately owned (and eventually free-flying) commercially operated platform in LEO.

Meanwhile, Russia's Roscosmos State Corp. for Space Activities is preparing for a May 2021 launch of the

The ISS Through the Years

On Nov. 2, NASA and its 14 international partners mark 20 years of continuous human presence aboard the International Space Station (ISS). Here are some of the key milestones along the way.


PRESIDENT REAGAN FOUNDATION

1984 Jan. 24 | President Ronald Reagan announces midway through his third State of the Union Address: "America has always been greatest when we dared to be great.... Tonight, I am directing NASA to develop a permanently manned space station and to do it within a decade." He directs NASA to invite other countries to participate, giving birth to Space Station Freedom.


NASA

1986 Jan. 28 | Space Shuttle Challenger breaks apart 73 sec. after liftoff on STS-51L, the program's 25th mission, claiming the lives of seven astronauts. The fleet is grounded for 2.5 years, delaying Reagan's goal of completing the station by 1994.

1989 July 20 | On the 20th anniversary of the Apollo 11 Moon landing, President George H.W. Bush unveils the Space Exploration Initiative, calling on the U.S. to return to the Moon and eventually send explorers to Mars. The plan extends support for Space Station Freedom, but debate continues over its design, mission and cost.


NASA

1991 Dec. 25 | The Soviet Union collapses. Russia inherits the Soviet space program and seeks civil space partners for its programs, including the Mir space station, whose nine-year assembly began in early 1986. The U.S. and Russia kick off a new alliance with a series of astronaut-cosmonaut exchanges. First step: Figure out how to dock a space shuttle at Mir.

NASA

1993 June 23 | An effort in the U.S. House of Representatives to terminate Space Station Freedom fails, 216-215; the late Rep. John Lewis (D-Ga.) casts the deciding vote. Despite NASA's recovery from the Challenger tragedy and opportunities to cooperate with Russia and other nations in the aftermath of the Cold War, congressional support for the increasingly costly project is marginal during Bill Clinton's presidency.

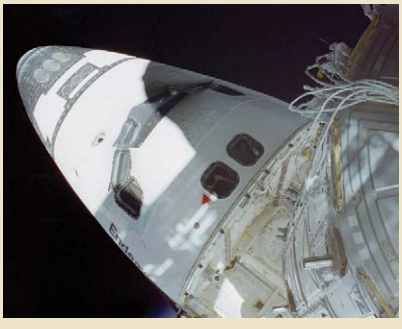
NASA

October | Russia and NASA merge station development efforts, leading to the first shuttle mission to rendezvous with Mir, in February 1994. Pictured aboard Mir is cosmonaut Valeri Polyakov.

1998 Jan. 29 | NASA gathers high-ranking officials from 15 nations in Washington to sign agreements for the design, development, operation and utilization of the ISS.

Nov. 20 | Russia launches Zarya, the first ISS element. Russia builds the functional cargo block, though NASA funds it.

NASA



Dec. 4 | NASA launches the first U.S.-manufactured ISS element, Unity, aboard the shuttle Endeavour. Unity serves as the link between the U.S. and Russian ISS segments.

Nauka multipurpose laboratory module, followed six months later by the arrival of a five-port docking hub for the Russian segment, says Roscomos Director General Dmitry Rogozin.

The growth spurt coincides with the resumption of ISS crew rotation missions from the U.S., a service that has been unavailable since the space shuttles were retired in 2011. Looking for a safer and less expensive alternative, NASA shifted to fixed-price contracts and partnerships to deliver first cargo and then crews to the ISS.

U.S. station resupply lines are currently operated by SpaceX and Northrop Grumman, with Sierra Nevada Corp.'s Dream Chaser winged spaceplane expected to join the fleet in 2021. SpaceX and Boeing have NASA contracts to fly crew, with the first operational Commercial Crew mission, SpaceX Crew-1, now targeted for launch in November.

The arrival of Crew-1, with NASA astronauts Michael Hopkins, Victor Glover and Shannon Walker and Japan Aerospace Exploration Agency astronaut Soichi Noguchi, will mark the beginning of five-member U.S. Operating Segment staffing, which will dramatically increase the time available to conduct research, the primary purpose of the station.

To date, the station has hosted nearly 3,000 investigations involving scientists in 108 countries from a wide range of fields including pharmaceutical research, fluid physics, chemistry, human physiology, biotechnology, Earth science, astronomy and astrophysics. "To my knowledge and to many others' there is no other international activity that has been as successful as [the ISS] has been," says Joel Montalbano, NASA's ISS program manager.

NASA is counting on a growing commercial space sector so that it can free up funding to push human exploration and development into deep space with the Artemis program. The agency intends to rely on commercially provided services and platforms to continue research and technology demonstrations in LEO, especially after the ISS comes to an end.

The 15-nation ISS partnership, which includes the U.S., Russia, 11 European nations, Japan and Canada, is looking to keep the station operational at least until 2028-30, and possibly longer. NASA needs the ISS or other LEO platforms to test life support, ex-

NASA

ISS by the Numbers

Rotating crews of U.S., Russian, European, Japanese and Canadian astronauts and cosmonauts have been living aboard the station for an unbroken string of 20 years as of Nov. 2, 2020. Here are some more facts and figures about the orbital outpost.

64
Resident crews

Pressurized volume
32,333 ft.^{3}
(**32,898** ft.^{3} with BEAM expanded)

357 ft.
Length

75-90 kW
of power from
8
Solar arrays

3,000
Science investigations from more than **100** countries

3 hr.
Quickest flight to ISS

340
Days, longest single mission by NASA's Scott Kelly and Russia's Mikhail Kornienko

241
Different people visiting from **19** countries, some returning as many as **5** times

8
Maximum number of visiting vehicles

Habitable volume
13,696 ft.^{3}
larger than a 6-bedroom house

240 ft.
Solar array wingspan

1,452 hr. **3** min.
Total ISS Extravehicular Activity time

More than
2,000
peer-reviewed research papers based on science done on the ISS

925,335 lb.
Mass

168
Science facilities, including **23** owned by **11** companies

More than
400
suppliers to ISS prime contractor Boeing

Assembly missions
37
space shuttles and **4** by Russian Proton and Soyuz vehicles

350,000
Sensors monitored by on-orbit software

93%
Urine recovered, recycled, with goal of + 98% after next system upgrade

17
Modules, connecting nodes, airlocks, with Russia's Nauka due to arrive in 2021

ercise equipment and other technologies for long-duration missions to the Moon and eventually Mars.

"As we go farther away from low Earth orbit, where we don't have a capability to resupply very easily—if at all—we have to understand the reliability of these systems. We have to be able to plan for the right number of spare parts and be confident that we're going to have a successful mission," says NASA acting ISS director Robyn Gatens.

"What we've learned so far with more than 10 years of operating the [life support] system on ISS is that we're still learning about it," she says.

Other U.S. agencies besides NASA fund microgravity research aboard the ISS, which also operates as a national laboratory. "There are a lot of things that have been discovered or developed in microgravity that have done good for people on Earth," says Michael Lopez-Alegria, a former NASA astronaut and ISS commander who will be training and accompanying three paying passengers to the orbital outpost under a contract with Axiom. The flight, known as AX-1, scheduled for late 2021, is among a handful of private crewed orbital flights in development.

"We've been living in orbit for 20 years now, and we've kind of made access to at least low Earth orbit become—I hate to say 'routine' because space is never routine—but something that is reliable and can be counted upon," says Lopez-Alegria. "That really enables a transition from government to commercial entities to establish an LEO economy that then supports beyond-LEO exploration. It's changing the paradigm from making sojourns into space to actually inhabiting space for the first time."

NASA is parlaying its 20 years of experience operating the ISS into a new human exploration initiative beyond LEO. For Artemis, commercial partners are being brought in early, with the requirement that they finance some of the hardware development. In exchange, the partners retain their intellectual property and can sell their services to customers outside of NASA.

