Lockheed Martin's Quiet Supersonics

AIM-260 Revealed
U.S. Answer to China's Missiles

End of the Line
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AHAB AND THE PHOENIX
I had a feeling of deja vu as I read your excellent article on the “Lung-Like” propulsion of the Phoenix airship (May 20-June 2, p. 34). In the early 2000s, I worked at one of New Mexico State University’s labs as an aeronautical engineer and was privileged to be the program manager for a very similar vehicle. We called it the Aerobody (sometimes nicknamed AHAB, due to its whale-like proportions). The Aerobody was a solar-powered lighter-than-air vehicle (nonrigid rather than semi-rigid, as is the Phoenix) that pioneered the idea of using a ballonet to cause buoyancy and changes in center of gravity to enable propeller-less forward flight.

We took the concept far enough to demonstrate the validity of the underlying physics by building a subscale prototype that we successfully tested in indoor flight tests. Ultimately, the then-existing limits to photovoltaic cell and battery technology kept us from going past the prototype stage. I look forward to the British team continuing their present progress and successfully flying a larger prototype at a much higher altitude.

Mike Fisher, Logan, Utah

WING MAKER
There is a shameful omission in “Those Who Made Airbus What It Is Today” (June 3-16, p. 53). Who made the wings, or rather which individual kept British technology on board? Sir Arnold Hall, chairman of Hawker Siddeley, that’s who! There is a mention of the company in the text, but Sir Arnold was the man who could have made something special. Indeed, when the UK reentered the program in 1978, the original contract had to be rescinded. I interviewed him in the late 1970s, and he was forthright then about the importance of his original commitment.

Keith Hayward, London, England

DEFENSE DOUBLE-DECKER
In your interesting coverage of Airbus at 50, the section “Double-Deck Fuselage” in the “Innovation Drive” article (June 3-16, p. 59) seems to ignore that a double-decker flew for almost 20 years with Air France and the French Armée de l’air. This was the “Breguet deux-ponts,” aboard which I had my first flight back in the late 1950s.

Pierre Bernhard, Le Bar sur Loup, France

A MATTER OF TIME
Jeff Bezos’ lunar lander looks good (May 20-June 2, p. 30), but it is only what we used to call “Vu-graph engineering,” i.e., conceptual studies. It is worth looking, programmatically, at what it takes to deliver a crewed lunar landing in 2024. Here are some sobering planning milestones in support of a 2024 flight that should add some realism to the discussion:

- Flight: 9/30/24 (assumption)
- Launch vehicle integration and prelaunch testing: 1/24 to 9/30/24
- Flight test and certification: 6/1/22 to 1/1/24
- System and subsystem qualification: 6/20 to 6/1/22
- Design/development: 1/1/19 to 6/1/20
- Contract award: 1/1/19
- Request for proposals/proposal prep/evaluation: 4/1/18 to 1/1/19

The message is that more funding does not fix the issue of not enough time between now and 2024. The milestones above are unrealistically aggressive and contain significant risk for something as complex as a lunar lander program—and that doesn’t even take into account that we have already missed the contract available-to-promise by six months.

Tom Megna, Littleton, Colorado

ONLINE, On “MAX Grounding Challenges Both Boeing’s Present And Future” (June 17-30, p. 34), BERNAK MOORE comments:

I highly recommend that as Boeing and 737 MAX operators decide on their technical and training fixes that they do not underestimate the widespread fear, nervousness and doubt that is in the minds of airline passengers as they wait to see how FAA, Boeing and the airlines will implement a fail-safe fix. What they know is that FAA, Boeing, and the carriers all failed them and betrayed their trust, with fatal consequences. They will have just one more chance to make things right. I read how minimal the proposed simulator training and classroom training will be, and it concerns me that they don’t get it. The flying public is wary and feels betrayed. Go the extra mile to win them back.

On “Can New Concepts Reshape The Narrowbody Market?” (June 17-30, p. 49), myke PREDKO writes:

Thank you for the informative article. I would like to see a road map of technologies that the OEMs can pursue. If Boeing ever moves on the NMA, I would think that they would be looking at higher-aspect wings along with rear-mounted engines (for boundary-layer ingestion, with the added bonus of eliminating the need for MCAS). I would think that would make more sense than make up for the increased drag of a dual-aisle aircraft.

From there, it will be interesting to see what the approaches will be in the 2030s and 2040s.
Black was vice president/general manager for Leonardo DRS.

Connect Airways, a joint venture of Virgin Atlantic, Stobart Group and Cyrus Capital Partners, has promoted Mark Anderson to CEO from Virgin Atlantic executive vice president. Flybe may soon be part of the company.

Nok Air has appointed Wutthiphum Jurangkool as its new CEO and executive director. Jurangkool takes over the position from acting CEO Pravej Ongartsittigul, who has been named chairman of the executive committee. Wutthiphum Jurangkool is one of the four sons of Hathairatn Jurangkool, who has 22.15% share of the airline together with his brothers Nuttapol Jurangkool (24.33%) and Thaveechat Jurangkool (20.94%). In all, the Jurangkool family controls 67.4% of the airline's shares.

ExpressJet Airlines has named Jonyt Meyer as vice president and chief information officer, a new position. ExpressJet flies for United Airlines as a United Express carrier. As the company prepares for acquisition by ManaAir, Meyer will oversee all aspects of information technology operations.

Tanya Pemberton has joined The Aerospace Corp. as senior vice president for the National Systems Group in Chantilly, Virginia. Pemberton was chief information officer and director of information technology services the National Geospatial-Intelligence Agency.

StandardAero has named Roger Ross president of its Airlines and Fleets division. He was president of Esterline Technologies’ Sensors and Systems group.

Tamarack Aerospace Group, Inc., which has filed for Chapter 11 bankruptcy, has named Jacob Klinginsmith president and Nicholas Guida CEO. Klinginsmith had been chief engineer.

Philippe Wirth has been appointed chief financial officer and executive committee member at Gurit, effective January 2020. Wirth was chief financial officer of Crealogix and before that held several finance-related roles at Mettler-Toledo. Group Controller Patrick Sparer will serve as interim chief financial officer until January.

Jerry Hogge has joined Mitre Corp. as public sector senior vice president. He has held executive roles and led civilian and defense IT programs at SAIC, QinetiQ, Unisys, Level 3 and IDT Corp.

Marshall J. Taggart, Jr., has been named executive director of the Montgomery (Alabama) Regional Airport. Taggart had been deputy airport director at DeKalb Peachtree Airport.

Bob Sanchez has been appointed to the newly created position of director of government business development at Universal Avionics. Sanchez served 11 years in the U.S. Air Force as an avionics flight test engineer. He also worked with BAE Systems and as a consultant to the military and NASA before joining Universal Avionics in 2014 as program development manager for military and government.

Scott Stoki has been promoted to engineering overaul manager of operations at Duncan Aviation’s Lincoln, Nebraska, turbine engine maintenance facility. He was quality control inspector. Duncan also recently hired John Petersen as northwestern U.S. regional manager. He had been an avionics field service engineer for Honeywell.

Priscilla Branco has been hired as GE Capital Aviation Services’ regional manager for Latin America and the Caribbean. She was head of aircraft programs at Azul Airlines, where she led purchasing, leasing and financing activities.

Revima has elected David Hess, Marc McGowan and Franck Terner as board members/senior advisors. Hess has held leadership roles at United Technologies Corp., Pratt & Whitney and Hamilton Sundstrand; McGowan served at StandardAero and Honeywell; and Terner had been Air France CEO.

CDB Aviation, an Irish subsidiary of China Development Bank, has hired Luis da Silva as head of commercial for the Americas. He had been GECAS senior vice president/regional manager, Latin America and before that held senior sales positions at Airbus.

Richard Hjelmberg has joined UMS Skeldar as executive sales director. Hjelmberg was head of Saab maritime surveillance marketing and sales for the Asia-Pacific region. He is a licensed aircraft engineer.

Fiona Langton has been hired as managing director of Stobart Jet Center, based at London Southend Airport, which provides helicopter transfers to and from central London. Langton, who specializes in VIP aviation, comes from Stansted Airport and previously managed logistics in remote military-conflict zones.

Aviation Safety Resources has appointed David Treinis to its board, expanding the number of directors to five.

Universal Avionics has appointed Robert Randall to the new position of director of strategic business development to liaise with airframe and avionics OEMs.

HONORS & ELECTIONS

The CAE Women in Flight scholarship program has named Georgina Thomas-Watson, Daniella Saucedo Orozco and Bisma Petafi as its 2019 scholarship recipients.

 Ericka Hardin will receive the General Aviation Manufacturers Association’s Edward W. Stimpson Aviation Excellence Award. An active member of the Civil Air Patrol, Hardin will study Missionary Aviation Technology at the Moody Bible Institute.
50 YEARS AGO
IN AVIATION WEEK

Apollo 11 Commander Neil Armstrong was featured on our June 30, 1969, cover lifting off in the Bell Aerosystems Lunar Landing Training Vehicle during a maneuver designed to simulate a landing on the Moon’s gravity. He completed eight tests of the wingless vehicle in three days at Ellington AFB, Texas, flying a total of 40 min. 14 sec. Aviation Week’s Zack Strickland reported that Armstrong found the free-flying trainer to be a “significant improvement” over a Lunar Landing Research Vehicle that he had been forced to eject from when it crashed during a test flight 13 months earlier, an incident featured in the 2018 movie “First Man.” Armstrong became the first person to set foot on the Moon on July 20, 1969.

Subscribers can access Aviation Week’s original Apollo 11 coverage and every issue back to 1916 at: aviationweek.com

FIRST TAKE
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COMMERCIAL AVIATION

Production of the CRJ is to end in 2020 after Bombardier agreed to sell the program to Mitsubishi Heavy Industries for $550 million in cash and the assumption of $200 million in liabilities. Acquisition of the CRJ sales and support network will boost prospects for Mitsubishi Aircraft’s SpaceJet. When Boeing’s 737 MAX will return to service remains uncertain, but the beleaguered type has been boosted by a 200-aircraft purchase commitment from British Airways-led International Airlines Group.

Boeing is rejigging the 777X program to maximize ground testing to compensate for a lengthy delay to first flight following discovery of a durability issue with its General Electric GE9X engines.

CEOs of four major European manufacturers—Airbus, Leonardo, Rolls-Royce and Safran—have asked the EU to create a new public-private partnership to help aviation meet its environmental targets.

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CEOs of four major European manufacturers—Airbus, Leonardo, Rolls-Royce and Safran—have asked the EU to create a new public-private partnership to help aviation meet its environmental targets (page 20).

Supersonic airliner startup Boom has slipped first flight of the XB-1 demonstrator into 2020 but says its 55-seat Overture remains on track to enter service in 2025-27.

Regional aircraft lessor Nordic Aviation Capital has signed a $2 billion letter of intent for an additional 35 ATR turboprops, plus 35 options and purchase rights on another 35.

Delta Air Lines has acquired a 4.3% stake in Korean Air parent Hanjin-KAL, with the intent to eventually raise its stake to 10%.

Amid mounting losses, Lufthansa low-cost unit Eurowings will exit the long-haul market and no longer integrate sister company Brussels Airlines.

Daher, French producer of the TBM single-engine turboprop, has acquired Quest Aircraft, U.S. manufacturer of the Kodiak 100 utility aircraft (page 29).

Korea Aerospace Industries is to build wings for the Gulfstream G280 business jet under a $500 million contract from Israel Aerospace Industries.

TECHNOLOGY

NASA’s X-57 Maxwell electric-propulsion demonstrator has begun ground runs with electric motors replacing the piston engines on the modified Tecnam P2006T.

Rolls-Royce has secured a jump-start on the electrification of aircraft with the surprise acquisition of Siemens’ electric and hybrid-electric aerospace propulsion unit.

Electric motor developer MagniX has teamed up with certification specialist Aerotec to convert the Cessna 208B Caravan to electric propulsion, with flight testing to begin by year-end.

Airbus Helicopters is to fly an H130 single-turbine helicopter with an electric backup drive system in 2020 under a program with the French aviation authority DGAC.

Boeing is to collaborate with the Cora division of startup Kitty Hawk, which is developing an autonomous air
taxi. Kitty Hawk is funded by Google co-founder Larry Page.

DEFENSE

Israel Aerospace Industries and Embraer are to develop the P600 low-cost airborne early warning platform, mounting Elta's ELM-2096 radar atop Embraer's Praetor 600 business jet.

Spain has formally joined the Franco-German Future Combat Air System next-generation fighter program. First contracts for Spanish industry are expected by year-end (page 38).

Iran shot down a U.S. Navy Northrop Grumman RQ-4A Broad Area Maritime Surveillance-Demonstrator on June 20 while the unmanned aircraft was flying over the Strait of Hormuz.

Lockheed Martin is developing a new air-to-air missile for the U.S. Air Force and Navy with significantly greater range than the AIM-120 as a counter to China's new PL-15 weapon (page 36).

Russia reveals the Sukhoi S-70 Okhotnik flying-wing unmanned combat aircraft has a length of 14 m (45 ft.) and span of 19 m, making it comparable in size to Northrop Grumman's X-47B.

The UK has conducted the first operational missions with Lockheed Martin F-35s flying with Eurofighter Typhoons over Syria. Nine F-35Bs are deployed to RAF Akrotiri, Cyprus.

The Italian government has committed to place €700 million ($795 million) in orders with Piaggio Aerospace, in receivership, covering engine maintenance, Avanti turboprops and unmanned P1HHs.

SPACE

Hoping to shorten the span between the first and second test flights of its Space Launch System, NASA has awarded Bechtel National $383 million to build a second mobile launch platform by 2023.

Dassault wants 30% of the Space Rider reusable spaceplane program if it is given the go-ahead by European space ministers in November. Italy's Avio and Thales Alenia Space are co-prime contractors.

A SpaceX Falcon Heavy delivered 24 payloads into three orbits from Kennedy Space Center, Florida, on June 25 during a trial run for the U.S. Air Force that marked the military's first use of recycled boosters.

PROMOTED

Christopher Calio is to take over as President of Pratt & Whitney when Robert Leduc retires in early 2020. Calio has been in charge of Pratt's commercial engines business since 2017.

OBITUARY

Gary Burrell, co-founder of GPS-maker Garmin International, died June 12, aged 81. Formerly with King Radio and AlliedSignal, he co-founded Olathe, Kansas-based Garmin with Min Kao in 1989 and saw the company grow to become a supplier of integrated flight decks for business aircraft.

AWARDED

Aviation Week Network editors snagged three 2019 Aerospace Media Awards in Paris. Aviation Week & Space Technology was named Best International Publication. David Esler of BCA magazine won Best Business Aviation submission. And Inside MRO's Paul Seidenman and David Spanovich took the Best Propulsion submission. The awards were presented on June 16 at the Aero Club de France.

Representing Aviation Week at the awards were (from left) editors Victoria Moores, Thierry Dubois, Lindsay Bjerregaard, Steve Trimble, Lee Hudson, David Esler, Guy Norris and (foreground) Joe Anselmo.
Sustaining competitive advantage in the U.S. defense market will require more private investment alongside government-funded R&D. The business model favoring pure-play defense firms is under threat, and the Raytheon Technologies merger is a response: The scale of the company’s balance sheet and cash flow can accommodate big-bet investments on breakthrough innovations. This was the dominant message of the two CEOs’ pitch for the merger, and it rings true against the backdrop of recent Pentagon awards in which the winner’s up-front investments or willingness to bear back-end risk proved decisive.

Commercial aircraft suppliers will no longer abide bet-the-company projects, and diversification of end markets will form another line of defense against cost-cutting and risk-sharing imperatives. The ability to walk away is the ultimate leverage in any negotiation, and the merger with defense-focused Raytheon buttresses the hefty scale and scope UTC attained by acquiring Rockwell Collins, further strengthening its posture toward new projects like Boeing’s new midmarket airplane.

In an era of worrisome macroeconomic indicators, the uses of corporate development to shore up balance sheets will come into vogue. While the complementarity of the two companies’ capabilities and markets is being featured, it is the pairing of their capitalizations that as powerfully drives this transaction. As UTC Chief Financial Officer Akhil Johri put it in response to an equity analyst’s question about debt, “That’s the big benefit of this merger as well, where the shareholders can see some immediate benefits without having to focus on deleveraging, which would otherwise have been the case for the [the residual businesses of] UTC.”

The UTC-Raytheon merger is a salutary throwback to an era before 1993 when the capabilities and assets of commercial aerospace and defense firms were combined under iconic brands like Lockheed, British Aerospace, Goodrich, Hughes and even Raytheon itself. Raytheon Technologies expresses a back-to-the-future story line that begins to reintegrate our industry and reclaim the financial, technological and economic synergies that a more diversified portfolio can exploit.

Contributing columnist Steve Grundman is the principal of Grundman Advisory and a former deputy undersecretary of defense for industrial affairs.
Spreading ‘a Gospel’

A sea change in aviation points to a hybrid-electric future

brid-electric aerospace propulsion activities, the eAircraft business (page 20). Another highlight came when seven chief technology officers of major aerospace manufacturers issued a joint statement about their commitment to sustainable aviation (see photo).

“The thing that I found interesting here is the focus on environmental [issues], and the push for more environmental airfares,” Accenture A&D leader John Schmidt told Aviation Week during the show. “You saw the announcement that came out from the chief technology officers of some of the largest companies in aerospace and defense. And then you see the demonstrators, the small electric propulsion, the hybrid propulsion and fuels. It is quite interesting in how much of a focus this year this seems to have been.”

Industry consultant Richard Aboulafia of Teal Group agrees. “This Swedish girl Greta, she seems to be spreading a gospel that’s got some traction, and you never know what becomes of a demographic that way,” he says.

Days ahead of the show, several financial analysts sensed change was in the air. A group from Jefferies said they suddenly saw environmental concerns emerging as the next major risk to commercial aircraft deliveries, on top of international trade wars and other conflicts. “We believe something is up,” the analysts said in a June 7 report. “There is a risk of contagion. More uncertainty ahead feels probable; an adverse event possible.”

Recent comments from industry executives have raised eyebrows as well. “We need growth, but we do not need blind growth. We need high-quality, sustainable growth,” Lufthansa Group Chairman and CEO Carsten Spohr told investors at his company’s shareholders meeting on May 7. “Tickets for less than €10 ($11), as offered by some of our competitors, are economically, ecologically and politically irresponsible.”

Another memorable moment occurred during aerospace and defense supplier Meggitt’s investor conference May 15, when the company’s director for engineering and strategy, Hugh Clayton, said industry would heed a call to action. “It is becoming a generational issue,” he said. “It will become a defining issue for the sector in the future.”

A mid-May public poll of about 2,000 Americans and Germans for UBS Evidence Lab, a data-crunching operation inside the investment bank, found around 22% of respondents said they had already reduced their air travel on environmental grounds, while 38% said they

**GOING CONCERNS**

**MICHAEL BRUNO**

**WHILE GRETA THUNBERG PROBABLY did not attend the 2019 Paris Air Show, she seemed to be everywhere. The 16-year-old Swedish student—who has spurred Europeans and others to forgo flying on their summer vacations, due to carbon emissions from airliners—was not cited in formal press releases or announcements, but the “flight-shaming” effect she has helped foster was not far from some attendees’ minds.**

Just weeks ago, many aerospace and defense participants thought the 2019 extravaganza at Le Bourget would be doomed to be the air show without major orders. While that turned out not to be the case, the latest annual European air show may be better remembered as industry’s inflection point to a hybrid-electric and generally more environmentally friendly future.

To many people’s surprise, the show was punctuated with environmental announcements. Rolls-Royce announced a deal to buy Siemens’ electric and hy-
WHEN COMPARED TO MOST OTHER airframe manufacturers, Pilatus Aircraft is tiny. Last year it turned out just 128 aircraft.

But to make up for its modest volume, Pilatus embraces the values and standards of some older Swiss manufacturers, such as watchmakers Vacheron Constantin, Patek Philippe, Chopard, Piaget and Breitling, among others, whose products are not only mechanical masterpieces but a kind of art form as well.

No one would ever regard the soon-to-be-discontinued but ever-fabulous Pilatus PC-6 Porter as a thing of beauty, yet to witness its short-takeoff-and-landing performance is to behold a kind of aerial ballet. And that’s the thing about Pilatus—it bends the rules of everyday aviation to create something unique. In market-speak, that’s called “differentiation,” and it’s key to success in any marketplace.

Back in the late 1980s, the Stans, Switzerland-based company, whose offices and production hangars are close by the massive 7,000-ft. Mt. Pilatus, was primarily focused on single-engine military trainers. Its PC-9 was eventually adapted by Raytheon (later Hawker Beechcraft) to become the T-6 Texan II, which is now the basic flight trainer for the U.S. Air Force and Navy along with the air forces of several other countries. An iteration is also being promoted as a light attack/close air support aircraft.

To help rebalance that dependence on the defense market, Pilatus placed its faith and fortunes in developing a civilian aircraft unlike any other: a fast, pressurized machine powered by a single Pratt & Whitney Canada PT-6 turboprop that sported an executive cabin, but which notably featured a large, aft cargo door and was to be certified to operate out of short, unpaved airstrips.

Some aviation traditionalists were dismissive of the radically unconventional design. After all, who would want such a flying oddity, one that cost upward of $2 million and is produced and supported by such a small entity? Well, a quarter-century later, satisfied operators worldwide have signed for some 1,600 of them, and that list grows with every passing year. So much for “conventional” wisdom.

One of Pilatus’ next moves was to capitalize on the success of its corporate/cargo turboprop. And thus was begat the PC-24, the company’s first jet and like the PC-12, a multirole machine. Powered by two Williams International FJ44-4A turbofan engines each rated at 3,420-lb. thrust, the 18,300-lb. (maximum takeoff weight) aircraft can operate out of a 2,930-ft.-long airstrip—unpaved, of course—climb at 4,000 ft. per min. to an altitude of 45,000 ft. and cruise at 440 kt. for 2,000 nm with four passengers and 1,800 nm with six. Oh, and it features quick-change passenger seats and an aft cargo door as well, so it can double as a freighter, or whatever.

When Pilatus opened its orderbook for what it calls its “super-versatile” jet at the European Business Aviation Convention and Exhibition (EBACE) in Geneva in 2014, it closed the book within two days having accounted for 84 units, its first three years of production.

Among the buyers—and for a half-dozen—was George Antoniadis, the founder and CEO of PlaneSense, a Portsmouth, New Hampshire-based fractional aircraft ownership company and the world’s foremost PC-12 operator. Today PlaneSense operates three dozen PC-12s. His company took delivery of the first production PC-24 in February 2018 and logged some 1,100 hr. with it in its first year.

Victory Lap for Versatility

It’s all about differentiation

Now operating three PC-24s, he reports that “there’s a fantastic response” to the jet among PlaneSense owners, who appreciate its sturdiness, quiet and “voluminous” baggage compartment easily accessed through the cargo door.

When Pilatus finally reopened the orderbook for the now $10.7 million jet at EBACE 2019, Antoniadis was among those who signed for a combined total of 40 more. It was a clear victory lap for the Swiss planemaker.

The jet’s versatility is reflected in its range of applications. Beyond PlaneSense executive and vacation-travel owners, the PC-24 serves as the Swiss government’s “Air Force One,” as well as a Royal Flying Doctor Service air ambulance in the Australian Outback.

The enthusiasm for the Pilatus jet is also underscored by hundreds of turbine aircraft owners polled in the respected JetNet iQ survey. Among those who said they wanted or intended to buy a new aircraft, the PC-24 has been their clear favorite for the past three quarters.

Rolland Vincent, the creator and director of the poll, commented that Pilatus is “very good at what they do and selective about what they take on, with products that offer a unique value proposition.”

William Garvey is Editor-in-Chief of Business & Commercial Aviation
MUCH HAS BEEN WRITTEN LATELY about aviation and space history, including the 50th anniversary of the first flights of the Concorde and Boeing 747 and Airbus’ founding. And more is coming, with the anniversaries of the Apollo 11 Moon landing in July and Embraer’s founding in August.

Another historical milestone is worth looking at as well: July 13, 2008. It might not have the same magnitude as the others, but it is pretty important. On the eve of the Farnborough Airshow, Bombardier announced the formal launch of what was then known as the C Series. Former Airbus sales director John Leahy once called it “a nice little airplane.” Of course, the C Series was much more than that (and Leahy knew it)—its advent had a deep influence on the commercial aircraft sector and the airline industry as we know it today. That Bombardier completed its exit from the regional aircraft segment by selling the CRJ program to Mitsubishi on June 25 can also be placed within that context.

Eleven years ago, airlines were pushing aircraft manufacturers to finally develop more fuel-efficient aircraft than the A320 and Boeing 737NG—but neither Airbus nor Boeing were prepared to move. However, Bombardier was building on its own numerous studies for a larger aircraft and on the availability of Pratt & Whitney’s geared turbofan engine. Then it found Lufthansa, an airline that wanted to send a strong signal to Toulouse and Seattle. And the rest is history.

Although that history turned out differently than expected. In response, Airbus launched the A320neo program on Dec. 1, 2010. It was a major commercial success from the start. When Airbus was set to take all of a huge American Airlines narrowbody order a few months later, Boeing had to react and launched the 737 MAX. Board approval came on Aug. 30, 2011.

Boeing and Airbus were committed to keeping their duopoly and did everything they could to contain the C Series to a small base of operators. Their vast financial resources helped them throw out big discounts as needed. That, and out-of-control development costs for the C Series, caused Bombardier to go into crisis mode.

To save the company, Bombardier CEO Alain Bellemare decided to leave the regional aircraft business. The C Series was taken over by Airbus in 2018 and is now the A220; CRJ production will end in 2020, as Mitsubishi’s purchase deal focused on aftermarket services and, most important, the CRJ customer base to which it needs access. Parts of Bombardier’s aerostructures business are still for sale.

The success of the first generation of Embracer E-Jets also contributed to Bombardier’s existential crisis, and it is a bitter irony that that crisis has now forced Embracer to surrender its independence in the commercial aircraft business. Approvals for the Boeing Brasil joint venture are pending, but if everything goes to plan the Boeing-controlled unit will be operational by year-end.

Eleven years after the launch of the C Series, the Airbus/Boeing duopoly is more solid than ever. It controls the market not only from 150 seats upward but now down to 100 seats or (in Boeing’s case) 76 seats. The incumbents are so powerful, they can afford to buy a major aircraft program like the Embracer E2 when they are actually not that interested. Having access to Embracer’s low-cost and high-quality engineering capabilities was much more important—the E2 came as a little side dish. Buying it delayed China’s access to Western aircraft integration know-how for some years, opportune as well.

As Mitsubishi is now trying to become established with the M90/100 program, it is no longer competing with Bombardier or Embracer but Boeing instead. If it decides to stretch the aircraft further, as it has considered, it will compete with Airbus, too. The prospects seem bleak for any other new aircraft program becoming even mildly successful in the foreseeable future. Maybe a next-generation aircraft following the Craic CR929 has a chance, given China’s resources and the aerospace know-how it may have built up by then.

Lufthansa’s idea to create more competition among aircraft manufacturers by placing the original C Series order backfired completely. From the airline industry’s perspective, supplier positioning is far worse than it had been. The only good news is that the Airbus/Boeing rivalry remains fierce in many campaigns. It is therefore all the more important for big carriers not to become reliant on either. The threat of being able to switch over to the other manufacturer must remain credible.
The company believes its baseline design can economically operate on routes up to transpacific length while simultaneously overcoming the problems of sonic boom and airport noise that killed off the Concorde 16 years ago. Unlike earlier supersonic transport (SST) attempts by the industry, including by Lockheed, this time the concept builds on new enabling technologies in design, propulsion, aerodynamics and systems that were either not previously available or not sufficiently advanced.

The low-boom demonstrator for NASA and sensing the potential for an early jump start in the emerging commercial supersonic market, Lockheed Martin has unveiled details of a Mach 1.8 concept capable of transpacific routes with up to 40 passengers.

The company believes its baseline design can economically operate on routes up to transpacific length while simultaneously overcoming the problems of sonic boom and airport noise that killed off the Concorde 16 years ago. Unlike earlier supersonic transport (SST) attempts by the industry, including by Lockheed, this time the concept builds on new enabling technologies in design, propulsion, aerodynamics and systems that were either not previously available or not sufficiently advanced.

The design breakthroughs owe much to the X-59 QueSST in addition to leveraging studies conducted earlier this decade under NASA's N+2 quiet supersonic initiative, which preceded the low-boom demonstrator. These studies proved for the first time that low boom could realistically be combined with a good supersonic-cruise lift-to-drag ratio and established the fundamental building blocks of both NASA's latest X-plane and Lockheed's newest large supersonic concept.

“We now have the technology to dramatically reduce the impact of those sonic booms that were completely unacceptable from the Concorde,” says Michael Buonanno, Lockheed Martin air vehicle lead for the X-59. With the new demonstrator, which is targeted for first flight in 2021, “we are shifting the whole design space and proving we can shape sonic booms to make them dramatically quieter,” he says. “Leveraging data from X-59, regulators may replace the current boom with standards that future manufacturers of supersonic airliners could design to. So this could really usher in a new age of commercial transportation.”

The sharply swept delta-wing quiet SST design is 225 ft. long with a span of 73 ft., making it significantly longer than the Concorde but slightly narrower in span. Almost 70 ft. of the overall length is made up of the nose section, while the cabin occupies the central 78-ft. section of the fuselage. Twin tail-mounted nonafterburning engines, rated at 40,000 lb. thrust, are located between V-tails. “We’ve gone back to V-tails, which we studied early on for X-59. They’re best for the shaped-boom criteria, but we had challenges from a stability and control standpoint. We have now figured out the nuances of how to integrate those to get the benefit,” says Buonanno.

To get the most from the technology, Lockheed conducted a rigorous SST market analysis, which established a set of basic requirements for range, takeoff field length, passenger capacity, sonic-boom loudness at the start of cruise, overwater and overland cruise Mach number and airport noise. These were each given minimum threshold
values, below which the concept would not be viable, and objective values for optimum performance.

“We know it’s going to be very difficult to come up with an airplane that meets all the design objectives, so as we went through the process we looked at those trade-offs to see where we could give a little, though still not be worse than the threshold,” says Buonanno. “But it did enable us to come up with a sweet spot in terms of the design.”

Threshold range was set at 4,200 nm, which the company believes is sufficient for most top city pairs, while an objective range of 5,300 nm will enable nonstop transpacific missions. Target takeoff field length is less than 10,500 ft., though under 9,500 ft. is preferred, while the sweet spot for passenger capacity is set at 40. Using the Concorde as a reference, “we explored different markets and looked at load factors, and thought 40 [passengers] would be a good place,” says Buonanno. The minimum viable payload is 19, below which seat-mile costs are considered unrealistic.

For sonic boom loudness, the threshold requirement was set at less than 80 PLdB, with less than 75 PLdB as the optimum target. Whether these values are realistic depends on the outcome of the upcoming community-acceptance tests with the X-59, says Buonanno. The latest round of performance trades has projected a design with 5,200-nm range and a boom loudness of 80 PLdB. “So that’s slightly louder than the X-59 but still much, much quieter than Concorde,” he notes. “It’s an area we want to explore further, but until we get data from flight testing, it will be hard to gauge where the threshold of acceptability really lies.”

For the overland cruise, Lockheed’s design is optimized for Mach 1.7 or higher. Speeds of Mach 1.6 or lower adversely affect aircraft utilization and cruise efficiency. For flight over water, Mach 1.7 or greater is preferred, but speeds above Mach 1.8 begin to increase sonic boom loudness to unacceptable levels.

Airport noise targets are “consistent with future standards,” and although the exact requirements are still being decided by regulators and the International Civil Aviation Organization, Buonanno says the design and its propulsion system will be capable of meeting whatever is defined. “Noise regulations are still in development but are kind of a moving target, and we are aware of those,” he says.

To meet the requirements, the Lockheed design embraces four key enabling technologies: shaped-boom design, integrated low-noise propulsion, swept-wing supersonic natural laminar flow and the external vision system (XVS) for visibility from the cockpit. “These are things that have really changed in the past 10-20 years as a result of investments by the government and industry,” Buonanno notes.

The shaped-boom design technology is one of “the key ingredients as to why we think it’s a good time to move forward,” he says. “Ten years ago, the technology wasn’t there to truly hit low boom, and back 20 years ago, low boom was thought to be 85-90 PLdB. So the investment that NASA made to build up to the X-59 has become critical here, and the tools and methods we have used to shape the design of the X-59 are 100% transferable to a larger-scale commercial design.”

Major strides to tailor for low boom while minimizing the impact on supersonic cruise efficiency were made starting almost a decade ago during Lockheed’s work with NASA on a high-speed N+2 design. Advances in computational fluid dynamics (CFD) capabilities enabled more accurate modeling of the flowfield, while a new generation of geometry manipulation tools allowed designers to explore complex 3D flow perturbations. In addition, a new set of optimizers provided a means of quickly identifying realistic configurations. At the time, these tools were applied to a concept aimed at NASA’s N+2 goals for a 35-70-seat, Mach 1.6-1.8 jet with an 85-PLdB boom and airport noise 12 EPNdB be-

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**Quiet SST Key Features**

- Fixed STEX inlet directs shock upward
- Medium-bypass, non-afterburning turbofan engines
- Lifting, all-flying V-tail increases aft equivalent area, reducing signature
- Wing shielding eliminates inlet spillage contamination to signature
- Swept supersonic laminar flow for increased range and reduced emissions
- XVS/EFVS systems provide forward visibility
- Extended, equivalent area-matching nose shapes forward shock
- Source: Lockheed Martin
SUPersonics

low Stage 4, all of which came close to Lockheed’s 2019 quiet SST concept.

The second enabling technology, integrated low-noise propulsion, addresses the issue of airport noise, “which hamstrung Concorde just as much as its sonic boom,” says Buonanno. “Tackling that problem is going to be critical to having an acceptable future commercial supersonic transport. Lots of building blocks are now in place in terms of fundamental research that’s taken place over the past decade or so. When we put together those pieces, we can come up with an integrated propulsion system that will allow us to be successful.”

Elements include recent developments in advanced plug-nozzle designs, noise-shielding concepts and distortion-tolerant fan blades that operate at high efficiency yet cope with the turbulent flow in inlets designed for low boom. One such design is the streamline-traced external compression (STEX) inlet, which showed in NASA tests that it could direct the shockwave from inlet flow spillage up and away from the aircraft, providing both noise shielding and reduced boom.

Optimized for speeds of Mach 1.6 or slightly above, the STEX design incorporates an external supersonic diffuser and an inward-turning inlet that produces external cowl angles with low wave-drag compared to conventional axisymmetric spike inlets. The inlet leading edge is scarfed, and as the terminal shock was in tests seen to be located near the end of the diffuser, subsonic spillage was localized to a small part of the cowl lip. This feature could enable the inlet to be integrated with the overall aircraft to control the interaction of the spillage with the upper-wing surface.