The public-private partnership model, first tested with ISS cargo resupply services, shifts to human spaceflight with the first crew rotation mission scheduled to launch in November. "Very reliable, cost-effective crew transportation is the basis for

NASA

2000 Nov. 2 | The first ISS crew—NASA astronaut Bill Shepherd, commander (center), and cosmonauts Sergei Krikalev (left) and Yuri Gidzenko—arrive aboard a Russian Soyuz capsule. They return to Earth aboard the shuttle Discovery after a 141-day mission. Shepherd urges the ISS partnership to develop onboard hand tools and strategies that crews could use for repairs and maintenance rather than sending troubled hardware back to Earth. Sixteen years later, Made in Space activates its Additive Manufacturing Facility on the ISS for the commercial 3D production of hand tools and parts.

NASA

2001 Feb. 7 | The U.S. Destiny Laboratory module, the home for most ISS research, lifts off on STS-98 aboard the shuttle Atlantis.

NASA

March 19 | Cosmonaut Yury Usachev becomes the first Russian to assume command of the ISS.

everything else," says Kathryn Lueders, associate administrator for NASA's Human Exploration and Operations Mission Directorate.

For Artemis, NASA intends to retain a traditional role transporting astronauts to and from lunar orbit using expendable Space Launch System (SLS) heavy-lift rockets and reusable Orion capsules, programs that have been in development for more than a decade. The SLS and an uncrewed Orion spacecraft are now expected to launch on a flight test around the Moon in November 2021. That would be followed by a crewed flight test in 2023, with the goal of landing two astronauts on the lunar south pole before the end of 2024.

The lunar landing depends on at least one of NASA's three industry partners—Blue Origin, Dynetics and SpaceX—having a system ready to transport crew between lunar orbit and the surface of the Moon. NASA is requesting $3.2 billion for the program for fiscal 2021. "If we can have that done before Christmas, we're still on track for a 2024 Moon landing," Bridenstine said in September.

The initial lunar foray may bypass NASA's planned Gateway, a staging platform and technology testbed in lunar orbit that, unlike the ISS, will be designed to be operated with or without crews. "The way we're going to be assembling and deploying our equipment around the Moon is not going to be as challenging as assembling the space station, but only because we had the space station first," Lueders says.

The challenge will be in extending ISS logistics, supply and crew transportation systems from LEO to cislunar space, she adds. "We have to be able to show that spaceflight is routine," says Lueders. "And for a lunar mission that is very tough for us."

The ISS partnership also serves as the role model for future international cooperation in space projects. NASA took the lead in creating an agreement, known as the Artemis Accords, which so far has been signed between the U.S. and Australia, Canada, Italy, Japan, Luxembourg, the United Arab Emirates and the UK.

The document is based on the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, otherwise known as the Outer Space Treaty. Specifically, the Artemis Accords reiterate the commitment by the U.S. and signatories to explore space for peaceful purposes, register objects

that are put into space, provide emergency rescue services to astronauts and openly distribute scientific information, among other practices.

"What we're trying to do is establish norms of behavior that every nation can agree to so that we can avoid any kind of misperception or anything that could result in conflict," Bridenstine says.

Jointly operating the ISS over the last 20 years has not been without problems. The 2003 Columbia accident ultimately led to the U.S. decision to retire the space shuttles, putting the responsibility of staffing the station solely on Russia. That arrangement continued despite the political and economic fallout stemming from Russia's invasion of Ukraine in 2014.

Five cargo ships—three Russian, one SpaceX and one Northrop—were lost between 2011-16, complicating resupply efforts. In particular, the SpaceX Falcon 9 accident in June 2015 claimed a docking adapter needed for upcoming U.S. crewed capsules.

In October 2018, a Soyuz capsule carrying two members of the ISS Expedition 57 crew made an emergency landing after a failed launch, the first Soyuz launch abort in 35 years. There have been emergency spacewalks to replace failed components and to hunt for a leak in a docked Soyuz spacecraft.

"If you think about all of the things that have to happen to keep our crew onboard and healthy and to maintain the systems—when anomalies occur, fly the right spare parts, plan the EVAs [extravehicular activity/spacewalks] and fix whatever happened—all the while conducting all of this research, that by itself is an amazing achievement," Gatens says.

Recent upgrades to lithium-ion batteries and planned replacement of the solar arrays could keep the station operational for another decade. "We keep evolving this platform and expanding what we can do with it," Gatens says. "We're celebrating this anniversary and what we've accomplished so far, but we're on the cusp of huge payoffs from this platform."

NASA's Phil McAlister, director of commercial spaceflight development, adds: "We have had a generation of humanity that has essentially lived their entire lives with people in space continuously. It probably does not feel profoundly different day-to-day for most people. But I think we will look back on this time and see that this was an inflection point in human history and in our exploration of the cosmos."

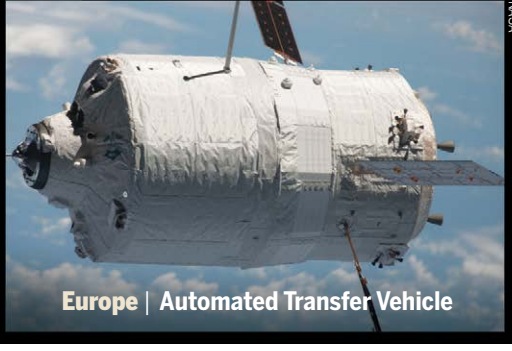
Visiting Vehicles

Here is a look at the ISS transportation fleet past, present and future.

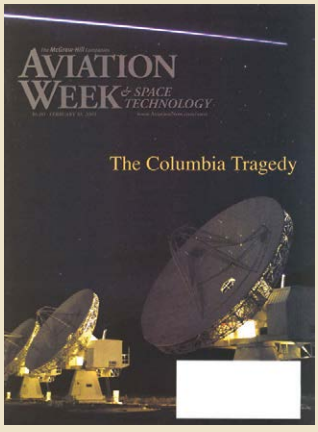
BILL INGALLS/NASA

KEN ULBRICH/NASA

NASA



NASA

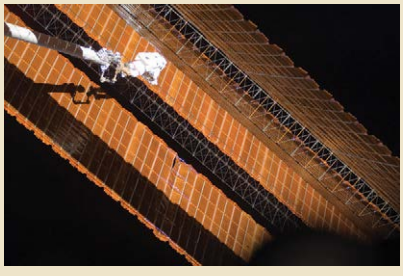


AW&ST ARCHIVE

2003 Feb. 1 | Seven astronauts on the STS-107 space shuttle mission perish when the orbiter Columbia breaks apart during descent back to Earth, following a 16-day orbital science mission intended to enhance ISS-style research plans. The tragedy renews a discussion about the space shuttle's future and disrupts ISS assembly.

NASA

2007 Oct. 12 | NASA astronaut Peggy Whitson, a biochemist, becomes the first woman to serve as commander of the ISS.



NASA

Oct. 23 | The shuttle Discovery launches with a crew of seven on STS-120, perhaps one of the most dramatic of the ISS assembly missions. After delivering and installing the U.S. segment Harmony module, the STS-120 crew, commanded by Pamela Melroy, turns to the relocation of the station's initial solar truss module. The first solar array module, initially designated Z-1, was installed in a vertical configuration. As the crew transfers the module, now designated P-6, to the far port side of the ISS, the lengthy fabric solar array is retracted. A tear in the solar blanket appears as it is redeployed. Discovery astronauts Scott Parazynski, an emergency room physician and mountaineer, and Douglas Wheelock, a U.S. Army test pilot, conduct a 7-hr. 19-min. spacewalk on Nov. 3 to repair the tear.

NASA

2011 May 16 | The shuttle Endeavour launches on STS-134, a 16-day mission with six astronauts, to deliver and install the Alpha Magnetic Spectrometer (AMS) on the ISS solar power truss. Led by the U.S. Department of Energy with partnerships from institutions in 16 countries, the AMS was developed to seek out antimatter and dark matter and assess their influence on the evolution of the universe.

BILL INGALLS/NASA

July 21 | NASA's 30-year space shuttle program comes to a close, as Atlantis and its STS-135 crew of four, commanded by Chris Ferguson, touch down at NASA's Kennedy Space Center after a mission to deliver the Raffaello multipurpose module, spare parts and crew supplies to the ISS. In all, 37 shuttle missions participate in the assembly and resupply of the ISS and crew exchanges. NASA now becomes dependent on Russia for ISS crew launches.