Researchers also found that the low external cowl angles and localized subsonic spillage helped reduce external pressure disturbances that contribute to sonic boom. However, the STEX has challenges that will require further study. For instance, in tests it was found that interaction between the terminal shock and the boundary layer led to lower total pressure recovery and higher total pressure distortion compared to an axisymmetric spike inlet designed for the same conditions. Potential solutions could include adding bleed to the throat section or introducing vortex generators.

With the plug nozzle and modern engine cores from high-bypass-ratio turbofans adapted with new low-pressure systems, “We can thread the needle,” Buonanno says. “For efficient supersonic operations, we tend to want smaller fans and higher fan-pressure ratios, but for low noise, we want bigger fans with lower fan-pressure ratios. Now we have the key ingredients that let us come up with a solution that gives us good performance at supersonic flight and in the take-off-and-landing environment. A big part of this is the Mach 1.6-1.8 sweet spot, where we think we could come with a “first chip” ceremony, Congress passed the FAA Reauthorization Act, which directed the agency to reopen the case for civil supersonics. The legislation specifically requires the FAA to “develop and issue noise standards for sonic boom over the United States and for takeoff and landing and noise test requirements applicable to civil supersonic aircraft.”

“It’s all about overturning that regulation,” says Peter Iosifidis, Lockheed program manager for NASA’s Low-Boom Flight Demonstrator. “There are a lot of challenges to supersonic flight, but this is the primary goal. NASA is taking the lead on what is really going to allow aircraft manufacturers to go out and ultimately build commercial supersonic products.”

Although companies such as Boom and Aeron are pressing ahead with designs that circumvent the law by only flying supersonically over water; or by flying at transonic and low-Mach-number speed to minimize sonic boom, others including Lockheed Martin, are waiting in the wings for the regulatory landscape to change. “They won’t move forward and make the investment without that rule change in place, and that’s what this is really about,” adds Iosifidis.

Lockheed Martin Begins Assembly of X-59 Low-Boom Demonstrator

CRITICAL DESIGN REVIEW IS ON TRACK FOR SEPTEMBER

WING ASSEMBLY IS SET FOR COMPLETION IN 2020

Guy Norris Palmdale, California

Assembly of the X-59, the first purpose-designed piloted NASA aeronautics research X-plane since the X-31 nearly 30 years ago, is getting underway inside the cavernous Lockheed Martin Skunk Works facility in Palmdale, California.

Although only the first few sections of aluminum wing spars and keel beam have so far been loaded into the jigs, the outline of the assembly support structure reveals how the slender planform of the highly swept aircraft will eventually look. With a stiletto-like nose and a cockpit set amidships, the X-59 QueSST low-boom flight demonstrator is one of the most unusual designs to emerge from the Skunk Works.

Measuring 96 ft. 8 in. in length and with a wingspan of just 29 ft. 6 in., the X-59 is designed to validate whether careful airframe shaping can transform the traditional sonic boom of a supersonic aircraft into a publicly acceptable muted “thump.” Flying at Mach 1.4 and 50,000 ft., the X-59 is designed to produce a sonic thump of less than 75 PNLdB, compared with the 105-110-PLdB “double-bang” sonic boom produced by the Concorde supersonic airliner.

If the test program can prove that shaping will prevent shockwaves from the airframe coalescing into a conventional, loud N-wave boom, this could open the door to the development of environmentally acceptable commercial supersonic aircraft.

But before that can happen, the law in the U.S. must be changed. In October 2018, just a month before Lockheed marked the official start of parts manufacturing for the X-59
up with a good solution with today’s technology to meet those noise constraints.”

Another key enabler is the potential for swept-wing supersonic natural laminar flow (NLF). “[NLF] is at a fairly low technology readiness level, but we have identified it as having significant potential,” says Buonanno. Although Lockheed previously studied laminar flow with Aeronautics for application to that company’s AS2 supersonic business jet, “that technology would not be compatible for our low-noise or shaped-boom criteria,” he says. “However, NASA has done research in the past few years looking at the possibility of significant amounts of supersonic NLF with swept wings, and that would be highly swept. It would significantly help achieve our upper-range goals. The key is to get drag reduction without compromising the shaped-boom characteristics.”

Natural laminar flow can be created by designing the wing with a favorable pressure gradient to delay the transition of flow from laminar to turbulent. However, all previous practical NLF wings have been applied to either small aircraft or designs with low sweep. Lockheed’s challenge is that with increased sweep angle, the now-3D flowfield becomes susceptible to a form of boundary-layer instability called crossflow vortex instability. This causes the boundary layer to become turbulent closer to the wing leading edge.

The fourth enabler is the XVS high-definition camera and display system being developed by NASA for the X-59. As swept wings require higher angles of attack for takeoff and landing, the long nose obscures the view from the cockpit. The Concorde got around this with a droop-nose design, “but now we have the benefit of modern technology and can avoid that weight and complexity with an XVS,” Buonanno notes.

So what does Lockheed Martin hope to achieve by releasing the concept?

“We’ve been making investments to reduce sonic boom for decades, and now we are taking it to the next level,” says Peter Iosifidis, Lockheed program manager for NASA’s Low-Boom Flight Demonstrator. “We are taking those results and considering how we can leverage that learning into developing a supersonic product in partnership with somebody or perhaps to license it. We will explore all options.

“We are closer now than we have ever been, and with our work with the X-59, we are probably in the best position to put something forward to meet the demand for faster travel times,” he continues. “How that’s going to happen has not been determined, but this is the next step. We have put some significant engineering resources into creating a concept with some validity to it, although there’s a lot more work to be done,” Iosifidis says. “With this concept, we are putting our toe in the water to say we are open to explore those opportunities, wherever they might be.”

Lockheed is meanwhile moving toward a critical design review (CDR) in September, having completed crucial inlet distortion tests in the NASA Glenn Research Center’s 8 X 6-ft. supersonic wind tunnel. “The results were in line with predictions, so we don’t have to change the design of the inlet and won’t have restrictions on engine operability during the mission. It is also probably the last wind tunnel test we will have to do for this airplane,” says Iosifidis.

The tests, which were conducted at supersonic speeds covering all mission parameters, verified that the centrally mounted inlet will not ingest the fuselage boundary layer or suffer from inlet buzz, a condition in which a violent oscillation of the supersonic shock system can occur inside the inlet.

With clearance in hand to freeze the inlet design, Lockheed recently completed manufacturing readiness reviews for all major sections of the aircraft, including the forebody, wing and empennage. The review “validates the fact that the big bones of the airplane aren’t going to change, so manufacturing is in place and parts are being made,” says Iosifidis. “We are pumping out drawings at a regular rate, and beyond CDR, the next major milestone is first flight in the first half of 2021.”

Key structural elements, including the nose section and inlet, are being built by California-based Swift Engineering, a specialist company involved in aerospace composite manufacturing and the development of technologies for autonomous systems, robotics, urban mobility and power management. The chines are being built by aerostructures specialist San Diego Composites, while Moog is supplying actuators for the T-tail, ailerons and motors for the flaps.

The vertical tail is provided by aerostructures specialist D-J Engineering, while Lockheed is building the small T-tail, which is designed to help shape the sonic boom signature. “We are also building the forebody as well as the upper and lower empennage and nacelle. We are doing most of the spine and wing,” Iosifidis adds. Buildup of the first composite-skin panels began on the Skunk Works’ large fiber-placement machines in mid-June. The wing
The cockpit will be dominated by the large upper XVS conformal display and twin Collins Pro Line Fusion displays.

is due to be structurally complete by February 2020.

The relatively thin wing section has also driven Lockheed to pursue alternate options for monitoring fuel quantity, the correct measurement of which is made more vital because of the aircraft’s relatively restricted mission capability. It is designed to be able to perform only two back-to-back 50-mi. supersonic runs up to 100 mi. from a takeoff-and-landing site. Vermont-based Liquid Measurement Systems, which specializes in graphite composite fuel quantity measurement probes, is providing the X-59 system.

Collins Aerospace will provide flight deck avionics based on its Pro Line Fusion system and a dual-camera multispectral infrared enhanced vision system (EVS), the EVS-3600. Together with Lockheed, the companies are jointly developing software for the flight deck avionics. Pilot forward visibility is reduced because of the X-59’s long nose. The EVS—mounted beneath the nose—will be used primarily for landing and will work in conjunction with an external vision system (XVS), a forward-look- ing 4K camera system in development by NASA that will be mounted on the upper surface of the nose.

“We have stabilized the cockpit design and now we are nailing down the configuration,” says Lockheed Martin X-59A chief test pilot Dan Canin. Referencing the reuse of many other aircraft parts and components in the supersonic project, ranging from the standby instrument from an F-16 to the entire rear seat and canopy from a T-38, he adds, “In spite of the fact we have cobbled together parts from various legacy systems, very little of this looks like the airplane it came from.”

Along with a large-format upper display system for the XVS and test-related instrumentation, the X-59 cockpit also includes some unusual features such as a U-2-derived hydrazine air start system and a thermal battery system taken from a T-50 trainer that will run the aircraft’s emergency fuel-pump system.

Flight-control laws are also in development for the aircraft, which will be tuned to govern up-and-away handling qualities and adapted to approach and landing characteristics that are different because the aircraft is closer to the ground. “We have the basic control-law mode, which is like a fighter with pitch-rate and roll-rate command as well as sideslip with the pedals, but the greatest focus areas are on safety and working synthetically through the displays,” says Canin. Pilots should quickly get used to not having a forward window to look out of and instead using the displays, he adds. “It should not be spooky as long as we have depth perception.”

In the cockpit mockup, which is soon to become the systems-integration lab with real Collins- and NASA-provided equipment, Lockheed is also developing backup safety procedures in case of display failures. “Pilots would like to be able to land with no avionics at all,” says Canin. “Maybe with a chase aircraft and a spotter on the ground, and using the side windows for peripheral cues, we think we’ll be able to do that safely. Everyone will feel happier going into the development program if that’s possible.”

The sheer length of the aircraft, added to the aft location of the 17-ft., 6-in.-wheelbase landing gear, is driving careful consideration of flight-control laws for landing. “The amount of aircraft that’s aft of the gear gives us tailstrike potential after about 9.2-deg. pitch and on approach about 6 deg.” says Canin. The aircraft will therefore come in at a nominal 2.5-deg. approach angle and, although Lockheed estimates it will come over the fence at about 160 kt., Canin says, “We don’t want to get into a situation where we overrotate and get into a pilot-induced oscillation.”

To guard against this, the X-59 may take a leaf out of the Lockheed Martin F-35C control-law book. “Our initial concept for landing is going to be flightpath command with speed hold, in which we lock in the angle of attack and the flight path,” he adds. “So basically, we do a very shallow carrier landing where we don’t flare, and we just let it fly onto the deck. Flightpath command has changed the game for carrier aviation with the F-35C.”

Planning for the uncertainties of first flight is already underway. “The aircraft is very unstable longitudinally in pitch and very sensitive to cross-winds. The very high sweep angle gives us a lot of rolling moment with a bit of sideslip, so the more augmentation modes I can have for first flight the better,” says Canin. “The whole idea of the first flight is to get it back safely. So we are not going to move the gear and, after we take off, we will do practice approaches to make sure we can get back. Therefore, we want to have as many other options for that control law in case basic is not perfect.”

Lockheed plans to conduct initial airworthiness tests with a series of 10 or fewer flights out of Palmdale before taking the aircraft to the nearby NASA Armstrong Flight Research Center at Edwards AFB for an envelope expansion program expected to encompass 30 flights. These will be flown with NASA as part of the first of three main phases planned by the research agency.

Phase 1 covers aircraft development “from critical design all the way
In the cockpit mockup, which is soon to be structurally complete by November over Galveston, Texas, during which a NASA Boeing F/A-18 was used to simulate the reduced shockwave signature by flying a special supersonic dive profile off the coast. The maneuver resulted in a muted sonic boom reaching the community-response survey area onshore and anecdotally “sounded like a car door closing in the distance,” says Maliska, who was in Texas to witness the event.

<image: VIEWPOINT

Accelerating Supersonic Safety Standards

By Dan Elwell

Describing supersonic transportation as “the challenging new frontier in commercial aviation,” and “essential to a strong and forward-looking nation,” then-President John F. Kennedy, in remarks on June 5, 1963, called for a joint government-industry effort to develop a supersonic transport aircraft.

Over the next 50+ years, the U.S. led the world in the development of commercial spacecraft, unmanned aircraft, and electric aircraft—yet we have been unable to get a supersonic transport aircraft over the horizon. Now the FAA is reviewing and updating existing regulations to help enable innovation through the development and certification of new, commercially viable and environmentally responsible civil supersonic aircraft.

Today, we are taking an important step to accelerate the effort to reintroduce supersonic aircraft. The FAA is issuing a notice of proposed rulemaking (NPRM) to streamline the process for obtaining approval for flight testing of new supersonic aircraft. This paves the way for domestic supersonic aircraft manufacturers, startups and investors to continue their work and secure approval for supersonic flight testing in the U.S., and it is a signal to the rest of the world that the U.S. is making a serious regulatory commitment to the future of quieter and commercially viable supersonic aircraft.

New aircraft designs, propulsion systems and airframe materials offer promising benefits and require thorough assessment and evaluation for safety, as well as environmental impact such as noise and emissions—just as with every new aircraft we certify. The process to develop and approve these aircraft will take time. We will not see them overhead tomorrow, but we are committed to putting in place the regulatory framework to reenergize this exciting technology.

While there remain challenges ahead, do not bet against this group of high-flying entrepreneurs, experimental aviators and rocket scientists who aim to launch new aircraft designs, propulsion systems and airframe materials offer promising benefits and require thorough assessment and evaluation for safety, as well as environmental impact such as noise and emissions—just as with every new aircraft we certify. The process to develop and approve these aircraft will take time. We will not see them overhead tomorrow, but we are committed to putting in place the regulatory framework to reenergize this exciting technology.

While there remain challenges ahead, do not bet against this group of high-flying entrepreneurs, experimental aviators and rocket scientists who aim to launch new era of supersonic travel. Years of research, investment and technological advancement have paved the way for a new generation of commercially viable supersonic aircraft. Our goal is to enable U.S. innovators to safely open new aviation frontiers. As these supersonic entrepreneurs bring the world closer, they will create jobs, economic prosperity and aviation growth for all Americans. Let’s open the skies for them.

Dan Elwell is acting administrator of the U.S. FAA. The views expressed are not necessarily those of Aviation Week.
Fifty years after the appearance of the world’s first wide-body and supersonic airliners at the Paris Air Show signaled a new era of speed and capacity, the debut this year of an unprecedented wave of electric and hybrid-electric aircraft shows the industry is getting increasingly serious about sustainable growth.

Ranging from light aircraft to plans for large-scale technology demonstrators, the upsurge in electrically powered projects was also paralleled at the show by broader strategic policy moves that underlie the emerging sea change toward reducing aviation’s environmental impact.

The CEOs of four major European manufacturers used the air show as a platform to ask EU institutions to create a new public-private partnership that will help aviation meet ambitious environmental targets. Separately, chief technology officers from industry archrivals jointly reiterated industry’s commitment to halving 2005-level CO2 emissions by 2050.

“Global warming is a reality. This will not be easy, and we need to invest to develop the technology—and it’s something we need to do together,” said Airbus CEO Guillaume Faury, who was joined by Leonardo CEO Alessandro Profumo, Rolls-Royce CEO Warren East and Safran CEO Philippe Petitcolin. The group formally handed over the joint declaration to European Commission Director General Jean-Eric Paquet. Twenty-three signatories were represented, including Dassault Aviation, MTU Aero Engines, Thales and several other major suppliers as well as research centers.

Agreeing on the need for a “deep decarbonization” of air transport, the declaration is expected to redirect the ongoing pan-European Clean Sky aeronautical research project toward more electric propulsion and other sustainable technologies. Referring to “limiting climate change and pursuing the Paris Agreement goals,” the declaration says a technical road map will be completed by year-end.

Despite a promise to focus on more radical technologies, the signatories acknowledge there will be no single silver bullet and that solutions will come from a combination of advancements in fuel, propulsion systems and air traffic management. The goals are not yet defined in numbers, but the promoters of the proposed next, and third, phase of the Clean Sky initiative referred in April to an 80% cut in CO2 emissions, baselined against current standards, for an aircraft entering service in 2035.

Paquet says the required financial support may come from several EU schemes. “The challenge on the EU’s side will be connecting the dots between these budgets and finding a continuum for research on low technology readiness level, demonstrators and [products],” he adds. But the EU’s contribution is a fraction of the industry’s own effort, he adds. The EU’s 2021-27 budget is expected to be voted on by year-end, and the detailed allocation will be decided over the course of 2020. The hoped-for Clean Sky 3 could start on Jan. 1, 2021, at the earliest.

The chief technology officers (CTO) of Airbus, Boeing, Dassault, GE Aviation, Rolls-Royce, Safran and UTC meanwhile outlined a shared commitment to reducing emissions and ensuring a more ecologically sustainable future for aviation. But the path to reaching ambitious goals remains unclear and, despite good progress toward targets set by the Air Transport...
Action Group, they say step changes will be required to ensure the industry’s future is sustainable.

One such change, they argue, is greater production of sustainable alternative fuels. So-called “drop-in” fuels are already available and can reduce emissions on current platforms without modification. But uptake is limited by low levels of supply and high cost. “It’s a problem that’s big enough that we have to come together to tackle it,” Boeing CTO Greg Hyslop tells Aviation Week. “From the fuel perspective, we have to get incentives in place for the oil industry, and we have to get that going now.”

“We will work closely with fuel producers, operators, airports, environmental organizations and government agencies to bring these fuels into widespread aviation use well ahead of 2050,” the CTOs say in a statement released at the show. “We will meet three times a year because there is so much to be done,” adds Rolls CTO Paul Stein.

Amid a flurry of related electric aviation developments at the show, Rolls-Royce bolstered its position by the surprise acquisition of Siemens’ electric and hybrid-electric aerospace propulsion unit. Based in Germany, Siemens’ eAircraft business has been developing all-electric and hybrid-electric propulsion systems for aircraft such as Eviation’s Alice nine-seater commuter aircraft and the E-Fan X hybrid-electric demonstrator with Airbus and Rolls-Royce.

Under the acquisition, the company’s electric-propulsion design team of 180 specialists will be integrated into Rolls-Royce’s recently created electrification unit. While aimed initially at new markets ranging from electric vertical-takeoff-and-landing vehicles to small regional airliners, the move opens potential doors to longer-term ambitions such as propulsion systems for future hybrid-electric single-aisle successors to today’s Airbus A320 and Boeing 737 families.

“We were very pleased with the progress Siemens had made on electric flight, particularly in the smaller side of things,” says Stein. “They’ve developed tremendous intellectual property and have a top-class team of engineers. The first step is to amalgamate them with our electrical capability. It really will be a situation where one plus one equals three.”

Airbus and Rolls-Royce in the meantime remain on track to start modifying a BAe 146/RJ100 airliner into the E-Fan X hybrid-electric demonstrator in 2020. Stein says that “gets us into the megawatt-class of electrical systems, which is breakthrough technology for the future.” Under the revised arrangement, following the Siemens changes, Rolls will continue to oversee the power-generation system and associated power electronics and now has complete responsibility for the electric-propulsion unit, including a 2-megawatt e-motor and inverter.

Airbus is responsible for the overall integration of the hybrid-electric propulsion system into the aircraft and the system’s lithium-ion battery pack as well as the 3-kilovolt AC/DC distribution network, harnesses and power distribution center. Both companies collectively take care of thermal management and the control architecture.

The 2.5-megawatt turbogenerator at the heart of the demonstrator is based on a Rolls AE2100 turboprop from a Saab 2000 mounted in the rear fuselage. It will provide electricity to the battery pack mounted under the cabin floor and an electric motor that replaces one of the aircraft’s four Honeywell LF507 turbofans. The motor will power a fan from a Rolls AE3007 mounted in an inboard nacelle.

“This is an incredibly challenging task for our teams,” says Airbus CTO Grazia Vittadini. Flight testing, which begins in 2021, will focus particularly on “handling power transients which are critical on something like this,” she adds.

United Technologies Advanced Projects (UTAP) also updated progress on Project 804, a 2-megawatt-class hybrid-electric propulsion demonstrator based on a modified Bombardier Dash 8-100 regional turboprop. Unlike the E-Fan X, which is purely a drivetrain demonstrator, Project 804 is intended to produce a system that is “producing—capable of being developed into a product.”

Retaining the standard Pratt & Whitney Canada (P&WC) PW121 turboprop on one side, the second engine will be replaced by a new 1-megawatt turbine engine under development by P&WC. This turbine, or “thermal,” engine drives a gearbox that powers the propeller. The 1-megawatt electric motor, powered by batteries installed under the cabin floor, drives the same gearbox.

For takeoff and climb, both the thermal engine and electric motor drive the propeller. In cruise, only the thermal engine is used. On descent, the motor operates as a generator, and excess thermal-engine power is used to recharge the batteries to ensure sufficient energy is available for a go-around. With a preliminary design review complete and critical review set for year-end, UTC CTO Paul Eremenko says the project is on track for ground tests in 2021 and flight tests in 2022. “That makes it a very aggressive race,” he notes. “But 1-megawatt is a sweet spot for various products, and bringing them into flight will position us as a leader.”

Illustrating the growing commercial reality of electric aircraft, Israeli-based startup Eviation revealed U.S. regional carrier Cape Air as launch customer for the Alice. Powered by three pusher propellers, the aircraft is offered with a choice of 260-kW electric motors provided by either Siemens or MagniX. The latter also disclosed that it is teaming with certification specialist AeroTEC to convert the Cessna 208B Caravan to electric propulsion.

Flight testing of the single-turboprop utility aircraft repowered with the 750-hp Magni500 electric motor is planned to begin by the end of 2019. Eviation is also joining with AeroTEC to flight-test the Alice at the U.S. company’s facility in Moses Lake, Washington, later this year. MagniX has already announced agreements with Canada’s Harbour Air to convert the de Havilland Canada DHC-2 Beaver seaplane
to battery-electric propulsion. In a similar move, U.S. startup Ampaire has announced Personal Airline Exchange (PAX) as the launch customer for a modified Cessna 337 Skymaster in which the aft engine is replaced with a battery-powered electric motor. PAX has placed an order for 50 Ampaire 337s, plus options for 50 more. Ampaire is aiming to certify the six-seat aircraft, also called the Electric Eel, in 2021.

A modified Cessna 337 is also being used by French startup VoltAero to begin the phased development of the Cassio, a hybrid-electric aircraft that will be available with four, six or nine seats. Based on a series/parallel hybrid design, the Cassio will be able to fly as a pure electric aircraft over ranges up to 200 km (108 nm) at 200 kt., as a battery-assisted mild hybrid over 200-600 km and to ranges exceeding 600 km as a strong hybrid making more use of the combustion engine.

Led by CEO Jean Botti, former chief technology officer at Airbus, VoltAero displayed an “iron bird” mockup of the demonstrator at Le Bourget with an electric motor on one wing and an integrated power module in the rear fuselage. In its final form, the aircraft will have two electric-driven tractor propellers mounted on the wing and a third pusher propeller mounted on the rear fuselage, driven by a power module that combines an internal-combustion, or thermal, engine and three electric motors.

Daher, Airbus and Safran also unveiled plans at the air show to

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**Boeing May Reset the NMA Sequence as Airbus Launches the A321XLR**

*Jens Flottau and Guy Norris, Le Bourget*

When Airbus Chief Commercial Officer Christian Scherer looked back at a long and exhausting Paris Air Show, he said he felt “mild, if not violent, satisfaction.” The biannual event was exhausting for the Airbus sales director because he spent more time onstage announcing orders than many might have anticipated—and even more time trying to finalize deals behind the scenes. “Violent satisfaction” kicked in for the same reasons.

Airbus had come to the show looking to prove that its approach to filling the space between the traditional single-aisle aircraft and widebodies works well, to the extent that it significantly shrinks the addressable user base for Boeing’s proposed new midmarket airplane (NMA).

It is fair to assume that the total of commitments and specific deals for the newly launched A321XLR will add to the pressure on Boeing to proceed with the NMA and bring it to market sooner rather than later. American Airlines’ decision to replace its Boeing 757 fleet with the XLR is particularly painful, because the carrier was a key target in the NMA sales campaign. Yet American, which ordered the original Airbus A320neo family in 2011 and so forced Boeing to launch the 737 MAX in 2012, did not wait. Others, particularly those needing to replace larger 767s, may go in different directions.

As much as Airbus portrayed the XLR launch as a major success, some in the market also voiced caution about the true prospects of the latest A321neo version. The sharpest pushback came from Lufthansa CEO Carsten Spohr. While he says that the XLR could find a role in the group’s network, he also described the variant as a “niche aircraft” that cannot compete with wide-body comfort levels, both in terms of cabin dimensions and noise levels.

The CEO of one of the largest lessors said he remains hesitant to order the XLR. He expects the market to be around 400-500 aircraft, therefore not big enough for those in the leasing industry that focus on the most common types. Airbus, of course, argues that the changes and weight penalty compared to the A321neo and A321ACF (for Airbus cabin-flex) are marginal, and thus the aircraft can be used in interchangeable roles.

Airbus went ahead with the launch on the back of several large commitments—from American, Air Lease Corp. (ALC), Indigo Partners and JetBlue Airways, among others. In total, airlines signed firm orders or letters of intent for 229 aircraft (see table, page 24). Middle East Airlines is the launch customer, and it is planned to enter service at the end of 2023. That would be around two years ahead of the earliest conceivable NMA entry-into-service date.

“[There is] potential for 50 new airlines [ordering the XLR] in the next five years at least,” says ALC CEO John Plueger. “[It will be] a formidable [NMA] competitor . . . and it will be available years earlier.”

The A321XLR differs in some ways from the baseline A321neo and the A321LR. Its maximum takeoff weight is increased to 101 tons from 97, the landing gear will be strengthened, and Airbus is developing single-slotted flaps. Engine thrust requirements are not changing, according to Airbus, although ALC Executive Chairman Steve Udvar-Hazy hints that engine manufacturers will “have to make some improvements.”

The main change to the aircraft’s configuration is the addition of an integrated rear center tank (RCT) for increased fuel volume. Airlines also have the option to add another auxiliary fuel tank forward of the wing, should missions require it.

The aircraft will be capable of flying 4,700 nm in a configuration for around 200 passengers. That is around 700 nm, 15% more, than the LR variant, which in turn is 15% above the baseline A321neo. The extension puts the aircraft into the same range territory
American Airlines ordered 50 A321XLRs to replace its Boeing 757s.

As the 757. The A321neo is certified for up to 244 passengers and may burn 30% less fuel per seat than the 757, which is currently used on thin long-haul routes by many airlines across the Atlantic. The real figures depend on cabin configuration.

The RCT will hold an additional fuel volume equivalent to four auxiliary fuel tanks, but will occupy only the space of two and weigh as much as one of the removable tanks. The arrangement, Scherer pointed out, will liberate space for cargo. The RCT will weigh “a few hundred pounds” and will therefore not add a lot of unnecessary structural weight to the aircraft on shorter missions where the additional capabilities are not required.

The XLR can fly routes such as Sapporo, Japan, to New Delhi, India; the Middle East to Bali, Indonesia; Japan to Australia; Rome to New York; or Miami to Buenos Aires, Argentina.

Airbus’ thinking behind the introduction of the RCT was to keep changes as simple as possible. One of the reasons for that is because the XLR will be produced on the same final assembly lines as the other A320neo-family versions. “A smooth industrial introduction is the main challenge,” says Airbus Executive Vice President for Engineering Jean-Brice Dumont.

Another challenge the XLR is facing is to serve routes that are more important to the airline. For example, routes like European short-haul or Asian long-haul, where the A320neo can already provide a good service.

The engine rating that will be required for the XLR is around 35,000 lb. of thrust, but currently only 33,000 lb. are used by some airlines requiring high engine performance. According to Dumont, it is clear that no more than the 35,000 lb. are needed for the XLR, so no additional engine work is required. But the move up could also entail higher spending on maintenance; Airbus is evaluating whether the lower current operational maximum will be sufficient.

The A321XLR is likely not the last A321 product development. Airbus has studied more substantial upgrades, including introduction of a composite wing or a stretch to accommodate more passengers. The OEM opted for the lowest-risk, highest-commonality path for now. But the A321neo has further upgrade potential “in many directions,” Dumont makes clear. Exactly what direction might be pursued in the future is less clear. “The question is: What does the market want? I’m not sure you need even more range,” says Dumont. One area Airbus could explore is technology to cut back on turnaround times, he notes.

Further changes will strongly depend on the design choices Boeing makes for its NMA. Given the continuing grounding of the 737 MAX fleet, the project is not well-known to the public, but industry sources say engineering work and supplier talks continue ahead whenever upgraded versions of the existing aircraft family are launched.
of a potential launch at next year’s Farnborough Airshow.

In spite of the relative quiet, some new thinking is emerging around the NMA. Boeing is leaning toward offering the larger of the two proposed variants first, for delivery in 2025, as it nears closing the business case and obtaining board permission for formal authority to offer later this year.

Boeing traditionally leads new product introductions with a baseline variant before launching follow-on stretch versions and, until recently, was expected to follow convention with the NMA, which will be offered in the 225-seat NMA-6X and 275-seat NMA-7X configurations. The shift to prioritizing the larger member of the new family appears to reflect the emergence of the XLR.

The A321XLR effectively competes with the Boeing 757/6-6X market sector, so prioritizing the -7X would also give Boeing an earlier opportunity to access an untapped segment with an all-new design. Airbus plans to address the upper end of the middle market with the two versions of the A330neo.

Indications of the manufacturer’s shifting stance on the NMA came from General Electric Aviation President David Joyce, who says Boeing is likely to “start with the -7 and not the -6.” The engine-maker, bidding to provide a new turbofan of at least 50,000 lb. thrust from its CFM International joint venture with Safran, says it is working to be sole source supplier.

Joyce says Pratt & Whitney is also pursuing a similar course with a variant of the PW1000G geared turbofan, Rolls-Royce having withdrawn its UltraFan geared engine earlier this year. “The size of the market doesn’t support the investment of two engine-makers,” he says.

Although declining to discuss specific family variants, Boeing Commercial Airplanes President Kevin McAllister says the business case studies continue for the NMA and that “once completed, we will make a decision.” He adds that Boeing is trying to “drive as much of the definition of the program as far left as possible.” The focus remains on the opportunity to bring an airplane that really is sized to the middle of the market; 20% greater in seats or in range versus today’s 757 family, he says. “So for us, it is [about] making sure that we’ve got the production system lined out correctly.”

### Mitsubishi Deal Spells the End to CRJ Sales and Production

> **BOMBARDIER WILL CONTINUE TO SUPPLY CRJ COMPONENTS**
> **SALES AND SUPPORT NETWORK WILL BOOST SPACEJET PROSPECTS**

#### Graham Warwick and Michael Bruno Washington

What do you do if you have a next-generation aircraft but no installed base of operators to sell into? For Mitsubishi Heavy Industries (MHI), the answer is to buy Bombardier’s CRJ program, providing access to a support network and potential customers for the SpaceJet regional jet family under development by Mitsubishi Aircraft Corp.

For Bombardier, the deal—announced on June 25 and expected to close in the first half of 2020—will complete its exit from the commercial aircraft market, a key element of the five-year turnaround plan launched in 2015 by new CEO Alain Bellemare (see page 13). Once complete, the Canadian company will emerge from the turn-around focused on business aircraft and rail transportation.

Bombardier will not make much from the sale of the once-mighty CRJ program, but removing the loss-making business from its books will modestly improve its finances. Analysts expect Bombardier to net only about $170 million from the $550 million in cash that MHI will pay, but its ongoing liabilities will be reduced and capped.

MHI will acquire the support and sales activities for the CRJ but not its production. Bombardier will deliver the aircraft currently in backlog, then shut down the production line in Mirabel, Montreal, in the second half of 2020. There were 51 of 1,950 CRJs sold still in backlog as of March 31.

Bombardier will continue to supply CRJ components and spares to MHI. But the deal has implications for the company’s Belfast, Northern Ireland, and Casablanca, Morocco, aerostructures plants, where CRJ parts and assemblies are produced, but which are also up for sale as part of the turnaround plan.

There are two key aspects to the deal. First, MHI will assume about $200 million in liabilities for credit and residual-value guarantees previously provided by Bombardier to CRJ buyers. Bombardier will retain about $400 million of these liabilities, to be paid out over the next four years, but the amount will be fixed and not subject to future changes in aircraft value. Previously, Bombardier estimated its worst-case exposure to these guarantees at $1.1 billion.

Second, Bombardier’s net beneficial interest in the Regional Aircraft Securitization Program (Raspro), valued at approximately $180 million, will be transferred to MHI. Raspro is a trust established in 2005 to own 70 regional aircraft, including 65 CRJs, and lease them to four U.S. airlines. It is this transfer that reduces the net value of the selloff to Bombardier.

“But Mitsubishi’s acquisition of Bombardier’s CRJ assets is the ultimate win-win for stakeholders,” says industry consultant Kevin Michaels.
Managing director of Aerodynamic Advisory.

What MHI will get from the deal is a profitable support business based in Montreal and Toronto and service centers in Bridgeport, West Virginia, and Tucson, Arizona, as well as the CRJ type certificates. “In combination with our existing infrastructure and resources in Japan, Canada and elsewhere, we are confident that this represents one effective strategy that will contribute to the future success of the Mitsubishi SpaceJet family,” says Seiji Izumisawa, president and CEO of MHI. Acquisition of an established sales and support network will boost Mitsubishi Aircraft’s efforts to sell the SpaceJet, particularly into North America. The smaller, 76-seat member of the rebranded Mitsubishi Regional Jet family—formerly the MRJ75, now the M100—has been redesigned to be compliant with U.S. pilot scope-clause limitations, and a memorandum of understanding for 15 aircraft was signed at the Paris Air Show by a potential North American launch customer.

With no sign yet that scope clauses will change, once the CRJ is out of production in 2020, only the M100—and Embraer’s current E170—will comply with the limits. But by then, Embraer’s commercial aircraft business will be part of a joint venture with Boeing. With the SpaceJet competing against Embraer’s E2 family, this will put Mitsubishi’s bulked-up regional aircraft business head-to-head against Boeing—the exact move that drove Bombardier out of the airliner market.

Only about 50 of the 1,950 CRJs sold remain to be produced.
Boeing Faces New Hurdle in MAX Recertification Effort

Sean Broderick Le Bourget and Washington and Jens Flottau Le Bourget and Frankfurt

The recent Paris Air Show provided a dramatic stage for an unexpected, emphatic boost to the Boeing 737 MAX’s public perception, as International Airlines Group (IAG) announced its intention to purchase 200 of the grounded model—easily the largest order-related announcement unveiled during the weeklong aerospace extravaganza. But even as industry pondered the move’s significance, events taking place in the U.S. would soon further complicate the grounded fleet’s prolonged and uncertain return-to-service prospects.