NASA

2012 May 25 | A SpaceX Dragon capsule becomes the first commercial spacecraft to reach the ISS, a demonstration of commercially provided ISS cargo resupply services. A second supply line, operated by Orbital Sciences (since acquired by Northrop Grumman) begins flying in September 2013. The fleet is due to expand again in 2021 with Sierra Nevada Corp.'s Dream Chaser spaceplane.

NASA

2016 March 1 | NASA astronaut Scott Kelly and cosmonaut Mikhail Kornienko return to Earth from the ISS aboard the Soyuz TMA-18M capsule in remote Kazakhstan, concluding a 340-day mission, the longest ever for a U.S. astronaut.

The ISS Opens for Business

In addition to research and technology demonstrations for national agencies involved in the International Space Station program, the orbital complex also hosts commercially developed and operated hardware. Here are some commercial facilities currently aboard and due to launch to the station this year.

Techshot
BioFabrication Facility (BFF)
Advanced Space Experiment Processor (ADSEP)
Multi-use Variable-Gravity Platform (MVP)
Bone-Densitometer (Bone-D)

Bioserve
Commercial Generic Bioprocessing Apparatus (CGBA)
Space Automated Bioproduct Lab (SABL)
Bioserve microscope

Space Tango
TangoLabs

Nanoracks
Nanoracks Cubesat Sat Deployer (NRCSD)
Nanoracks External Platform (NREP)
NanoLab
Kaber
Microplate reader
NR Bishop Airlock (scheduled to launch in November)

HNu Photonics
Mobile Space Lab

Made In Space
Additive Manufacturing Facility (AMF)
Recycler

Alpha Space
Materials on ISS Experiment-Flight Facility (MISSE-FF)

Teledyne Brown Engineering
Multi-User System for Earth Sensing (MUSES)
DLR Earth Sensing Imaging Spectrometer (DESIS-30)

Craig
Cyclops

Sierra Nevada Corp.
Small Mass Measurement Device

Space Technology and Advanced Research Systems (STaARS)
STaARS-1 Platform

Airbus
Bartolomeo external payload platform

Note: List does not include Bigelow Aerospace's BEAM module, which is a tech demo.

Dozens of science investigations involving Kelly and his Earth-based twin brother, Mark Kelly, also a NASA astronaut, study changes that the human body undergoes down to the genetic level in the absence of gravity.

FRED DEATON/NASA

2019 March 26 | Vice President Mike Pence, chair of the White House National Space Council, directs NASA to return to the surface of the Moon with astronauts in 2024, four years sooner than previously planned. The strategy calls on NASA to transition oversight of low-Earth-orbit activities such as those on the ISS to the commercial sector.

SPACEX

2020 May 30-Aug. 2 | SpaceX carries out a NASA Commercial Crew Program flight-test certification requirement by launching its Crew Dragon with NASA astronauts Robert Behnken and Douglas Hurley to the ISS for a 64-day mission. The launch from NASA's Kennedy Space Center is the first for U.S. astronauts from the U.S. since the shuttle fleet was retired in July 2011. The milestone sets the stage for regularly scheduled commercial crew launches to the ISS, a 10-year objective intended to end NASA's reliance on Russia for ISS crew launches. SpaceX's Crew 1 launch with four U.S. and Japanese astronauts is set for November.

—By Mark Carreau, Jen DiMascio and Irene Klotz

Digital Extras *See a more complete ISS timeline:* **AviationWeek.com/ISS-Timeline** *Take a virtual tour of the ISS and look back at AW&ST coverage of its development:* **AviationWeek.com/ISS-Tour**

NASA Asteroid Sampler Nails Touch-and-Go Maneuver

> FIRST U.S. ASTEROID SAMPLE MISSION

> OSIRIS-REX DUE BACK ON SEPT. 24, 2023

Mark Carreau Houston

Flying autonomously more than 200 million mi. from Earth, NASA's Osiris-Rex spacecraft made a delicate and brief descent to the rocky surface of the small asteroid Bennu, aiming to collect a few pounds of pebbles and soil for return to Earth, the first such sample-return mission for the U.S.

The 4.5-hr. touch-and-go maneuver went as planned, though how much material was collected would not be known for several days. The goal was to have the spacecraft's 11-ft.-long sampling arm sweep up between 0.13 and 4.4 lb. (60 grams-2.2 kg) of nickel-sized pebbles and soil from a landing spot named Nightingale near the asteroid's north pole.

Once ground teams confirm the sample was collected, the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer, commonly known as Osiris-Rex, will be cleared to depart Bennu in March and fly back to Earth 2.5 years later.

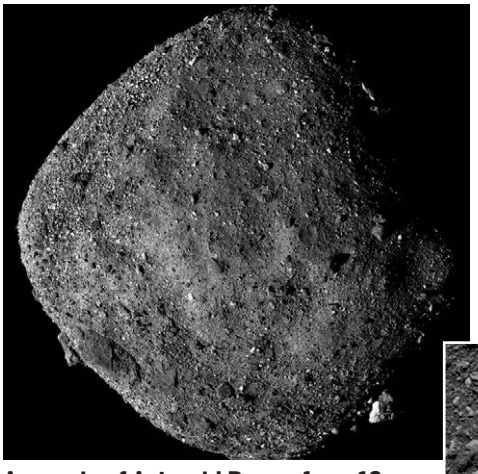
On Sept. 24, 2023, Osiris-Rex, built by Lockheed Martin, is to release its sample-return capsule for a parachute-assisted descent to the U.S. Army's Test and Training Range in Utah.

Data relayed by the probe showed a successful encounter at 6:08 p.m. EDT on Oct. 20, spurring cheers and elbow bumps among the mask-clad flight control team at Lockheed's Littleton, Colorado, mission support facility. "Everything went just exactly perfect," says University of Arizona planetary scientist Dante Lauretta, Osiris-Rex principal investigator. "I can't believe we have pulled this off."

The aim of the mission, which cost NASA about $1 billion, is to analyze the samples to learn more about the role asteroids played in the delivery of water and organics—the building blocks of life—to Earth and the rest of the inner Solar System's rocky planets.

Osiris-Rex launched on Sept. 8, 2016, aboard a United Launch Alliance Atlas V rocket and reached the asteroid on Dec. 3, 2018. A lengthy reconnaissance of Bennu, which is shaped like a spinning top, followed so scientists could assess chemical and physical properties of the 4.6 billion-year-old object and select a promising, safe site for sample collection.

The 1,640-ft.-wide asteroid is believed to be carbon-rich rocky debris from a suspected collision between two planetary bodies. Bennu may share chemistry similar to carbonaceous meteorites that fall to Earth. Samples from Bennu will be studied for their chirality, or the asymmetry of amino acids believed to be present in the asteroid.



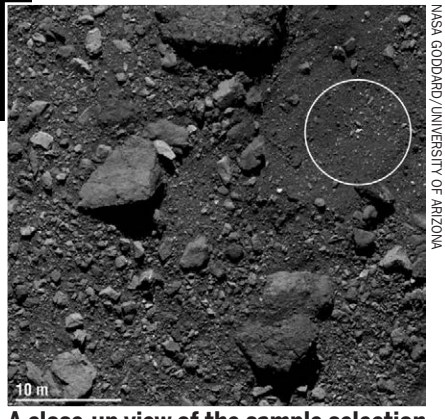
A mosaic of Asteroid Bennu from 12 images taken by NASA's Osiris-Rex spacecraft at a distance of 15 mi.

"We know that amino acids are present in carbonaceous meteorites. . . . We know [amino acids] are essential to life on Earth," says Goddard Space Flight Center researcher Jamie Elsila. "We are trying to look at that connection [between] which amino acids may be found on Bennu, which amino acids were present in the Solar System, how they might have been distributed to the early Earth and how that might have helped life on Earth."