As many marveled at Boeing’s public-relations coup, FAA test pilots were putting updated MAX flight-control software through its paces using the company’s engineering flight simulator, running through runway stabilizer scenarios and the requisite non-normal checklist. The initial step is to use control-column-mounted electric-trim switches to command horizontal stabilizer movement to “neutralize control-column pitch forces,” as Boeing explains in a November 2018 flight crew bulletin, and to counter the runaway. A subsequent step, if needed, is to toggle cutout switches that disable the trim motors. A source with knowledge of the simulator test says the FAA pilots found response to the electric-trim inputs lagged.

The issue has been traced to how quickly a flight-control computer (FCC) chip processes data, the source says. The discovery came during a very specific failure scenario, the source cautions, and it is not clear whether it can be linked to two fatal 737-8 accident sequences due to faulty angle-of-attack data being fed to the FCC. The MCAS’ failure can result in a runaway stabilizer scenario, and Boeing’s long-held assumption was that pilots would quickly recognize the failure mode and counter it with the “stabilizer runaway” checklist, which is supposed to be committed to memory.

Preliminary reports on both accidents suggest pilots used the column-mounted switches to counter the MCAS. Neither crew followed the runway stabilizer checklist step by step and neither was able to counter the MCAS’ repeated horizontal stabilizer nose-down inputs. Both accident sequences ended with high-speed dives that killed all 346 passengers and crew onboard both aircraft.

Discovery of the computer-chip issue is the latest, and arguably most visible, item on an extensive list the FAA has flagged in its review of Boeing’s MCAS software changes and of related systems. Not long after the MAX’s grounding, some within the agency expressed confidence that Boeing’s changes, triggered by early findings in the Lion Air accident investigation and well into development, would be finalized by early May. The FAA arranged a May 23 meeting of global regulators in Fort Worth, with the intent of presenting its analysis of Boeing’s changes and justification of why the updates alleviated the U.S. regulator’s concerns about the MAX’s safety.

By early May, however, it became clear the timeline would be stretched.
A VIATION WEEK & SPACE TECHNOLOGY /JULY 1-14, 2019

Boeing Faces New Hurdle

A newly discovered issue will keep MAXs parked even longer.

As many marveled at Boeing's public perception of the MAX, a dramatic stage for an unexpected boost to the aerospace extravaganza. But even as the largest order-related announcements of aerospace and airline deals roll through the markets, Boeing has been working on changes to the model's flight control systems. Not long after the MAX's return to service, the agency says. "The FAA is following a thorough process, not a prescribed timeline, for resolving the safety issues that led to the MAX's grounding, some within the agency says. The discovery came during a ground test of the MAX's flight-control computer. The issue has been traced to how the software processes data from the flight's sensors.

The FAA recently found a potential risk with the MAX's software, specifically the Maneuvering Characteristics Augmentation System (MCAS). The MCAS system was designed to prevent the aircraft from stalling by automatically trimming the nose down in certain flight scenarios. However, the FAA found that the system could activate erroneously in both accident sequences due to faulty angle-of-attack sensors.

Preliminary reports on both accident sequences ended with high-speed dives and high-angle-of-attack conditions. Both accident sequences suggest pilots used the control column to counter the runaway stabilizer checklist step by step and neither was able to counter the nose-down inputs in certain flight scenarios, and it is not clear whether it can be linked to two fatal accidents. Expert panelists will be on hand from the ranks of active deal-makers and leading advisors to provide first-hand perspectives.

The MAX has been grounded since late March, following the March 10 Ethiopian Airlines Flight 302 accident in Ethiopia that killed all 157 passengers and crew. Also, the 737 MAX was grounded in March in the U.S. after a similar accident in Indonesia that killed all 189 passengers and crew. Government officials, and gain exclusive intelligence enabling you to keep a competitive advantage in these dynamic markets.
CR929 Has ‘Soft Orders,’ Delivery Due in 2025-27

FIRST FLIGHT EXPECTED IN 2023–25
ENGINEERING CENTER WILL BE IN RUSSIA

Maxim Pyadushkin Moscow and Bradley Perrett Beijing

The Craigir CR929 widebody airliner program has gained its first preliminary sales agreements, says consortium partner United Aircraft Corp. (UAC), which has also widened development schedule targets to allow for slippage from earlier dates. First delivery may now occur as late as 2027, according to UAC. That would be two years later than the timing that the Chinese partner in the program, Comac, mentioned in 2018.

The statements on both orders and program timing, made by UAC President Yury Slyusar, seem to address differences from earlier opinions expressed by the two sides. In both respects, UAC has tended to be more conservative than Comac in its outlook.

In its initial CR929-600 form, the aircraft is designed to fly 12,000 km (7,500 mi.) with 291 passengers in a two-class seating arrangement.

The program has gained “soft orders” for 200 aircraft, Slyusar told the St. Petersburg Economic Forum, a high-level conference sponsored by the Russian government. Slyusar did not define “soft orders,” but Comac, in its own commercial aircraft programs, has sometimes booked orders that could be called soft because they have had little binding effect. Indeed, some of its contracts have evidently been signed and announced just for show.

Comac and UAC have not previously announced contracts for CR929s in any form. But in April Comac’s deputy director of marketing and sales, Yang Yang, said the first orders would be booked at the end of this year. The chairman of the Craigir board, Russian Deputy Minister of Industry and Trade Oleg Bocharov, contradicted Yang on the following day with a more conservative outlook. Bocharov said orders were not expected to come before the beginning of flight trials, then due in 2023. At that point, the initial flight parameters would be confirmed, he said, implying that only then would Craigir know exactly what it was selling and customers would know what they were ordering (A&WST May 6-19, p. 29).

The concept of the soft order seems to bridge the gap between Chinese and Russian opinions.

But the date of the first flight may now be later than 2023, as part of the looser schedule that Slyusar mentioned. Before CR929 development was launched in 2017, the partners said that up to 10 years would be needed for development. That implied a first delivery in 2027. But in 2018, Comac said the target was 2025—prompting considerable skepticism from industry managers involved in the program. Even Slyusar told Aviation Week in November 2018 that the objective might be optimistic.

At the St. Petersburg conference, he said the first delivery would be made in 2025-27—again seeming to accommodate both Russian and Chinese opinions. But whereas the company president has previously said the 2023 target for the first flight should be regarded as firm, he now says the aircraft will initially take to the air in 2023-25.

Receipt of soft orders from airlines is a goal of the current stage of the CR929 program, Slyusar says. Development is currently passing through the stage of draft design, which includes definition of the final configuration and selection of suppliers of subsystems and components, he adds.

Slyusar cites a capacity of 280 passengers for the CR929-600, apparently referring to seating in three classes. The stretched CR929-700 will accommodate 320 passengers, while the shorter CR929-500 version will have seats for 250; these figures are presumably also for three-class cabins.

The smaller variant may not offer
ways-led IAG jump-started what had been a relatively sedate Paris Air Show by announcing an intent to purchase 200 MAXes—a mix of 737-8s and 737-10s. The deal accounted for 80% of the new-airliner business Boeing announced at the event, but more important, it provided a major confidence boost for its troubled narrowbody program.

“We’re partnering with the Boeing brand,” said IAG CEO Willie Walsh. “I’ve worked with Boeing for years, and it’s a brand I trust.”

While it is not a firm order, and is likely a deal with a significant discount, considering the circumstances, it is difficult to understage the importance of IAG’s intent to purchase while the MAX is under extreme scrutiny. IAG would be switching from the Airbus A220 to the MAX, adding more substance to the deal.

If the FAA simulator testing was not enough to dim Boeing’s suddenly brighter spirits, rival Airbus made sure its U.S. counterpart would not bask in the limelight for long. The European manufacturer’s top executives said that IAG has not requested proposals to satisfy its narrowbody needs. When that changes, Airbus will have a response.

“We will be very happy to make our offer when it comes to a tender at a later stage,” Airbus CEO Guillaume Faury says. Adds Chief Commercial Officer Christian Scherer: “We have not received a request for proposals, but we are taking the position that we would like to bid for the business.”

Daher’s Merger and Acquisitions Plan Is in Full Swing

> U.S. AIRFRAMER AND COMPOSITES SPECIALIST TAKEOVERS TO CLOSE BY YEAR-END
> FRENCH SUPPLIER AIMS AT MORE BOEING CONTRACTS

Thierry Dubois Le Bourget

Daher, a French company known mostly for its Airbus aerostructures activity and TBM 910/940 business turboprops, has since 2018 been swiftly implementing a strategy aimed at becoming a major Boeing supplier.

“How to become a respected player in the U.S. aerospace industry” is the question Daher has been asking itself since 2013. A first contract last year with Boeing, followed this year by the acquisition of a company with expertise in advanced composites and the takeover of a small U.S. airframer, mark an acceleration in finding an answer.

For Daher, reaching its goal would translate into less dependence on European customers. It is not the only European aerostructures company with this idea. However, for the others—such as Aernnova, Premium Aerotec and Stelia Aerospace—Daher’s recent progress means it may have an edge.

The company’s first foray into the realm of Tier 1 suppliers for U.S. manufacturers was announced in 2014. Daher has since supplied carbon-fiber main landing gear doors for the Gulfstream G500 and G600 business jets.

The next step was the Boeing contract disclosed in January 2018. Daher

much more seating than a proposed stretched version of the UAC MC-21 narrowbody airliner, the MC-21-400. Although UAC is focused on certification of the baseline MC-21-300 with a capacity of up to 210 seats in one class, Vice President for Marketing Kirill Budnev says the company is also closely looking at a chance to develop the MC-21-400.

Slyusar also says UAC and Comac are still preparing to set up the CR929's engineering center. He confirms it will be located in Russia. Until the center is established, development is conducted by a joint engineering team. The members meet either in Moscow or in Shanghai five or six times a year. Comac and UAC are equal partners in the program, which, industry sources have said, was launched at the behest of the top leadership of the partner countries. Difficulty in multinational cooperation has slowed progress, other industry sources have said.

Meanwhile, Russia and China have made an important step toward CR929 airworthiness certification, updating their bilateral air safety agreement (BASA) to accommodate Russia’s shift to national aircraft certification by the Federal Air Transport Agency (FATA). The process was formerly handled by the Interstate Aviation Committee, representing all members of the Commonwealth of Independent States.

Practical implementation of the new BASA required a deal on realisation procedures, which was signed on June 5. The FATA says these procedures make possible mutual validation of aircraft certifications by Russian and Chinese aviation authorities.

Daher’s Pursuit of U.S. Development and Advanced Composites Manufacturing

2013 Manufacturing start of thermoplastic parts for the Airbus A350
CEO announces Boeing contract is a key target

2014 Gulfstream aerostructures contract

2017 Thermoplastic wing rib exhibited at Paris Air Show

2018 Contract for thermoplastic parts on the Boeing 787

2019 KVE Composites takeover

Acquisition of U.S.-based Quest Aircraft
describes its work package as "elemental structural parts" for the Boeing 787’s fuselage and wing. Thermoplastics replace metal and more conventional thermoset composites.

Its management team believes thermoplastics and their associated technologies will become increasingly relevant in the aerostuctures market. Thermoplastics are easier to manufacture than thermosets, allowing for greater productivity while retaining the weight advantage of the carbon-fiber reinforced plastic family. As a result, they have the potential to be used for major structural subassemblies, in Daher’s view.

Thermoplastics also generate less waste during production and are recyclable. Daher CEO Didier Kayat predicts the use of thermoplastics will grow to 1,000 metric tons (2.2 million lb.) per year in 2029, from today’s 300 metric tons.

Therefore, the acquisition of Netherlands-based KVE Composites, announced last month, is in line with the expected evolution of the aerostuctures market.

KVE’s expertise is in induction welding of thermoplastic composite components. The process paves the way for a reduction of nearly 75% in the number of rivets traditionally used in the assembly of fuselage structures, Daher estimates. In addition to a 15% weight saving, the removal of some fasteners makes production faster.

The company will continue to live autonomously. “If we swallow it up, the technology will lose its interest as others will develop their own techniques,” says Kayat. Therefore, Daher will use KVE’s technologies, which it will market to third parties. “KVE’s lead will make the process a standard,” he says.

Being an airframer with the TBM program has helped Daher win aerosstructures contracts with other airframers, a spokesperson points out. The takeover of Sandpoint, Idaho-based Quest Aircraft could help in the same way—this time in North America. The project was announced last month and is expected to close by the end of 2019.

Daher manufactures the 10-seat Kodiak 100 turboprop single. “The Quest

### Long-term Profitability Strategy Critical to Air France-KLM’s Future

**MORE STRATEGY DETAILS EXPECTED AT INVESTOR DAY IN NOVEMBER**

**COMPETING WITH IAG AND LUFTHANSA IS CEO SMITH’S GOAL**

Helen Massy-Beresford
Paris

New Air France-KLM CEO Ben Smith managed to calm a long-running, disruptive and costly labor conflict with impressive speed, but there is no resting: A long-term strategy to improve profitability is vital, with the context worsening for European airlines.

Smith, celebrating his first anniversary in September, inherited the union mess from former CEO Jean-Marc Janailac, who lost a gamble over a pay deal with staff last year.

The Lufthansa Group’s June 16 warning that profitability would be lower than expected, with pressure on yields in a “challenging” European market only partially offset by strength in long-haul routes, is the latest sign to highlight the seriousness of the situation for European airlines.

Air France-KLM is already on its back foot—Janaillac’s attempts to boost profitability, close the gap with airline peers and, in particular, better face up to competition from Gulf carriers were at the heart of the conflict with his workforce.

Smith wants Air France-KLM to improve its performance to be able to compete financially with International Airlines Group (IAG) and Lufthansa, a goal the former Air Canada executive believes is “definitely achievable: five years is the timeline we’ve given ourselves.”

“It should be feasible for Air France-KLM to compete financially with IAG and Lufthansa” JLS Consulting Director John Strickland says. “After London, Paris is the richest air market in Europe in terms of density, wealth profile and the amount of point-to-point traffic as opposed to transfer traffic. If you combine that with the already strong performance of KLM, then it should be possible. But that’s in an ideal world, without the French factors.”

Smith will have his work cut out making the structural changes and cost reductions necessary to bring Air France-KLM in line with its European counterparts. Smith may have resolved the immediate conflict with unions, but he can expect pushback as he seeks to get his longer-term strategy implemented.

And not just from staff: Tensions developed between Air France and its smaller partner KLM culminating in the Dutch government’s surprise move earlier this year to buy a stake in the group, leaving it with 14% compared with the French state’s 14.3%.

But Smith said at the Paris Air Forum June 14 that modifications to the group’s governance had evened the balance between Air France and KLM and paved the way for smoother functioning of the group.

“The challenge is getting the company into the same shape that Willie Walsh has got IAG into,” Strickland says. “That means heavy negotiation with unions to achieve structural change and cost levels that match the kind of revenues they’re able to achieve in the marketplace and being able to deliver sustainable profitability.”

Air France-KLM Executive Vice President Strategy Angus Clarke told the forum that under Smith’s leadership the group’s priorities were simplicity around the fleet, efficiency of aircraft layouts, consistency of product, employee engagement and balance sheet strength. “These things take time,” Clarke said. “It’s a five-plus-year mission to get Air France to the same operating margin as KLM, which is the aspiration, and having a strong group that can compete very effectively with Ryanair, EasyJet, IAG and Lufthansa. That’s the ambition.”

Smith is set to give a more detailed strategy update at a capital markets day planned for November, and setting out how Air France-KLM can better compete in the face of stiff competi-
Aircraft Co.’s acquisition represents an additional step in our development in the U.S. and an overall strengthening of our aircraft manufacturing business,” Kayat says. “This key acquisition for Daher is perfectly aligned with the strategy of intensifying our company’s links with the North America market’s leading aerospace players.” The deal provides the company with its first industrial site in the U.S.—potentially the place for an aerostructures production facility along the lines of Daher’s main site in Tarbes, in the southwest of France.

The addition could put the airframer on even firmer footing. Geographically, the TBM 910/940 and Kodiak have been essentially sold in different areas—North America for the TBMs, Asia and Africa for the Kodiak, says a company executive. The TBM is certified in 38 countries and the Kodiak in 67. This gives Daher a more global presence.

The Kodiak may become a platform for special missions, especially where the TBM has failed to adapt. “The Kodiak has a high wing, making it suitable for carrying optronics or other external payloads. It can loiter for a long time over a given area and is much cheaper,” the executive explains. It sells for $2.1 million, while the TBM 910/940s costs more than $4 million.

As far as the typical TBM customer—an owner or pilot with more than one aircraft in his or her hangar—is concerned, acquiring a Kodiak may make sense, says the spokesperson. The TBM’s design is focused on greater speed—up to 330 kt. in cruise. The Kodiak was created to access remote areas with short, possibly unpaved runways and, at 10 seats, has greater capacity.

Moreover, Quest’s factory may one day be used to produce TBMs, in case a production hike is needed beyond the current capacity in Tarbes, the spokesperson says.

As for component procurement, the two aircraft have the same avionics, engine and propeller providers, which opens up the possibility for better deals with Garmin, Pratt & Whitney Canada and Hartzell.

Smith is considering how long Airbus A380s will remain in the fleet.

Fleet simplicity will be a key improvement for the group. Air France-KLM will consider Boeing 737 MAX, Airbus A320neo and Airbus A220 types as it prepares to renew its short- and medium-haul fleet, Smith told Aviation Week on the sidelines of the forum. The group is also considering how long the Airbus A380 will remain part of its fleet.

On short- and medium-haul, Smith said, “We’re in no rush; we are evaluating all three major options out there: the MAX, the Neo and the 220.”

Low-cost subsidiary Transavia also looks set to be an important tool in improving the group’s performance on the challenging European short-haul market, and talks with unions over increasing the Transavia France fleet, currently capped at 40 aircraft, are going well, Smith said.

The results of those Transavia talks will be “Step one” in the process of short- and medium-haul fleet renewal, as the group needs to decide whether Transavia’s fleet could be renewed at the same time as the rest of its short- and medium-haul aircraft.

Air-France KLM is also considering the future of its Airbus A380s, of which it has 10, with three already due to exit the fleet. “The other seven have older seats, and we’re in the middle of making the decision on how long those A380s will be staying in the Air France fleet and whether we should invest €30-40 million [$35-45 million] per aircraft in upgrading those seats,” Smith said at the Paris Air Forum.

A more modern, more streamlined fleet will help improve performance, especially in the French market where intensifying low-cost competition is upping the pressure. But for Strickland, it’s not just about the aircraft. Air France will need to improve the consistency of its network and timetables.

“The schedule has to be strong for business customers,” he says. “With new aircraft like the Boeing 787 and Airbus A350 coming through, they’ll be able to serve new and emerging markets more efficiently.”

AviationWeek.com/awst
t last year’s Farnborough Airshow, Airbus picked some delicious low-hanging fruits. The agreement to take over control of the former Bombardier C Series program had just been approved, and some big customers were finally ready to sign big deals. The event was a not-to-be-missed marketing opportunity to reposition the newly renamed A220 as an Airbus product and Airbus-typical success. Large orders from JetBlue Airways and David Neeleman’s new venture, code-named Moxy, were announced.

But there was one dirty little secret: The orders were based on negotiations undertaken by the old Bombardier management and could not fully be attributed to Airbus, although the takeover plans had been announced before the air show. Also in May 2018, Martin Gauss, Air Baltic’s CEO and arguably the world’s biggest A220 fan, had upped his commitment to the type again by adding 30 more firm orders. But then things turned very quiet for the A220 for almost a year—raising the question of whether the Airbus takeover had provided the boost in confidence management had hoped for and underlining that it needed to increase production and ultimately make the aircraft profitable.

An Air Lease Corp. (ALC) deal for 50 A220-300s announced almost a year later at the recent Paris Air Show ended that period of uncertainty: “ALC is the first pure Airbus order,” says Airbus Canada Limited Partnership CEO Philippe Balducchi.

The commitment was “very important” as a show of confidence to the market, he says. “We were missing a blue-chip lessor with excellent access to operators. I can feel that operators are gaining confidence.”

More commitments followed at the Paris Air Show. JetBlue converted options for 10 A220-300s to firm orders. Lessor Nordic Aviation Capital (NAC) signed a memorandum of understanding for 20 aircraft. Delta Air Lines added five aircraft to its order and converted all commitments to the new version with the highest maximum takeoff weight (MTOW), which increased the aircraft’s range by around 450 nm.

The 2.3-ton increase in MTOW was based on a request that “came across the board from customers telling us a few hundred more miles [in range] would be ideal,” says Balducchi. The A220-300 will be able to fly up to 3,400 nm; the smaller -100 will have almost the identical range. The increase, essentially the result of software changes and release of design margins, will be available in the second half of 2020 for the -300 and a year later for the -100. It can be introduced retroactively for in-service aircraft; Delta picked that option.

The extended range turns the A220 into “definitely more than a regional aircraft,” Balducchi asserts, enabling it to fly not just short sectors but even long-haul missions across the Atlantic. “The beauty of the aircraft is its versatility,” he says.

ALC CEO John Plueger says the A220-300 not only will be used in traditional short- and medium-haul markets but also will be increas-
ingly deployed on transatlantic and U.S.-Latin America routes. Plueger noticed “a lot of demand over the last six months” for the aircraft.

The lessor will take delivery of the aircraft in 2021-26, according to the terms of the preliminary order. “[The A220] is a wonderful replacement of A319s, Fokker 100s and Boeing 737s,” says ALC Executive Chairman Steve Udvar-Hazy. “We spent several years analyzing the program. ALC will work hand in hand with Airbus to widen the customer base of the A220.”

Plueger was more cautious about a potential stretch of the A220, provisionally dubbed the -500. “The -500 is a little bit tougher of a business case,” as it borders on the A320neo segment, he says. Therefore, ALC is focusing on the -300 for now.

Airbus Chief Commercial Officer Christian Scherer says Airbus has “no plan to stretch the A220, but the aircraft is capable of it.” Balducchi believes a potential -500 “will have a role to play in the Airbus product portfolio.” Whether or not to go ahead with it—and, if so, when—are valid questions to him.

Airbus (and previously Bombardier) have collected a total of 536 firm orders for the two A220 versions, not counting the preliminary commitments by ALC and NAC. Of those orders, 80 came from five lessors. Macquarie Financial Holdings had the biggest portfolio with 40 A220-300s, but will now be eclipsed by ALC.

All of ALC’s A220s will be built on the Mirabel, Quebec, final assembly line and not in Mobile, Alabama, where Airbus is opening a second line for the U.S. market. Filling the planned production at Mirabel has remained a concern.

Airbus’ other big challenge is how to bring the program’s production cost down. Bombardier, in a weak negotiating position with its suppliers, was forced to sign expensive contracts that weigh heavily on the A220’s profitability. Airbus, targeting a double-digit cost reduction, seeks to shed those as soon as possible. “The target is confirmed,” says Balducchi. “We have routes to get there. Some negotiations are done, some are fairly advanced and some a bit less . . . and some will be slower.” Overall, he says he is “not too worried.”

Success in overcoming the cost challenge is intrinsically linked to more aircraft sales, as Airbus can then offer higher production volumes to suppliers and expect discounts in return. The talks “are also about the ramp-up,” says Balducchi, and “more orders are helpful.”

He stresses that while target dates have been identified for certain cost milestones, further reduction of supplier expenses will be a continuous process. “There won’t be a hard stop,” he says.

Airbus is not only addressing price issues with its suppliers but also the need to “make sure that we get parts on time.” To that end, it has sent a team of experts to Shenyang Aircraft Corp., an Avic subsidiary that builds the A220’s center fuselage and has had serious issues with its workshare in the past. “Shenyang is improving; we have our Airbus team working with them. They are now benefiting from the big Airbus experience,” Balducchi says.

Integrating the program into the Airbus organization has been another major focus over the past year. The A220 is now part of the bigger support and services network that Airbus offers. Sales, initially still dealt with separately, have now also been merged into the wider Airbus sales organization. “We have to make sure that all business units [inside Airbus] understand and push the aircraft,” says Balducchi. While the A220, he notes, receives “a lot of sympathy [in the organization],” he adds: “it is not natural to integrate. [But] I don’t want to create a little empire,” separate from the rest of the group.

The program is broadening its footprint with the addition of the Mobile final assembly line. Construction of the facility is ongoing, but the first Mobile-built A220s will be put together in the adjacent A320/A320neo final assembly building. The line will be transferred to the new hangar once that is completed in 2020.

The first fuselage sections for aircraft to be assembled in Mobile have arrived, and production will start in the coming weeks in the A320 hangar. Balducchi concedes that the arrangement is not ideal. Airbus initially added the Mobile line to mitigate the threat of U.S. import tariffs against the A220, based on allegations of illegal Canadian government subsidies for the aircraft.

Airbus delivered 33 A220s in 2018 and plans to hand over 45 this year. The company is vague about details of the future ramp-up but is keeping to the target of a monthly rate of 10 aircraft that it wants to reach by the middle of the next decade at the Mirabel plant. In addition, four aircraft per month are to be delivered from Mobile.
Attempts to design a supersonic combustion ramjet—also known as a scramjet—have achieved only limited success in experimental flight tests stretching back decades. But the Raytheon/Northrop team’s new approach to an operationally viable missile that relies on a relatively low-risk, all-metallic design and an additively manufactured scramjet engine designed by Northrop (formerly ATK) has inspired confidence based on wind tunnel tests and simulations.

Schedule details remain classified for the Defense Department’s three-pronged, $10 billion campaign to field multiple hypersonic weapons over the next five years, but Raytheon’s perspective is that scramjets finally are poised to leap slightly ahead of the winged-glider alternative. “The air-breathers have now evolved to the point where they’re actually more mature [than boost-glide systems],” says Tom Bussing, vice president of Raytheon Advanced Missile Systems.

It is a remarkable statement by a key player in the Pentagon’s rush to deliver weapons equivalent to or better than Russia’s ground-launched Avangard glider, which is scheduled to become operational later this year. Only seven months ago, Michael Griffin, the architect of the Pentagon’s hypersonic weapon strategy as defense undersecretary for research and engineering, said scramjets had fallen to the back of an impressive queue.

Its rivals in the Pentagon’s internal hypersonic race are two types of boost-glide systems. The most sophisticated are the winged glider programs, such as DARPA’s Tactical Boost Glide (TBG) program, which is aimed at reducing risk for the Air Force’s Air-launched Rapid Response Weapon (ARRW), also known as the AGM-183A. The relatively less complex alternatives include a cluster of biconic gliders all derived from the Army’s Advanced Hypersonic Weapon experiment and include the Air Force’s Hypersonic Conventional Strike Weapon (HCSW), the Navy’s Conventional Prompt Strike and the Army’s Long-Range Hypersonic Weapon.

In some ways, the scramjet-powered Hypersonic Air-breathing Weapon Concept (HAWC) operates in a more benign environment than...
Lockheed’s new rivals in the race to field the most advanced hypersonic weapons are now the Raytheon/Northrop Grumman scramjet for the Hypersonic Air-breathing Weapon Concept program (bottom) and a winged glider for the Tactical Boost Glide program.

The hypersonic glider, which must re-enter and then skip along the top of the atmosphere at speeds that create a superheated plasma field around the vehicle. But scramjets must conquer the challenge of compressing and combustion a supersonic airflow amid the extreme heat and aerodynamic shocks caused by flying at hypersonic speeds.

“Used to design hypersonic inlets for a living,” Griffin said Dec. 13 at a hypersonic conference hosted by the National Defense Industrial Association. “We’re not unaware of the difficulties right in front of us for air-breathing systems. Those are further out. Based on the flight-testing we have done, boost-glide systems are more a matter of industrial capacity, a matter of making choices.”

As of last December, Bussing might have still agreed with Griffin. Wind tunnel data and simulations had shown in 2017 that Raytheon’s original design for DARPA’s HAWC could not meet performance expectations. So DARPA selected a competing design for the HAWC by Lockheed Martin to move forward into the flight-testing phase.

Raytheon did not give up, however. “We went back and did our full redesign, and let’s just say our performance matches the predictions very, very closely,” says Bussing. “We’re doing another [design iteration] in the wind tunnel just to verify some other attributes of that system. So the maturity of that [iteration] is actually higher.”

DARPA rewarded the Raytheon/Northrop redesign with a $65 million contract in March to advance their concept into flight testing, providing a competitor to Lockheed’s HAWC, which is powered by a scramjet designed by Aerojet Rocketdyne.

Scramjet technology in the U.S. has a long history of lofty promises leading to often disappointing or incomplete results. Bussing acknowledges the historical track record but remains confident based on the new results in ground tests.

“My doctoral thesis was in scramjets, so I go way back,” he says. “But I was a skeptic, too, initially, until we actually built and tested them. We made some very careful decisions on the flight regime on how far the cruise has to operate.”

Top Air Force officials are also encouraged by the progress shown by the HAWC competitors, including Lockheed.

“The HAWC program has come along better than I expected. Scramjet is going to be a nearer-term, not a far-term capability, and I’m delighted to be able to say that publicly,” Will Roper, the Air Force’s assistant secretary for acquisition, told Aviation Week at the Paris Air Show.

For the Air Force, the testing schedule still puts the boosted biconic glider called the HCSW in the lead by about three months over the HAWC and ARRW, Roper added. But the rising confidence in the maturity of the HAWC designs has revived prospects to secure funding for scramjet-powered weapons.

“I think boost-glide [weapons] will fulfill one role for very long standoff. Scramjet will provide a low-flying target that can be useful for other things,” Roper said. “It’s important that we make sure there’s a home for both boost-glide and scramjet to move into programs of record if they succeed.”

Although the first flight tests are coming up within months, success and failure will be measured based on the results of multiple launches rather than any single program. The Pentagon’s schedule calls for staging 15 hypersonic flight tests by 2021 and 40 overall by the end of 2023, said Michael White, director of hypersonic programs on Griffin’s staff, who spoke at the Royal Aeronautical Society chapter meeting in Washington on June 13.

“If we fail, and they come back and say, ‘We thought this before, but we know this after; and here’s how we’re going to fix it;’ that’s exactly what made the Air Force great early in its history,” Roper said.

The message has resonated down the chain of command. Brig. Gen. Anthony Genatempo, the Air Force’s program executive officer for weapons, describes an intense pressure internally on maintaining test schedules, not on achieving a successful test.

“We’ll see if we have a spectacular catastrophe. . . . We’ll see how true that is,” Genatempo told Aviation Week on June 20. “But right now, today, I don’t feel that pressure. I get much more scrutiny if I have to come back and say I have to slip the flight test a week.”

Raytheon’s revelations at Paris came just a week after the first captive-carry test flight of the DARPA-Air Force Research Laboratory-developed TBG demonstrator; a prototype to the follow-on Lockheed AGM-183A.

The test vehicle, which the U.S. Air Force describes as a “sensor-only”
Raytheon’s three-decade grip on the U.S. military’s long-range air-to-air missile inventory will soon end. Lockheed Martin won a secret competition in 2017 to develop and field an even longer-range air intercept missile by 2022. U.S. fighter pilots will at last have access to a weapon with equivalent range to China’s PL-15, Europe’s MBDA Meteor and Russia’s Vympel R-37M.

The existence of the AIM-260 Joint Air Tactical Missile (JATM) was made public during a June 20 media roundtable in Dayton, Ohio, with Brig. Gen. Anthony Genatempo, the Air Force’s program executive officer for weapons. When asked for an update on the Air Force’s long-fixed portfolio of air-dominance weapons, including the short-range Raytheon AIM-9X Sidewinder and long-range AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM), Genatempo dropped any pretense of secrecy about the latter’s planned replacement.

“What I have going on in air dominance is the AIM-260, or the JATM, which is to counter PL-15,” Genatempo said. “That’s an effort we have ongoing with Lockheed Martin that’s proceeding extremely fast.”

Lockheed Is Quietly Developing AIM-260 To Counter China’s PL-15

> LOCKHEED MARTIN DEFEATED RAYTHEON FOR CONTRACT IN 2017
> AIM-260 SET TO ENTER SERVICE IN 2022 ON THE F-22 AND F/A-18E/F

The AIM-260 is scheduled to begin flight-testing in 2021 and achieve initial operational capability in 2022, Genatempo said. It will debut first inside the main weapons bay of the Lockheed F-22 and the Navy’s Boeing F/A-18E/F, then migrate later to the Lockheed F-35. It shares similar dimensions to the AIM-120 but provides “significantly greater” range, Genatempo said, declining to elaborate.

Lockheed is working on this project with propulsion system developer Aerojet Rocketdyne. “What they’ve done with the engine is spectacular. It’s an impressive piece of equipment in its simplicity but also its capability. It’s tough to get to, but we have high confidence it is going to work very well for our customer,” he adds.

The June 12 TBG flight was with an instrumented test vehicle. “So we were looking at the environment around the weapon and how it interfaces with the B-52, both from a loads and other-aspects point of view. This gives us a better idea of the vibration and noise levels. That program is going very well,” adds Babione, who describes the hypersonic glider element as being roughly 6 ft. long.

Meanwhile, Raytheon continues to develop its version of a winged glider under the TBG program, as an alternative to Lockheed’s AGM-188A ARRW. The company’s goal is not to deliver a “me-too” version of the Lockheed design, but something even more capable.

“We focused on capabilities that we don’t believe ARRW has,” Bussing says. “So I would look at Raytheon’s TBG solution as maybe the ARRW-2.”

—With Lee Hudson at Le Bourget and Graham Warwick in Washington
gel propellant. But the missile’s designers face a difficult challenge. “Getting a kinematic performance similar to the PL-15 but not using a rocket/ramjet is going to be interesting,” he says.

The accelerated schedule, with a five-year span from contract award to first flight, also suggests the Air Force is taking an aggressive approach. “It looks racy, from what’s in the public domain,” Barrie says. “But then again, who knows what’s been going on in the classified realm?”

The JATM will replace the Amraam as Raytheon deliveries phase out by fiscal 2026, Genatempo said. “As I bring up JATM production, Amraam production is going to start tailing off. Right now, my last production buy of Amraams is [fiscal] 2026, and that’s because the inventory I’ll have of [our current Amraams] plus the inventory I will have built up between now and then—and we’ll continue the build of JATM missiles—will answer the need.”

Separately, the Air Force Research Laboratory has canceled a new concept for a swarming, Lockheed-designed cruise missile called Gray Wolf, Genatempo added. Instead of developing a new missile, the Air Force has launched a new program called Golden Horde, with the goal of networking existing munitions for swarm attacks.

The Golden Horde concept arose from lessons that came out of the 2017 attack on Syrian airfields and military targets by about 100 BGM-109 Tomahawk cruise missiles and AGM-158B Joint Air-to-Surface Missiles.