Osiris-Rex began its sample-acquisition campaign by departing its shallow orbit around Bennu. Confirmation that the probe had fired its attitude control system to depart orbit was received at 2 p.m. EDT, all in response to a command sequence uploaded to the spacecraft earlier. Due to Bennu's surprisingly boulder-strewn surface, Osiris-Rex progressed cautiously, at about the speed of a tortoise, using Natural Feature Tracking to help guide its descent and motion—a spacecraft first.

The probe's lengthy survey of Bennu enabled ground teams to collect imagery and compile a catalog of surface boulder and crater hazards. The images were then uploaded for Osiris-Rex to use as it descended and maneuvered to a landing, enabling the spacecraft to compare its path in real time against the library of surface hazards so it could safely maneuver or, if necessary, abort the landing. The probe arrived at Bennu equipped to make up to three attempts to land and gather sample materials.

Samples from Bennu are not the only asteroid materials heading back to Earth. The Japan Aerospace Exploration Agency (JAXA) Hayabusa2 mission, which touched down twice on the asteroid Ryugu in 2019, is expected to drop off its sample-collection canister for recovery on Dec. 6 in Woomera, Australia.



NASA GODDARD/UNIVERSITY OF ARIZONA

A close-up view of the sample selection site, called Nightingale.

NASA and JAXA have agreed to exchange asteroid sample materials, though an estimated 75% of the Osiris-Rex bounty is to be preserved for future analysis as asteroid sciences and laboratory technologies advance. JAXA accomplished the world's first asteroid sample return in 2010 with its challenging Hayabusa mission to the asteroid Itokawa.

—With Irene Klotz at Cape Canaveral

AIRBUS

AVIATION WEEK'S 63RD ANNUAL

LAUREATE AWARDS

Seven months after the sudden onset of the COVID-19 crisis forced Aviation Week to postpone the 2020 Laureate Awards, editors honored more than two dozen winners from around the globe in a virtual event on Oct. 19. Winners of this year's Grand Laureates—the best of the best in Business Aviation, Commercial Aviation, Defense and Space—were announced and interviewed during the online presentation. This was the 63rd presentation of the Aviation Week Laureates, which have recognized outstanding accomplishments in aviation, space and defense since 1957.


EMBRAER

Defense

Grand Laureate

Embraer C-390 Millennium

Embraer delivered the first C-390 to the Brazilian Air Force in 2019. The tanker/transport is the largest and most sophisticated aircraft yet developed by Embraer and the most ambitious defense development program in South American history. The Millennium can move troops and cargo, conduct medical evacuations, participate in humanitarian missions and firefighting roles and refuel helicopters and fighter aircraft for combat—with a platform that boasts low life-cycle costs.

Laureates

Bell V-280 Valor (Platforms), Northrop Grumman F-35 Center Fuselage Production (Manufacturing), BAE Systems Typhoon Total Availability Enterprise (MRO), Air Force Research Laboratory Medium-Scale Critical Components Scramjet Program (Propulsion), Kratos XQ-58 Valkyrie (Technology & Innovation) and Missile Defense Agency/Boeing Ground-Based Midcourse Defense FTG-11 (Weapons).

Commercial Aviation

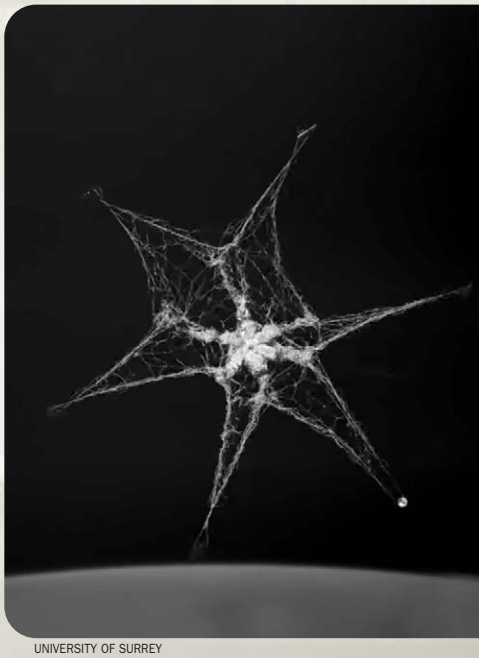
Grand Laureate

Airbus A321LR/XLR

Airbus' launch of the long-range versions of the A321neo has been highly successful. The XLR in particular will enable airlines to fly transatlantic routes using an efficient narrowbody aircraft, reducing trip costs and opening thinner direct routes that have been outside of the scope of widebodies. As aviation recovers from the COVID-19 pandemic, smaller long-haul aircraft are forecast to be in high demand. While the A321LR is already in service, the XLR is planned to enter service in 2023. It has collected more than 450 firm orders, according to Airbus.

Laureates

David Neeleman (Leadership), Adel Ali (Airline Strategy), Aireon (Air Traffic Management), Rolls-Royce (Propulsion), Boeing ecoDemonstrator (Sustainability) and Donecle (MRO).


UNIVERSITY OF SURREY

Business Aviation

Grand Laureate

Garmin Autoland

Garmin's Emergency Autoland is the ultimate co-pilot for desperate times. When activated with the push of a red button by anyone on board, the system takes control of the aircraft, evaluates winds, weather and fuel reserves, selects a suitable divert field and flies there while alerting air traffic control of its activation and intent. Upon approaching the selected airport, it descends, lowers flaps and landing gear, slows and touches down on the best runway available and then brakes to a stop. It is an aviation safety superlative.

GARMIN

Laureates

Gulfstream G500/G600 (Platforms), Pratt & Whitney PT6E Series (Propulsion), Rega Swiss Air-Rescue (Operations), Robotic Skies (MRO) and Wing Aviation (Technology & Innovation).

Space

Grand Laureate

RemoveDebris Mission

In a groundbreaking series of on-orbit tests amid concern over growing collision risks, the European Commission-funded RemoveDebris mission demonstrated a series of active debris-removal technologies designed to clean up low Earth orbit. Deployed from the International Space Station, the RemoveDebris satellite tested vision-based navigation, net capture, harpoon capture and drag-sail deorbiting.

Laureates

Spaceflight Industries (Launch Services), Chang'e 4 Moon Landing (Space Science), Mars Cube One Mission (Platforms), HawkEye 360 (Operations), Reaction Engines (Propulsion) and OneWeb Satellites (Supplier Innovation).

Lifetime Achievement

Philip J. Klass Award

UNITED TECHNOLOGIES CORP.

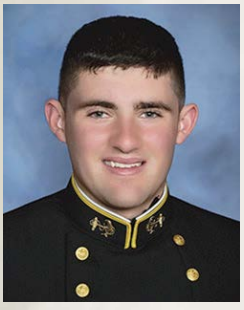
Robert Leduc

Veteran aerospace leader Robert Leduc came out of retirement for a third time to return to Pratt & Whitney as president and used his leadership skills to shake up the corporate team and guide the PW1000G geared turbofan engine through a challenging service introduction and production ramp-up, setting it on a path to success. He also oversaw the buildup of the F135 fighter engine. Leduc retired, again, at the end of 2019.

Cadets

Each year, Aviation Week recognizes an outstanding cadet from each of the four U.S. military service academies. This year's honorees are:

Cadet Capt. Matthew R. Arnold
U.S. Military Academy



Cadet 1st Class Jacob P. Cheeseman
U.S. Coast Guard Academy

Midshipman 1st Class Patrick N. Simons
U.S. Naval Academy

Cadet 1st Class Albert Q. Thieu
U.S. Air Force Academy

Video *Watch the 2020 Laureate Awards and an interview with Robert Leduc:*
AviationWeek.com/Laureates2020

Aviation Week also recognizes 20 outstanding students pursuing careers in aerospace. Read profiles of this year's 20 Twenties at:
AviationWeek.com/20Twenties2020

TOUGH CHOICES

- FATE OF THE U.S. F-35 BUY REMAINS UNCERTAIN
- JOINT ALL-DOMAIN COMMAND AND CONTROL IS HERE TO STAY

Lee Hudson Washington

NO MATTER WHO IS SITTING IN THE OVAL OFFICE JAN. 21, whether it is Donald Trump or Joe Biden, the overall Pentagon budget drafted by the White House will probably look about the same.