“The success of that mission was from a huge amount of mission planning, because each of those weapons was dropped at a certain time and had a preplanned flight,” Genatempo said. “There was no thinking or talking amongst themselves as to, ‘You know what? The first two of us that got here 4 min. earlier, we actually took out this target, so the two of you that were coming in behind us just to make sure, you can go to Target B.’ And within that 4-min. flight time, there would be time to adjust to go target B.”

The first Golden Horde demonstration flight is planned in 12 months.
Airbus and Dassault Reveal Vision for New-Gen Fighter

The Franco-German Future Combat Air System (FCAS) has become a pan-European project with the addition of Spain, but the effort could still be for naught if the partner nations cannot persuade Berlin to realign its views on defense exports.

It has been two years since French President Emmanuel Macron and German Chancellor Angela Merkel announced their intention to build a new fighter together in a bid to restore European defense industry sovereignty and produce a sixth-generation combat aircraft for the 2040s. Primes Airbus and Dassault are engaged in joint studies worth €55 million ($73 million) and preparing for a demonstration phase of the New Generation Fighter (NGF), the platform to be at the heart of the FCAS, they plan to fly by 2026.

The industry team working on the FCAS has begun to expand as well. Airbus is working with Thales on the wider combat cloud network and with missile manufacturer MBDA on the so-called remote carriers, the unmanned systems that will perform various roles, including electronic warfare, swarming attack or serving as “loyal wingmen” carrying additional weaponry. In addition, MTU and Safran are working on the new engine. The program has also welcomed German defense electronics companies Diehl, ESG, Hensoldt and Rohde & Schwarz, which have jointly formed the Future Combat Mission System consortium to work on the networked sensors and systems within the FCAS.

Madrid’s industrial role has yet to be formally outlined, although Spain’s acting Defense Minister Margarita Robles says, “Spain will participate in 33% of the technological projects,” with the first contracts for Spanish industry expected by year-end.

Safran displayed a small model of the NGF engine at Le Bourget, revealing a thrust-vectoring nozzle at its rear.

“This is a fundamental step toward continuity in the Spanish aeronautical industrial base,” Alberto Gutierrez, Airbus’ head of military aircraft, tells Aviation Week.

“The ambition from the Spanish government is to be a full partner all across the development activities,” he says, noting that its role in the production process later will depend on how many platforms they ultimately plan to purchase. Madrid wants national industry to be “relevant throughout the life cycle of the new aircraft,” he says, pointing out that technology transfers will benefit other national industrial sectors.

Despite this progress, fears remain that continuing disagreements between France and Germany over defense exports, particularly to Saudi Arabia, could drive a wedge into the collaboration.

“The export question is the biggest on the way forward for French and German collaboration,” Airbus Defense and Space CEO Dirk Hoke told journalists during the runup to the Paris Air Show. “If this cannot be solved, there will be none of the big Franco-German programs materializing, at least beyond the study phase.”

Merkel’s weakening grip on power in Germany, with the Green Party taking a leading position in recent European elections, has led to the prospect of more steadfast opposition to defense exports and the limiting of increases in defense spending. Not progressing such programs, Hoke said, would have a “drastic impact on the defense industry in Europe.”

The disagreements need to be solved next year, Hoke warned, before budgets required to take the program forward into the demonstration phase begin rising steeply. “This is the latest point where this question has to be answered positively,” he asserted.

The demonstrator phase will run from 2019 to mid-2021 and serve as “a starting point” for the demonstrators and technology development program, say Airbus and Dassault, with a contract award for the first demonstrator phase planned by year-end. The NGF demonstrator will be powered by a Safran M88 engine, which normally powers the Dassault Rafale but will be fitted with new technologies including a modified high-pressure core capable of handling hotter temperatures, enabling higher thrust levels. The demonstrator also will include low-observability stealth features and, crucially, the release of a weapon from an in-
The inclusion of YF-23-like tailerons in the NGF mockup may hint at a configuration compromise for land and naval use.

ing mission data including the position and range circles of enemy air defenses. Airbus officials say the NGF pilot and mission also will have direct access to optical sensors on other FCAS platforms, allowing them to perform standoff battle damage assessments. Both Airbus and the DGA showed concept videos of how the NGF might work in a future battlefield, with the remote carriers using spoofing and jamming to open a brief window in the enemy air defenses to attack the enemy command-and-control structure.

In Airbus proposals, a directed-energy self-defense laser deals with incoming surface-to-air missiles. Despite cyberattacks on communications systems, the distributed network adapts so that missions are not interrupted. This may be possible using distributed, agile networks capable of redirecting sensitive data away from the parts of the network being hacked.

Airbus has proposed a large remote carrier system designed to be air-launched from the rear of a transport aircraft.

Displayed alongside the NGF were mockups of remote carriers designed by Airbus and MBDA (AW&ST June 17-30, p. 97). The Airbus proposals leverage the company’s work on its Barracuda UCAV—which flew in the mid-2000s—offering a cruise-missile-shaped air vehicle that would weigh in at several tons and likely be powered by a turbofan or turbojet.

Featuring foldable wings, the Airbus remote carrier is designed to be air-launched, released from the back of an airlifter such as an A400M, or even from under the wings of the FCAS, and later recovered. Equipped with sensors and probably air-to-ground weapons, it would work more closely with the NGF, with increased range and performance compared to smaller systems, such as those proposed by MBDA, which would perform electronic warfare and attack and take out ground-based air defenses.

Check 6 Aviation Week editors discuss their highlights from the Paris Air Show: AviationWeek.com/podcast
Tweaked Terms for Canada’s Future Fighter Help F-35 and Rivals

> CANADA DELAYS RFP RELEASE FOR CONTRACT TO JULY
> ORIGINAL REQUIREMENTS FOR STEALTH AND OFFSETS SOFTENED

Steve Trimble Ottawa

Our years after he campaigned on a critique of the previous government’s selection of a new fighter for the Royal Canadian Air Force (RCAF) without first holding a competition, Prime Minister Justin Trudeau’s staff is finding out just how difficult the task can be.

In an extended series of drafts released to industry since October, the Public Services and Procurement Canada (PSPC) agency has rewritten key provisions of the solicitation, hoping to keep the process as open and competitive as possible, even if it means tinkering with once ironclad requirements.

After Dassault decided to withdraw from the bidding, the four remaining competitors for Canada’s Future Fighter Capability (FFC)—Airbus’ EF-2000, Boeing’s F/A-18E/F, Lockheed Martin’s F-35A and Saab’s JAS 39E—are now waiting to see the final terms for a contract for up to 88 aircraft.

Among the nine members of the original Joint Strike Fighter international partnership, Canada is the only one that has not committed to ordering the F-35, although Turkey now faces expulsion from the program if it follows through on plans to import the Russian S-400 air defense system. So Canada’s pending order for 88 aircraft represents a rare prize for Lockheed’s rivals in the fighter market.

The extended drafting process has included postponement of the final request for proposals (RFP) from this spring to July as Canadian procurement officials craft requirements that simultaneously keep as many bidders in the competition as possible, meet the RCAF’s operational requirements for a future fighter and ensure Canadian industry is looked after.

“This is a very complex process—as complex as any of the other processes that our government has ever conducted. The field is comprised of very different entities and dynamics. Conducting a truly open competition among that is a challenge,” said Carla Qualtrough, minister of public services and procurement, during an address on May 30 at the Cansec trade show in Ottawa.

It was supposed to be much simpler. The government joined the international partnership established to manage F-35 development in 2002, then agreed five years later to sign a memorandum of understanding to continue participating through the production and sustainment phase. In July 2010, then-Prime Minister Stephen Harper announced the decision to replace Canada’s aging fleet of CF-18s with F-35As, singling out the stealth features that made it the only aircraft on the market that met the RCAF’s requirements.

The absence of a competitive bidding process for the 65-aircraft requirement triggered a backlash from the Conservative Party’s political rivals, and Harper’s government never signed the order.

But Trudeau’s initial plan to replace the CF-18 fleet fell apart over an unrelated political dispute with Boeing. In 2016, Trudeau’s government announced plans to buy 24 F/A-18E/Fs as an interim replacement, delaying the long-term procurement decision until after his first term in office. But Trudeau canceled the order in the summer of 2017 after Boeing filed a trade complaint against Canadian aircraft manufacturer Bombardier, which a U.S. government panel eventually rejected anyway. Finally, in late 2017, Trudeau released a new plan for replacing the CF-18 fleet that called for a competitive bidding process of at least two years leading to a final contract award in 2020 or 2021.

The list of preferred suppliers released in February 2018 offered an early indication of the complexity facing Canadian procurement officials. It included two U.S. bidders—Boeing and the U.S. government, which represented the F-35 on behalf of Lockheed—and two European bidders with vastly different corporate backgrounds.

“My No. 1 job in this was to keep the field competitive,” Qualtrough told Aviation Week on the sidelines at Cansec. “So we had to look at creative ways, given the complexity of the suppliers. One supplier is a government, one supplier is a consortium, one is an international private company. So how do we create a procurement [process] that’s kind of level and fair for everyone.”

The original draft included a key concession that allowed the competition to proceed. The Harper government had treated the RCAF’s requirement for an aircraft with very low observability to radar as a mandatory gate. Trudeau’s government softened that requirement to allow other aircraft besides the F-35 to participate.

“So on the stealth example that used to be kind of a ‘yes or no’—you proceed or you don’t proceed if you have this re-
requirement,” Qualtrough said. “It’s now a weighted capability … instead of kind of a deal-breaker at the beginning.”

Although that concession allowed the F-35 to face competition for the contract award, a long-standing Canadian procurement policy almost forced the Lockheed fighter out of the bidding. The Industrial Technological Benefits (ITB) policy requires defense contractors to guarantee work for Canadian industry equal to 100% of the value of their deal. But the terms of Canada’s signed agreement as part of the F-35 international partnership prohibit member-states from imposing such offset requirements on aircraft orders. Last year, U.S. government officials notified the PSPC that ITB policy would prevent the F-35 from participating in the competition for the FFC contract.

Canadian procurement officials believe that over the last several months they have developed a compromise that accommodates the F-35, though not at the expense of competitors, which have voiced no objections to the ITB policy.

Instead of making bidders submit offers with contractually guaranteed offsets worth 100% of the value of the deal, the PSPC proposes to allow them merely to promise to provide such industrial benefits without a legally binding commitment to follow through, Qualtrough said. But bidders that do guarantee offset work will receive higher scores in the evaluation, she said. Finally, the Canadian government maintains the right to enforce offsets made without such guarantees, she said.

“You’re required to have 100% ITB or more, but you will lose significant points if you can’t contractually obligate your supplier to provide that 100% guarantee,” she said. “You have to have a plan now to do the 100%. There can be some kind of a legal recourse if that’s not met…. Being very clear: This in no way relaxes an obligation by a supplier to give 100%.”

Canada’s relationship with the U.S. military also imposes unique requirements on the FFC solicitation. In addition to membership in NATO, Canada is also part of the North American Aerospace Defense Command (NORAD), which creates a U.S. government requirement for the future fighter to be able to share special intelligence information between the two militaries.

Lockheed and Airbus declined to comment about the PSPC’s proposed alterations to the bidding, but the other two competitors voiced concerns. “It did surprise me they were tweaking a proven policy,” says Jim Barnes, Boeing’s capture team lead for Canada, referring to the ITB changes. “Why would you deviate from a policy that’s been so successful to accommodate a competitor?” Despite that objection, he gave no indication Boeing would withdraw. “Right now we think we can put a very compelling offer on the table even with the change,” he says.

Saab Canada’s executive vice president for business development and sales, Patrick Palmer, opines: “I’m concerned that the ability to respond in a nonbinding environment may not necessarily give Canadians the best value at the end of the day.”

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Pentagon and Lockheed Eye Broad Expansion of F-35 Modernization

> NEW WEAPONS, MANNED-UNMANNED TEAMING STUDIED FOR F-35

> TOP DEFENSE OFFICIAL DEFENDS LOCKHEED COST-REDUCTION PLAN

By the end of the mid-2020s, the F-35’s weapons capabilities could be expanded to include carrying hypersonic missiles externally and long-range, anti-radiation missiles internally.

Steve Trimble Le Bourget and Dayton, Ohio

Nothing about the F-35 program is ever small or easy. A transition to operational status, even after an extended and over-budget developmental phase, finds most military aircraft programs returning to relative anonymity. For Lockheed Martin’s single-engine fighter, the public spotlight has shifted to a newly launched $22 billion upgrade program, ballooning sustainment costs and a geopolitical conundrum embroiling Turkey—the F-35’s third-largest customer.

In a string of press conferences over a two-week period in mid-June, Lockheed and U.S. Defense Department officials laid out a path to fulfill an ambitious set of promises on Block 4 upgrades and a dramatic reduction in cost per flight hour. But the F-35 program’s rift with Turkey only deepened as officials in Ankara insist on accepting deliveries of an advanced Russian air defense system in July.

The long-delayed modernization of the F-35 is now in full swing, says Greg Ulmer, Lockheed’s vice president and general manager for the F-35 program. The Defense Department awarded Lockheed a $1.8 billion contract on June 7 to launch software development to support a newly expanding set of upgrades planned over the next decade under the Block 4 modernization program.

The contract opens a still-evolving upgrade that is enabled by the Technical Refresh 3 (TR-3) program. TR-3 plans to introduce an integrated core processor into the F-35 by 2023 that is four times more powerful and supports the Air Force’s “open systems” architecture for new applications. The full $22 billion investment in Block 4 modernization already includes more than 50 previously approved upgrades, including the insertion of a maritime strike capability, updates to the wing-leading-edge-mounted Bands 4/5 receivers for the electronic warfare system and additional weapons, including the ability to carry upgraded B61-12 guided nuclear bombs.

But those improvements might be only the beginning. For the first time, Ulmer elaborated on options for an even broader set of upgrades that are possible for the F-35 over the next decade. Hints of such developments have been growing over the past year. The Northrop Grumman Advanced Anti-Radiation Guided Missile-Extended Range (AARGM-ER), for example, is not listed in the F-35’s current weapons road map, but the latest budget documents show that a future Air Force derivative called the Stand-in Attack Weapon will be integrated into the stealth fighter’s weapons by 2024.

According to Ulmer, the TR-3-equipped F-35 fleet is being prepared for additional weapons and other capabilities, including an ability to carry hypersonic missiles underway. In addition to weapons, the F-35 could be adapted to become a flying hub within the emerging concept for multi-domain operations and manned/unmanned teaming. The TR-3 upgrades, which include a new panoramic display for the F-35’s powerful sensors, also could enable the aircraft to perform a new role as a forward-deployed missile defense platform, striking down missiles during a boost or ascent phase. There are also “quite a few classified programs on the books,” Ulmer said, without elaborating.

At the same time, Lockheed is studying several major capacity upgrades, including a bulkhead modification to allow the F-35 to carry six missiles internally instead of four; and Israeli-designed external fuel tanks to increase the range by 40%, Ulmer says.

Expanding the F-35’s operational potential could still be undermined by the costs of operating the fleet. The current $44,000 cost per flight hour should decline to $36,000 by 2024, but Lockheed has committed to reaching $25,000 by 2025. Although the former head of the Defense Department’s cost analysis office wrote off that objective as impossible, Lockheed’s plan received support on June 26 from Robert McMahon, assistant secretary of defense for sustainment. “No one has showed me that that’s physically impossible to get to,” McMahon says.

So far, Turkey’s status in Lockheed’s supply chain remains unchanged, Ulmer says. Turkish Aerospace Industries continues to manufacture and deliver center fuselages as a second-source supplier to Northrop. If Turkey accepts deliveries of the S-400 in July as planned, the Defense Department will banish Turkish military staff from the Joint Program Office. Turkish pilots and maintainers would be banned from U.S. training bases starting on July 31.

Ellen Lord, undersecretary of defense for acquisition and sustainment, said on June 7 that Turkish suppliers will be removed starting in fiscal 2020, as alternative sources are qualified to support full-scale production.
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SAUDI ARABIA MOVES TOWARD DEFENSE SELF-SUSTAINMENT

THE HUNT IS ON FOR PARTNER TO DEVELOP UAV FAMILY IN-COUNTRY

SAUDI ARABIA WANTS TO ACHIEVE 50% OF DEFENSE PROCUREMENT DOMESTICALLY BY 2030

Tony Osborne Le Bourget

Saudi Arabia’s all-encompassing Vision 2030 calls for the kingdom to diversify its economy away from oil and to source as much as 50% of defense procurement from local manufacturers by the end of the next decade.

Saudi Arabia appears keen on Airbus’ A400M for its airlift needs, but it is angling for its national industry to be involved on the project.

It is a tall order for a nation that in recent years has been one of the world’s biggest importers of defense equipment—Riyadh is estimated to have funded around 12% of all global arms imports in 2014-18, according to the Stockholm International Peace Research Institute. But radical change is underway to support that process.

Established in 2017, Saudi Arabian Military Industries (SAMI) is the new umbrella organization in the process of absorbing the country’s existing defense industry infrastructure, and it is gearing up for a new era of national development and local assembly and production.

SAMI’s plans come at a time of growing international pressure to halt arms transfers to Riyadh over its ongoing military operations in Yemen (AW&ST March 11-24, p. 52). Germany has set a unilateral arms embargo on the country, the UK recently halted the awarding of export licenses after appeal judges concluded that British ministers had approved exports to the country unlawfully, and the U.S. Senate voted to block transfers of aircraft spares and support services approved by President Donald Trump.

“The changes in the Saudi Arabia defense sector are dramatic,” SAMI CEO Andreas Schwer told Aviation Week at the Paris Air Show. “It is not only a change in industrial terms, but also the entire ecosystem that has to be built; administration and government-related services functions are being shuffled.”