Already analysts are predicting a leveling off in defense spending in the near term. But massive coronavirus relief efforts and a return to a discussion of the national debt and the deficit make it even more likely that the $740 billion-a-year allotment for defense will be less of a priority beyond 2021. Differences are probable in terms of how each candidate would spend those dollars.

Here is a guide to the defense priorities laid out by the candidates to date. A Trump Pentagon is likely to continue its focus on Joint All-Domain Command and Control (JADC2), nuclear modernization, the rebalancing of U.S. troops around the globe and equipping the Navy for a war against China.

While a Biden Defense Department also appears likely to prioritize JADC2, its approach to nuclear modernization may differ. Biden's campaign also draws a sharp contrast with its approach to NATO and other international alliances and is receiving advice about combat aircraft that could alter the current plan to buy Lockheed Martin F-35s rather than more Northrop Grumman B-21 bombers.

MASTER SGT. MICHEL SAURET/U.S. ARMY RESERVE

President Trump, pictured at his inauguration with then-Army Chief of Staff Gen. Mark Milley, would push JADC2 and nuclear modernization, urge Europe to spend more on defense and reset the Navy to meet the Chinese challenge.

TRUMP

JADC2

Both candidates remain committed to connecting the joint force on the future battlefield, a concept the military calls JADC2. The Army and Air Force signed a two-year agreement to collaborate on capabilities for JADC2, with a focus on defining mutual standards for data sharing.

Chairman of the Joint Chiefs of Staff Gen. Mark Milley has assigned various lines of investigation to the services supporting JADC2 development. For example, the Navy is assessing global and joint fires, the Army is studying logistics under attack, and the Air Force is developing an Internet of Things.

The Air Force and Army are currently conducting experiments and demonstrations that support integration and JADC2 development. The Navy and Marine Corps organized a series of demonstrations in fiscal 2019 called the Navy Tactical Grid experiment that focused on building a common operating picture provided by the Cooperative Engagement Capability. A new initiative, Project Overmatch, is replacing the Navy Tactical Grid effort. Project Overmatch focuses on developing the networks, infrastructure, data architecture, tools and analytics required to link hundreds of aircraft, ships, submarines and unmanned systems.

NUCLEAR MODERNIZATION

Under a Trump presidency, the U.S. would continue modernizing its nuclear arsenal. Nuclear modernization is an extremely large bill for the Pentagon, estimated to cost $1 trillion over the next 30 years.

The Defense Department has plans to update each leg of the nuclear triad to include the Columbia-class ballistic missile submarine, B-21 Raider, Ground-Based Strategic Deterrent and the Long-Range Standoff cruise missile. It will continue to upgrade the B61-12 nuclear GPS-guided bomb and is developing a low-yield W76 warhead.

In September, the Air Force awarded Northrop Grumman a $13.3 billion contract to replace the intercontinental ballistic missile (ICBM) system, known as the Ground-Based Strategic Deterrent. The Air Force Nuclear Weapons Center estimates it will take 8.5 years to design, qualify, test, evaluate and nuclear-certify the land-based replacement in the nuclear triad.

U.S. TROOP REBALANCING

Trump is relocating an F-16 unit from Spangdahlem Air Base in Germany to Italy, as part of a larger strategy shift that removes 11,900 U.S. troops from Germany. According to the president, this is happening because Berlin has not paid its "NATO fees," meaning the country has not allocated 2% of its GDP for defense.

"They're way off, and they've been off for years, and they have no intention of paying it, and the United States has been taken advantage of," Trump said in July. He contends Germany owes billions of dollars to NATO and that this is the reason for withdrawing U.S. troops. "We're reducing the force because they're not paying their bills. It's very simple," Trump said. He added that the U.S. may rethink the withdrawal from Germany "if they start paying their bills."

Reinforcing Trump's point, Defense Secretary Mark Esper emphasized that Germany is the wealthiest country in Europe and should pay more for its defense and at least meet the 2% standard.

"The president's directive in June accelerated that,

and we are excited about where we're going and what it will mean in terms of our ability to enhance returns and strengthen our alliance in the process," Esper said.

Pentagon officials say moving the 480th Fighter Sqdn. closer to the Black Sea allows the unit to better conduct rotational deployments in NATO's southeastern flank. The plan also calls for the 2,500 airmen based at Royal Air Force Mildenhall in England to remain there. The group, charged with special operations aerial refueling, was previously slated to move to Germany.

Another recent announcement altering military posture involved the return of 6,400 troops to the U.S. and another 5,600 service members leaving Germany for other NATO countries. U.S. European Command headquarters and its special operations component, U.S. Special Operations Command Europe, are moving to Mons, Belgium, from Stuttgart, Germany. There is a separate plan to move U.S. Africa Command headquarters, which is also in Stuttgart, to an undetermined location.

NAVY FORCE STRUCTURE CHANGES

One month before the election, Esper announced a radical plan that would alter the Navy to better compete with China. The changes include growing the surface-ship fleet, making changes to naval aviation and increasing the shipbuilding construction budget annually by 13% ($2 billion).

The Trump administration is open to sacrificing a sacred cow, the Navy's aircraft carrier requirement. By law, the Navy must have 11 operational aircraft carriers, but Esper is comfortable with as few as eight. He envisions adding six light carriers to the shipbuilding plan to support the traditional carriers in a war.

The new plan, Battle Force 2045, calls for unmanned ship-based aircraft of all types: early warning, electronic attack, fighters and refuelers. The Navy is currently developing the Boeing MQ-25 Stingray unmanned carrier-based refueling tanker to ease the burden on the Boeing F/A-18E/F Super Hornet fleet.

"While this was not analyzed in detail in the study, we will continue to assess the proper mix and range needed to overcome tomorrow's threats," Esper says.

BIDEN

JADC2

A Biden Pentagon is likely to support the work the military is currently conducting on JADC2. However, a Democratic administration would approach Congress differently by looping them in early, according to Michele Flournoy, undersecretary of defense for policy during the Obama administration and a top contender for defense secretary under Biden. She applauds the services' conceptual work but does not believe the Defense Department is doing enough to get buy-in from Congress to support the multiyear investment that will be required.

NUCLEAR MODERNIZATION

Under a Biden administration, the U.S. nuclear posture is likely to change. If selected for the top defense post, Flournoy would direct the next Nuclear Posture Review to assess if there are more cost-effective approaches than the current path of spending $1 trillion over the next 30 years. In interviews, Flournoy has been skeptical about whether development of a new nuclear warhead is necessary.

Former Secretary of State Hillary Clinton, a close friend of Flournoy's, agrees that the U.S. should not deploy a low-yield nuclear warhead on submarines or nuclear-armed cruise weapons because it expands the range of usage scenarios, which may increase the risk of miscalculation, she writes in *Foreign Affairs*, echoing the remarks of Rep. Adam Smith (D-Wash.), chairman of the House Armed Services Committee.

Clinton reinforces this point by advocating that the U.S. instill a "newer and fewer" approach to nuclear modernization by reducing the ICBM program, as opposed to Trump's approach of modernizing the nuclear arsenal.

SENIOR AIRMAN DAMON KASBERG/U.S. AIR FORCE

Former Vice President Joe Biden, pictured on a 2014 visit to Bucharest, would differ from Trump on his approaches to nuclear modernization and the NATO alliance, among other issues.

BOMBERS OVER FIGHTERS

Another stark difference on what equipment a Trump or Biden administration would buy revolves around the purchase of Lockheed Martin F-35 Joint Strike Fighters.

Like many military experts, Clinton contends in the *Foreign Affairs* essay that the next major war will make it difficult for aircraft carriers and other surface ships to get close to potential targets because of anti-ship missiles. But her conclusion is that the U.S. would thus not need as many F-35s and instead should invest in purchasing the Northrop Grumman B-21 Raider, a bomber designed to foil advanced air defenses. If Biden takes that advice, it would be a marked departure from what Trump and his predecessors have proposed.

NATO AND ALLIANCES

Biden has said he would renew commitment to U.S. alliances, a sharp contrast with the Trump administration. Trump ruffled European feathers when he likened NATO nations' defense spending to paying a fee.

Biden vows to bring a less transactional approach to diplomacy with European and other world leaders and sees that as a way to counter Russian influence.

"Russia seeks to undermine our democracy and our partners in Europe, including the members of the NATO alliance," Biden said in a response to questions posed by the Military Officers Association of America (MOAA). MOAA asked each candidate what they consider the greatest threat to U.S. interests abroad, how they would alter military presence, and if the U.S. military is overcommitted or undercommitted to missions and security concerns in other countries.

Biden pledged to listen to military leadership, civilian security experts and U.S. allies before making decisions on where and how to adjust our overseas presence.

"China poses the greatest strategic challenge to the United States and our allies in Asia and Europe," Biden said.

U.S. Congressional Races To Watch

★★★★★

Democrats Amy McGrath and Kim Mangone are challenging two of the most powerful Republicans in Congress, Senate Majority Leader Sen. Mitch McConnell (Kentucky) and House Minority Leader Rep. Kevin McCarthy (California), respectively. McGrath, a former U.S. Marine Corps pilot, and Mangone, an Air Force mechanic turned systems engineer, have extensive experience in aerospace. Pentagon Editor **Lee Hudson** spoke to McGrath and Mangone in the run-up to the election, and their comments provide a look at how two Democrats with a background in aviation might shape future policy if they win.

★★★★★

Amy McGrath The Kentucky Challenger

A retired U.S. Marine Corps lieutenant colonel and former F/A-18C/D pilot, Amy McGrath is nearing the end of her next battle—a fight for Senate Majority Leader Mitch McConnell's seat to represent the state of Kentucky in Congress. The Democratic Party has poured $82 million into her campaign, nearly $30 million more than her opponent. Still, The Cook Political Report rates this race as a "likely Republican" win for the incumbent, McConnell.

AMY MCGRATH FOR KENTUCKY

Amy McGrath

Mitch McConnell

Where is defense funding needed?
Defense is really important, but so are all these other things—like diplomacy. For part of my career, I was the Marine Corps liaison to the State Department for two years in the Pentagon. Retired Marine Corps Gen. Jim Mattis said it best: If we don't fund the State Department, "I need to buy more bullets." And I don't think there's enough members of Congress that get that. There are plenty of generals out there that do, but a lot of these generals don't turn around and run for office. Not only do we have to talk about helicopter gunships, [but] we also have to talk about [the] national stockpile of swabs [and] the biological engagement program.

How should the U.S. alter its nuclear defense posture?
It's always good to reassess what we need. I think we can have fewer ICBMs; we could go from 400 to, say, 300 and still save money in several ways, such as smaller operating costs due to a reduced force structure. We would have extra missiles that could be freed up to play the role of test missiles. As far as the [nuclear] triad: There's real value in having long-range bombers, there's certainly value in having your ballistic missile submarine force, [but] I'm not a fan of getting rid of the ICBM leg of the triad.

Should aerospace and defense firms get COVID-19 relief?
I really want to focus on making sure that we help employees instead of the large corporations. If we're going to do any additional bailout in the aerospace industry, I think it's going to have to have restrictions like no stock buybacks. Let's not keep lining the pockets of the CEOs.

Kim Mangone The Long Shot

A former U.S. Air Force C-130 aircraft mechanic, flight engineer and retired Northrop Grumman project systems engineer who worked on the B-2 bomber, Kim Mangone, is vying for House Minority Leader Kevin McCarthy's congressional seat. Her campaign raised $1 million, while McCarthy brought in $23 million. The race is not close, as McCarthy's seat is one of 153 "Solid Republican" contests in the House of Representatives, according to The Cook Political Report.

KIM MANGONE FOR CONGRESS

Kim Mangone

Kevin McCarthy

Where is defense funding needed?
I will always be pro-defense, but we have to look at budgets to see what makes sense [and] what programs are needed. But you have to do an evaluation. My systems engineering background has taught me to conduct evaluations, see where we need to bump up, see what we need to pull back and then go forward.

How should the U.S. alter its nuclear defense posture?
We need to go back to where we're reducing the threat of a nuclear war but must [still] show a strong defense because countries like North Korea and Iran do not like us. I want to see us get back into an agreement with Iran. I think we should have stayed in that and never gotten out of it. I want to see a strong relationship with NATO because they are allies, and we need to strengthen that relationship.

Should aerospace and defense firms get COVID-19 relief?
No, they should not. I am still in touch with people in that industry, and aerospace is better off than most because the defense industry is considered essential. Employees haven't lost their jobs, and no one was laid off. If it gets to the point where the defense industry is laying off workers, then yes, the employees themselves need help from Congress—but not the large corporations. The U.S. needs to focus on helping small businesses. A way to create jobs in my district is through training. We have many solar and wind farms, and our residents were not trained to work in that line of work, which forced those companies to bring people from out of state for those jobs.

ASK THE EDITORS

How Much Time Will the New Boeing 737 MAX Pilot Training Take?

Aviation Week Air Transport & Safety Editor Sean Broderick responds: The short answer: About 5 hr., including 2 hr. in the simulator.

The details: New minimum training requirements for 737 MAX pilots have not been finalized. But it is a safe bet that what FAA Administrator Steve Dickson went through to prepare for his Sept. 30 demo flight—and what is outlined in a Flight Standardization Board (FSB) draft report out for public comment through Nov. 2—is pretty close to what will be approved.

The training will be split into two parts. The "ground" training—think computer-based distance learning that can be done on a tablet—will take 90-120 min. It will be broken into modules that cover key issues, including the MAX's Maneuvering Characteristics Augmentation System (MCAS) flight-control law, other flight-control computer (FCC) updates and several non-normal procedures. There is a heavy emphasis on reviewing seven non-normal checklists that have changed.

Next up is mandatory simulator sessions. Actual device time is expected to take about 2 hr. But an added briefing and a 3-hr. block for the simulator portion are a safe bet.

The draft FSB report spells out the minimum that must be done in the simulator. Airlines can add more scenarios, of course, but these—straight from the draft—are the five scenarios the FAA is proposing:

- Demonstration of MCAS activation for each pilot
- A runaway stabilizer condition that requires the pilots to use manual stabilizer trim
- Use of manual stabilizer trim during approach, go-around and level-off phases of flight
- A cross-FCC trim monitor activation demonstration accomplished by either pilot acting as pilot flying (PF)
- Erroneous high-angle-of-attack alert on takeoff that leads to an unreliable airspeed condition accomplished by either pilot acting as PF.

Note that items 2 and 3 can be done on either a 737NG or a 737 MAX simulator, as the scenarios apply to each type and are not affected by Boeing's changes to the MAX. The full draft FSB report, plus instructions on how to comment, is available until Nov. 2: faa.gov/aircraft/draft_docs/fsb/

Simulator availability will be the pacesetter for airlines. Southwest Airlines expects to take at least two months to train its 9,800 pilots. American Airlines—which does not want to have every one of its pilots qualified on the MAX, unlike all-737 operator Southwest—has scheduled about three months to train 4,200 pilots.

Pilots also need to work the sessions into their schedules, of course, which should be an easier task now that COVID-19 has lightened schedules considerably.

FAA Administrator Steve Dickson completed new proposed 737 MAX ground and simulator training before piloting a demonstration flight on Sept. 30.

MIKE SIEGEL-POOL/GETTY IMAGES

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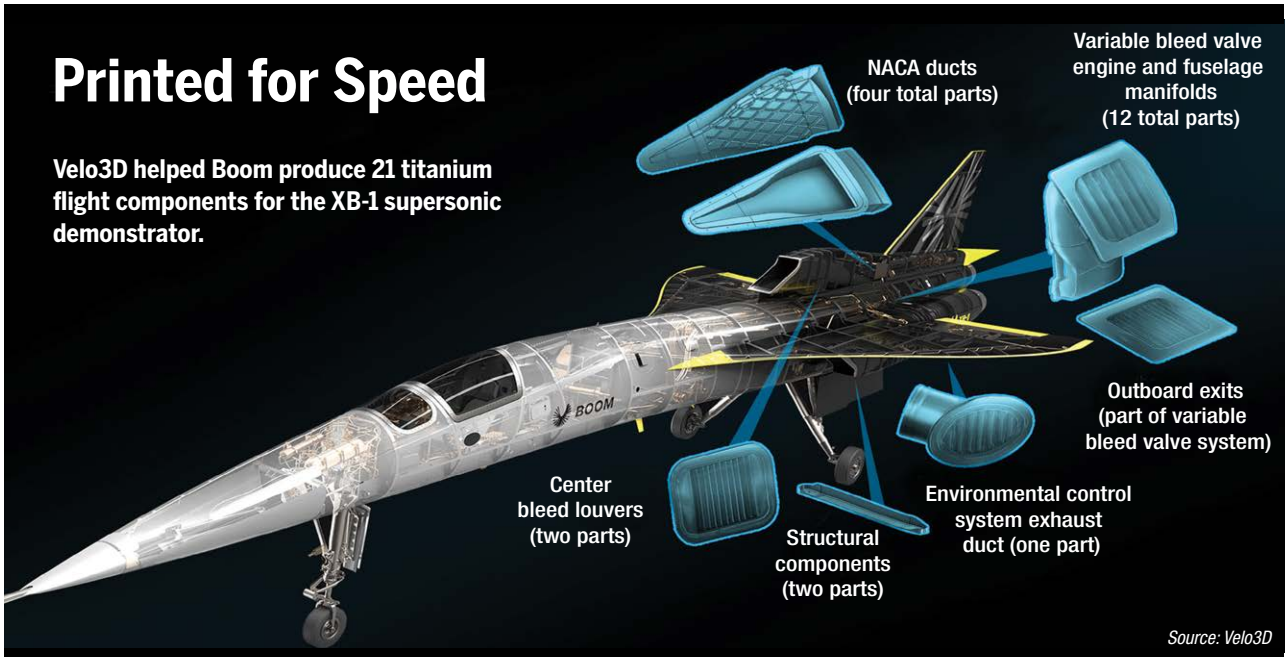
Start: Print

Startups embrace additive manufacturing for speed to market

Graham Warwick Washington

Disruptive startups are not only taking aerospace in new directions, they are also changing how the sector develops and manufactures products. In search of speed to market, these companies are embracing additive manufacturing with an enthusiasm that contrasts with the cautious approach of established industry.



From rocket engines to complete vehicles, space startups are using 3D printing to dramatically lower the cost of accessing and exploiting Earth orbit. Aviation newcomers from Boom Supersonic to Joby Aviation are following suit, using additive not only for prototyping but also in gearing up for production.

Boom has used polymer and metal 3D printing in building its XB-1 supersonic demonstrator, which was rolled out on Oct. 7. But Joby has gone further and is planning to use metal additive manufacturing for volume production of certified safety-critical parts for its electric vertical-takeoff-and-landing air taxi.

"If you look at companies that make products and ask yourself: 'Why would these companies consider additive manufacturing, not for prototyping but for actual production of end-use parts?' There are really two drivers," says Benny Buller, CEO of metal 3D-printing startup Velo3D.

"The first is the driver of new product innovation through the ability to create more optimal geometries than you could without additive," he says. "This is complexity you can do with additive that you couldn't do before—the consolidation of parts and design of geometries that were not possible before and that allow for better performance in multiple dimensions: weight, efficiency, size, reliability and sometimes cost."

There is an extra innovation advantage with additive, Buller says. "You not only can do a better product, but you can develop and iterate it much faster and spend much less resources getting your product to market more quickly," he adds. "You will not need tooling to start producing that product, and you can transition from development to production smoothly without first having to prove the tools."

The second driver toward the use of additive manufacturing is business agility, he says. "Often in aviation, the lead time on parts is measured in quarters—two, three, sometimes four quarters," Buller tells Aviation Week. "Additive can reduce lead time to a similar number of weeks. You go from quarters to weeks. That's more than an order of magnitude improvement in speed."

And that has a big impact on inventories. "A lot of companies pride themselves on having a backlog of years or sometimes decades," he says. "That's not a good thing for anyone. Because when you go into a depression, like we are now, you suddenly get to where the inventories are years of inventories."

Additive tools enable a more agile and responsive business and supply chain. But for startups, agility is not the driver, Buller says. "It may be important, but it will be important in the future. Right now, a startup lives and dies by being able to get a better product to market quicker, leapfrogging the competition and losing less cash. That's by far the most important thing."

Boom's adoption of additive manufacturing in building the XB-1 largely follows an established path for aerospace, using polymer 3D printing to produce tooling and prototype parts for physical fit checks. But 3D-printed parts, both polymer and metal, will be on Boom's demonstrator when it flies in 2021.

According to Stratasys, which worked with Boom on the manufacturing of polymer parts and tools, XB-1 Director of Production Mike Jagemann had previous experience with 3D printing and immediately brought in two printers to help with prototyping. He later brought in an industrial-scale machine to produce tooling and parts.

Use of printed parts to check fit and alignment saves engineering time. "With 3D printing, we've been able to obtain

parts very quickly and determine that they're either going to work or that we need to make changes," Jagemann says. "Rather than spend 8 hr. in [computer-aided design] trying to check space constraints, the engineer can continue working on other things. When the part is printed, they can check the fit."

The biggest savings, on cost and time, came from printing custom drill blocks to locate the fastener holes on the XB-1's airframe. Initially, Boom used tools that positioned one hole at a time. This was taking too long, Stratasys says, so Boom switched to 3D-printed drill blocks with multiple holes. By allowing them to position 20 or more holes at a time, the additively produced drill blocks proved to be "a huge manufacturing timesaver," Jagemann says.

VELO3D

Variable bleed valve manifolds are complex, high-temperature titanium parts 3D-printed for the XB-1.

Boom also used polymer 3D printing to produce hydraulic line clamps that will fly on the XB-1. The positioning of such clamps often needs to be adjusted during assembly. Additive allowed the parts to be left to the end of the design process because they could be printed quickly in-house. "That shortens the supply chain on certain components that are a good fit for 3D printing," Jagemann says.

Meanwhile, Velo3D has worked with Boom to produce 21 titanium flight components for the XB-1 using Velo3D's laser powder bed fusion system. The company's software and hardware were used to produce cooling-air inlet ducts, center-engine bleed louvers, variable bleed valve manifolds and exits as well as the environmental control system exhaust duct and two structural components.

Many of the parts are related to channeling air—some at temperatures exceeding 500F—and have complex vanes, ducts and louvers. The lightweight parts are characterized by tall, thin walls with high aspect ratios. These designs are inherently difficult to manufacture using traditional processes such as welding and casting, "or even most existing 3D-printing technologies," Velo3D says.

In addition to Boom, Velo3D has worked with several space startups. "Basically every rocket engine that has been designed in the last decade has been designed with additive manufacture in mind," Buller says. "The way we work with startup customers is [to] provide them free advice on how they can optimize their design, taking advantage of what we can do in terms of manufacturability."

The parts are then produced by contract manufacturers—partners that have bought Velo3D's machines. "The startups are using these contract manufacturers to make their parts," Buller says. "We do not have any business arrangements with these startups. This is no cash transfer. We are just partners in crime," he quips.

"The work we have done with Boom has been similar, in the sense that our contract manufacturers made the parts for them," he adds. "We help them with technical advice on how to make the most of their designs, to reduce the weight, to improve the cooling; but we were not paid for that."

Velo3D has other ways to work with potential disruptive newcomers. "There are some startups we have identified as very inventive that are at an early, pre-funding stage, so they cannot pay," Buller says. "Those we advise on how to make a better product and give them a loan of print hours that they will pay back after they get funding." This could promote greater use of additive by startups in the long term.

Established industry has been cautious and deliberate in embracing 3D printing because the focus is on producing certified safety-critical parts. This is a challenge with additive because both the material and component are produced at the same time, making process qualification critical to part certification.

"Joby Additive is essentially a supplier within Joby and was formed in late 2017," says Sean McCluskey, additive manufacturing lead at Joby. "We are the first organization in history to attempt certification of multiple safety-critical structural additive titanium components with the FAA."

Joby is looking beyond prototyping, at high-rate manufacturing. "We have a 100% in-house capability for metal additive," McCluskey adds. "We're committed to creating a data-driven platform for manufacturing certified components by embracing innovation, communication and accountability.

"Everyone who has attempted it knows certification is hard. It takes a long time, and the level of clarity and quality required is very high."

Certifying safety-critical components requires a secure digital workflow that is traceable from the finished part all the way back to the raw ore. Today, that process involves multiple steps that must be tightly controlled to enable certification.

Industry leader Dassault Systemes and startup Joby have been working together and have developed a workflow that connects the former's 3D experience product development software platform, via an immutable file type, directly to the latter's build-execution tool, which in turn controls the printer hardware directly.

"We've built a back end for our machines that can execute these file types directly on the machines to produce components and then a cloud-based service that links all the machines together . . . to maintain that traceability we need for each part back to its raw ore," he says.

Joby is looking well ahead as it prepares for 3D printing in rate production. "If we're going to spend all of this time, energy and money to build this system, we must also add capability for the future so we don't have to redo it every couple of years when the technology gets better," McCluskey says.

"This next-generation data structure has to allow for capability far greater than what we have today. Today, there's a set toolbox of hardware components that are used in almost all laser powder bed fusion machines. But that box will expand substantially over the next few years," he says. "We can handle an architecture that is completely different from what we have today as long as the fundamentals of additive remain the same," McCluskey adds.

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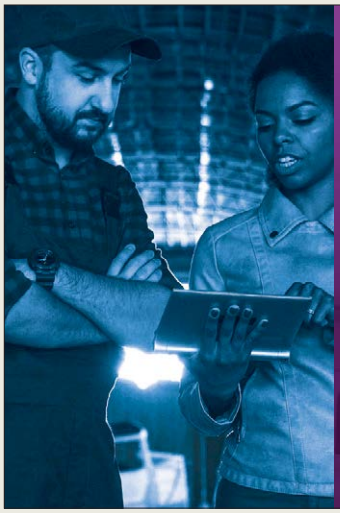

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Aerospace Calendar

To submit Aerospace Calendar Listings
email: aero.calendar@aviationweek.com

Oct. 27-28—Mexico's Aerospace Summit. Hybrid event. Queretaro Congress Center. Queretaro, Mexico. See mexicoaerospacesummit.com

Oct. 27-28—2020 FAA International Rotorcraft Safety Conference. Virtual event. See faahelisafety.org

Oct. 28-30—Hypersonic Weapons Summit. Virtual event. See idga.org/events-hypersonicweapons

Oct. 29-Dec. 10—RTCA Plenary Sessions/Committee Meetings. Virtual or various locations. See rtca.org/content/upcoming-committee-meetings

Nov. 2-4—AMTC20: Air Medical Transport Conference. Virtual event. See aams.org/events/amtc

Nov. 6—U.S. Corporate Aviation Summit. Virtual event. See aeropodium.com/uscas.html

Nov. 9-10—Global MilSatCom and Disruptive Space Technology Focus Day. Riverbank Park Plaza. London. See smi-online.co.uk/defence/uk/focus-day/global-milsatcom-small-satellites-and-disruptive-technology-focus-day

Nov. 10-15—Airshow China. Zhuhai, China. China International Aviation and Aerospace Exhibition Center. See airshow.com.cn/Category_1216/Index.aspx

Aviation Week Network Events

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

Nov. 11—Aviation Week A&D Mergers & Acquisitions Conference. Virtual event.

Nov. 11—CAPA Live. Virtual event.

Nov. 16—Business & General Aviation Conference. Virtual event.

Nov. 17-18—Military Aviation Logistics & Maintenance Symposium (MALMS). Virtual event.

Nov. 30-Dec. 4—Routes Reconnected. Hybrid event. Amsterdam.

Dec. 9—CAPA Live. Virtual event.

Jan. 13—CAPA Live. Virtual event.

Feb. 9-11—Routes Americas 2021. Bogota.

Feb. 10—CAPA Live. Virtual event.

March 2—Aerospace Raw Materials & Manufacturers Supply Chain Conference. Beverly Hills, California.

March 2-3—MRO Middle East. Dubai.

March 2-4—Commercial Aviation Industry Suppliers Conference. Beverly Hills, California.

March 10—CAPA Live. Virtual event.

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VIEWPOINT

Putting AI to the Test

By **Mark Roboff**

Artificial Intelligence (AI) is heralded as the next great technological revolution to transform aviation. Already it is changing how we service aircraft by powering predictive maintenance solutions, and one day AI will transform flying itself. For instance, AI is seen as critical to enabling new types of aircraft such as drones and autonomous air taxis, and it is likewise essential to managing a fast-evolving and increasingly complex airspace.

However, AI is far from guiding aircraft today, and no one is about to step on board an autonomously piloted airliner. While automation has indeed been a function of airplane systems for decades, AI—which, unlike automation, allows for machine decision-making at a high level—has not yet crossed from the realm of the IT data center into the aircraft or air traffic control system (ATC). That is about to change.

The technology to fly an airplane autonomously with AI (considered a flagship use case for the technology) or to manage the airspace is robust. The issue is not technological maturation but one of certification. In our regulated environment, how do we demonstrate that an AI system performing a safety-critical task is safe and can be trusted?

In June of last year, leaders from the aerospace engineering community gathered to answer this critical question with the creation of a new standards effort focused on AI certification. Born out of this work is a new joint international committee, SAE G-34/Eurocae WG-114. This committee—which now comprises more than 500 engineers, scientists and research fellows from across the aviation ecosystem—is working to create a strong and well-supported means of compliance for AI certification by the autumn of 2022. This is in line with the European Union Aviation Safety Agency's AI road map, released in January of this year, which calls for the first AI component to be certified by 2025.

"HOW DO WE DETERMINE THAT THE DATA GATHERED TO TRAIN AN AI SYSTEM IS SUITABLY REPRESENTATIVE OF THE REAL WORLD?"

The committee's research of existing aerospace engineering standards concludes that there is no clear pathway to certify AI through an existing means of compliance when using the critical AI subdomain known as machine learning with neural networks. (Machine learning with neural networks is widely viewed as the best way to build advanced AI-powered systems, up to and including autonomous flight systems.) The central issue is related to the concept of AI "explainability," which refers to the fact that, unlike traditional software code that can be read and logically understood, the inner workings of a neural network are an undecipherable mystery.

While R&D efforts are underway to make neural networks explainable, and while others are trying to find a new explainable approach to AI that proves just as powerful as neural networks, a consensus is forming that perhaps a better option is to devise a new approach to certification that works with neural networks as they are.

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Fortunately, we already have a useful model to work with: the certification of the human pilot.

When we bring a human pilot on a check ride, we do not wire diodes to the pilot's head in an attempt to read the neurons firing in their brain. We would not even know what to make of that information. Yet if we certified pilots like we certify avionics systems, studying the neurons is what we would be required to do. Since we do not have any physiochemical way to judge that a pilot can safely fly an airplane, we devise tools like the check ride, flight school or ground-school curriculum, which we then leverage to assign trust that the pilot can safely fly an airplane.

This analogy makes for a useful road map for a supposed certification of AI. Determining what constitutes a qualified ground school is similar to a critical question the committee is working on: How do we determine that the data gathered to train an AI system is suitably representative of the real world? Likewise, determining what constitutes a robust check ride is similar to another question: What are the requirements of the simulators and testing procedures used to verify AI performance?

While no one is going to rewrite the industry's approach to certification overnight, by tackling these critical questions, SAE-G34/Eurocae-WG114 is building a foundation that will finally bring AI to aircraft and ATC systems. The committee's first publication—a gap analysis of existing standards and statement of concerns for the development of AI certification—will be released this autumn.

Mark Roboff is the general manager for aerospace transformation at DXC Technology and chairman of the SAE-G34 AI in Aviation Committee.

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