The former Rheinmetall executive is one of many Westerners parachuted into the fledgling company to prepare it for operations by year-end.

“Unlike other countries, we do not have 50 years to catch up; we have 12 years to achieve something, [and] the only way to do this is by parallelizing everything and not copying what the others have done,” he said.

Once fully established, SAMI’s business will range from aircraft to ships, armored vehicles and missiles as well as the services to support them. It has also signed agreements with some of the largest defense companies in the U.S., Europe and Asia, reconfirming a joint venture with L-3 Technologies and announcing the building of an aerostructures plant in conjunction with France’s Figeac Aero, to be built in either Jeddah or Riyadh, during the air show.

SAMI has major ambitions for aerospace. The company plans to not only support what is the Middle East’s largest air force but also upgrade it and those of neighboring nations. Schwer expects SAMI’s aeronautics business to potentially generate as much as half the company’s revenues in the midterm.

Beyond local assembly of platforms and maintenance, repair and overhaul (MRO) services, the company also seeks to become a major aerostructures supplier to both military and commercial airframers in cooperation with the United Arab Emirates.

“In many cases, it is not easy to find the required amount of offset if you buy a handful of tankers or transport aircraft, because localization does not make much sense,” said Schwer. “So we see an opportunity for indirect offset in the commercial segment.” SAMI’s approach will need to be approved by GAMI—Riyadh’s newly established General Authority for Military Industries, which will become the country’s national armaments authority.

GAMI is writing new draft policies that could lead to major revisions in Saudi national offset policies. Previously, defense companies could provide offsets in industries as diverse as health care, but new rules are expected to mandate that aerospace programs result in aerospace-related offsets.

SAMI also wants to get involved in future combat aircraft projects, Schwer said, such as local assembly of Eurofighter Typhoons—if the sale of a second batch of 48 aircraft, agreed to in principle with the British government in March 2018, goes through.

“We want to learn step-by-step, complement that with work packages, develop our systems engineering, sensors and weapons integration, and then in the future work with one or two international partners on a major program,” he said. “This is not just about becoming an OEM but also a player and a partner.”

What appears to be a key focus for the company is Riyadh’s focus on growing its airlift capacity. Earlier this year, it emerged that work on the jointly developed Antonov An-132 turboprop airlifter had been frozen, following
SAMI’s takeover of the An-132 program from Taqnia Aeronautics and the King Abdulaziz City for Science and Technology.

“We have been taking a detailed look at the market and the commercial prospective for the An-132,” explained Schwer, “In the meantime, the focus of the Saudi air force and other local customers has changed from a 10-ton payload to something with higher capacity. So there is a shift in focus to bigger transport platforms. . . . It is no secret that the air force wants a platform with a 40-ton payload capacity. . . . That’s the reason we are in intense discussions with Airbus on the A400M.”

SAMI is also in the process of finalizing selection of a partner to support development of a family of unmanned aircraft systems (UAS) that can be locally developed and produced. The ideal partner will have already produced at least one platform as a potential baseline for development.

“We believe that the market on the UAV side is big enough to allow for further players; it is not oversaturated. So with a strong partner, we can play a significant role beyond the [Gulf Cooperation Council] in the future,” said Schwer. Riyadh had previously bought and operated, Chinese-built armed UAS.

Schwer said there are also plans for licensed assembly of light helicopters for military and commercial use and a medium-size transport helicopter, primarily for military use, possibly similar to Turkey’s approach to building the T-70 Black Hawk in conjunction with its local industry and Sikorsky.

Other changes envisioned include the merger of both commercial and military aviation businesses, Schwer said, noting that negotiations are underway to bring Saudia Airlines’ MRO business and its 4,000 technicians under the SAMI banner. That would, along with another 1,000 from Advanced Electronics Co. that SAMI formally took over on June 24, give SAMI a “baseline to start growing our aviation aspirations,” said Schwer. The company has also signed a number of agreements with several Saudi and overseas universities to recruit engineering students. Partners will also be encouraged to train and teach new recruits.

Schwer said Western companies have, after some initial uncertainty and hesitancy, embraced the radical new approach taken by SAMI, after years of reliance on government-to-government deals and programs such as the Foreign Military Sales system. “The change in the ecosystem brings added complexity and some commercial risk,” he said. “But we are overcompensating this risk with the attractiveness of a large market and a sole-source position for a long-period of time.”

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A NEWLY Merged L3 Harris Opens New Defense Product Strategy

After the scheduled closing of a $33.5 billion merger on June 29, the newly formed L3 Harris will set out to reshape an aerospace and defense market dominated by platform suppliers. The company’s plan is to leverage its vision and product strategy as a software-driven electronics and communications house.

The timing of the merger may be driven by concerns over forecasts of plateauing or declining U.S. defense budgets. But it also comes as a new military focus on a still loosely defined concept for multidomain operations and command and control emphasizes many of the technologies that form the core of the combined company.

The first all-new product created under the umbrella of the merged company likely will not appear for 2-3 years, William Brown, the former chief CEO of Harris Corp. and the newly assigned chairman and CEO of L3 Harris, told Aviation Week during the Paris Air Show.

But hints and ideas of future products and concepts have been forming behind the scenes for months. Although antitrust reviews by the U.S. and EU continued until final approvals came on June 22, the management teams of L3 and Harris have met regularly in the meantime to discuss arrangements for the merger as well as details of current products and investments that had been shielded from view by proprietary restrictions and the secrecy requirements of classified programs.

An obvious opportunity is finding new ways to connect Harris’ spacecraft and onboard processing capabilities with L3’s vast network of classified programs, including military surveillance aircraft, especially the modifications and upgrades managed by the Air Force’s Big Safari program office. Big Safari delivered the Air Force’s most sophisticated electronic surveillance aircraft such as the RC-135 Rivet Joint and Combat Sent platforms.

“What L3 has—they are really good in [intelligence, surveillance and reconnaissance]. They own the Big Safari program—that signals-intelligence capability that they built, that muscle, we don’t have that,” Brown says. “You can start to think about how you connect the airborne tier to the space tier.”

Within the space and airborne tiers, the connections between L3 and Harris technologies also seem intriguing. Harris’ new constellation of orbiting HSAT small satellites, for example, could benefit from access to L3’s multifunction phased-array technology. The same payload on a small satellite could be used as a synthetic aperture radar, signals-intelligence receiver or communications relay, depending on the customer’s need at that moment. It opens a new capability for combatant commanders to control space surveillance capabilities, rather than the larger, exquisite systems managed by the intelligence community.

“All of a sudden, that’s kind of appealing to the combatant commanders,” Brown says. “So it’s a whole different market space. Now you’re talking to the same people who control the assets on the airborne side, and people are starting to think differently around how you mix all these assets in different domains.”

L3 Harris hopes to link such combined capabilities with an entrepreneurial approach to product development.
ment. The goal is to exploit a trend toward installing an open systems architecture in combat aircraft, which would decouple the platform from the mission system. A first step in that direction, Brown says, was Harris’ sweeping victory in 2019 of all three elements of the F-35’s Technical Refresh-3 upgrade, which includes the aircraft memory unit, panoramic cockpit display and the integrated core processor. The latter will insert an open systems architecture into the F-35 mission system to bypass Lockheed’s proprietary standards and allow any company to develop new applications.

As such an approach proliferates across military aircraft fleets, a new business model will emerge, Brown says—one that will reward companies for anticipating customer requirements rather than waiting for the military customer to define them.

“I see the job of the larger combined company like L3 Harris as saying: ‘I hear what you want to do. I know you don’t know exactly how you want to act, but I hear where you want to go. Let me work with these technology portfolios, get some really smart people thinking about it and come back and talk to you about how you can realize that vision by some of the things that we’re doing,’” Brown says.

“If you sit there and you wait and you say: ‘OK, let this acting secretary come up with the ideas, generate the program, get the funding for the program and then go out to [bidding] and then bid it,’ you’re talking five years from now,” he adds.

L3 Harris’ new chief operating officer, Chris Kubasik, adopted a similar approach as the former CEO of L3. Kubasik wanted L3 to be the antithesis of a sclerotic, bureaucratic, lumbering prime. Instead, he wanted the company to be more like a nimble, innovative and responsive startup.

According to Kubasik and his team, L3 distinguishes itself from competitors by better understanding and responding to customer needs. “We listen better, we move faster, we invest ahead of the curve,” says Jeff Miller, corporate senior vice president and president of the ISR Systems Segment at L3.

In early June, ahead of L3’s merger with Harris, Kubasik and his team sounded as though they expected to employ the same approach at the combined company. “Performance is the best way to grow the business,” Kubasik says. “If you’re not performing on your existing business, you’re unlikely to win more.”

L3 has invested in “hackathons,” maker spaces and Silicon Valley-inspired “sprints,” where ad hoc teams are formed to dream up and prove a solution within a week or so, according to Miller.

One area where sprints have been applied is in L3’s space businesses. There, Kubasik sees particular synergies between L3 and Harris. “One of the things I found attractive with Harris is they have a well-respected, significant presence in space, both the small satellites and terminals, and the antennas they build. We have capabilities in satellites, as well.”

Miller says the companies could see a synergy in smallsat rapid production. L3 also recently conducted a sprint addressing how to link L3’s artificial intelligence to payloads and “quickly distinguish hotspots around the world,” he says, and another on how to apply high-volume production of airborne gimbals to satellite production to make as many as four birds a day.

## PROPULSION

### Ampaire To Fly Hybrid-Electric Testbed on Regional Routes

- **AMPAIRE 337 TARGETED FOR STC IN 2021**
- **WORK ON CONVERTING LARGER AIRCRAFT TO BEGIN NEXT YEAR**

Graham Warwick Washington

Less than a month after beginning flight tests of its electric-propulsion testbed, U.S. startup Ampaire says it has secured the company’s first customer for the modified Cessna 337 Skymaster.

Personal Airline Exchange (PAX), a U.S. startup developing an app-based per-seat, on-demand charter service, says it has placed an order for 50 Ampaire 337s, plus options for 50 more. Ampaire is aiming to certify the six-seat aircraft, known as the Electric Eel, in 2021.

Unveiled publicly on June 6 in Camarillo, California, the modified Cessna 337 Skymaster made its first flight on May 23. The twin-boom Skymaster has a “push-pull” configuration with Continental IO-360 piston engines mounted fore and aft in the fuselage. In the Ampaire 337, the rear...
engine is replaced with an electric motor powered by lithium-ion batteries. In the test aircraft, the batteries are mounted in the cabin, but Ampaire is aiming for supplemental type certification (STC) of a conversion for the Skymaster in which the batteries are housed in an underfuselage pannier now used for cargo.

The Ampaire 337 will use the forward combustion engine and aft electric motor in a parallel-hybrid propulsion system in which the piston engine is optimized for cruise operation and the electric motor provides a power boost for takeoff and climb.

“This will allow the combustion engine to sip fuel and eliminate the corner cases where high power is required [from the engine],” says Kevin Noertker, co-founder and CEO. The modified aircraft has a 200-mi. useful range, and the company is anticipating fuel savings of more than 50% from hybrid propulsion.

Ampaire plans to begin test flights by year-end on a route flown by Hawaiian regional carrier Mokulele Airlines. This will use a second modified Skymaster closer in configuration to the final aircraft for which the company anticipates receiving the STC by the end of 2021.

The second, preproduction aircraft will be flown for six months on Mokulele’s route between Kahului and Hana on the island of Maui. Operations on the 28-mi. flight between Kahului and isolated Hana are limited by poor economics with current aircraft, says Noertker.

Such short routes “are the biggest early opportunities for electric flights,” he says. Ampaire is working with Puerto Rican regional Vieques Air Link to establish a pilot project and says it has letters of interest from 14 other airlines around the world. PAX is developing an app that will enable users to request on-demand flights on aircraft flown by Part 135 charter operators. The system will negotiate and aggregate requests to enable 3-6 passengers to share a flight, says CEO Michael Azzarello.

“Our connection with Ampaire is driven by the flight profile of our trips,” he says. “PAX provides flights for trips that the airlines don’t make. In many cases, these are under 100 mi. with 3-6 passengers; the upper end is around 400 mi.”

PAX co-founder Bruce Sawhill was co-founder of DayJet, which offered on-demand air service in Florida using the Eclipse very light jet. DayJet owned and operated its aircraft, but

As the Cessna 337 is not in widespread regional-airline use, Ampaire plans to source and convert Skymasters for resale. But some airlines operating larger types want to convert their existing aircraft, so the company has relationships with organizations that modify the targeted types, Noertker says.

In the Skymaster, the pilot has separate power levers for the front and rear engines. Initially, the two levers will be retained in the Ampaire 337, one for the engine and one for the motor, with special displays to help the pilot balance the power to optimize efficiency. Eventually, this may be automated.

The Ampaire 337 uses lithium-ion batteries with an energy density of 200 Wh/kg at the pack level, says Noertker. The pack architecture and battery management system has been developed by the company. “This is a chemistry and an integration type FAA feels comfortable with,” says Noertker. Batteries will be recharged on the ground between flights, although some airlines are interested in a battery-swap capability to enable rapid turnaround, he adds.

With the beginning of test flights, the startup has launched a Series A financing round to fund the Ampaire 337 through to certification. “We estimate this will take about $20 million,” Noertker says, noting this is “an order of magnitude less” than the funding required to certify an all-new electric aircraft. n
Air Link to establish a pilot project with Puerto Rican regional Vieques fights, he says. Ampaire is working on early opportunities for electric aviation, says Noertker. Poor economics with current aircraft, including in the Hawaiian area. These flights will use aircraft already flown by Part 135 operators. Testing will commence on June 6 with flights made its public debut on June 14.

The Ampaire 337 is driven by the flight profile of our customers, says CEO Michael Azzarello. Our connection with Ampaire means we can find new opportunities for our customers, says Azzarello. "We will place [the flight planning] through the Ampaire 337, which is optimized for cruise operation and has a 200-mi. useful range." This will use a battery-swap capability to enable shut down during the 2008 economic crisis. "We have a similar focus to Ampaire, says Noertker." Batteries will be recharged on the ground between flights, allowing us to scale our growth on the second modiﬁed aircraft. This will use a second modiﬁed engine is replaced with an electric motor in a parallel-hybrid propulsion system.

The Ampaire 337 will use the for- mation (STC) of a conversion for the Eclipse very light jet. DayJet aimed for supplemental type certiﬁcation, says Noertker. The startup has launched a Series A round, and says it has letters of interest from 12 other airlines around the world. PAX says it intends to reserve the ﬁrst aircraft at selected opera- tions that modify the targeted types, their existing aircraft, so the company anticipates receiving the STC by the fnal aircraft for which the com- panies have access to aircraft, but our modiﬁcation algorithms that Bruce Sawhill was aiming for electric propulsion.

In the test aircraft, the batteries are mounted in the cabin, but Ampaire is considering a battery-swap capability to enable electric overnight combustion engine and aft electric motor in a parallel-hybrid propulsion system.

Ampaire plans to begin test ﬂights in a battery-swap capability to enable overnight combustion engine and aft electric motor in a parallel-hybrid propulsion system. A battery management system has been developed by the company. "This is a critical element for the planning and optimization of ﬂight planning. This is an import- ant element for the planning and optimization of ﬂight planning," he says. "Flights commence on June 6 with a ﬂight made its public debut on June 14." In the Skymaster, the pilot has separated the one for the engine and one for the electric. Noertker says. Batteries will be recharged on the ground between ﬂights, allowing us to scale our growth. This will use a second modiﬁed engine is replaced with an electric motor in a parallel-hybrid propulsion system.

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China’s Landspace Fires Main Engine and Plans Higher Thrust

INITIAL LIFTOFF THRUST IS 67 METRIC TONS

THE ENGINE USES THE GAS-GENERATOR CONFIGURATION

Bradley Perrett Beijing

Private Chinese space launcher builder Landspace has tested a complete methane-burning space-launch main engine, working toward the first flight of the company’s ZQ-2 rocket in 2020. The test also laid the groundwork for a move to higher thrust.

Landspace says it fired a TQ-12 engine four times, meeting a target to run it for the first time in May. In the longest test, the engine ran for 20 sec. Starting and shutdown were fast and stable, the company reports, adding that these and other parameters showed the engine met requirements.

The ZQ-2 is ultimately intended to become reusable, which was one reason for the choice of clean-burning methane fuel. The company points out that it is the third to develop a large methane-fueled engine, after SpaceX (with the Raptor) and Blue Origin (with the BE-4). The interval between the beginning of development and the first firing of the engine has been about two years—longer than planned in September 2018, when the engine was expected to run late in that year or early in 2019 (AW&ST Oct. 15-28, 2018, p. 34).

Thrust for the TQ-12 is 67 metric tons (148,000 lb.) at liftoff and an initial 76 metric tons in a vacuum, with potential for 80 metric tons, says a spokesperson. The test demonstrates that the company has all the technology it needs for an engine of 100-metric-ton thrust, Landspace says. Since the company has consistently classified the TQ-12 by its vacuum rating, the 100-metric-ton level is presumably also for a vacuum. Landspace has previously said it planned to drive the TQ-12’s sea-level thrust up to 75 metric tons.

The TQ-12 could be applied to small, medium and heavy launchers, says Ge Minghe, Landspace’s propulsion general manager. The initial, basic ZQ-2 will have four TQ-12s in its core first stage and no boosters. The first-stage module will be adapted as a booster for more powerful versions. A concept for one of those versions, ZQ-2C, has four boosters plus the core and therefore 20 TQ-12s firing at liftoff.

The basic ZQ-2 will have a similar but scaled-down engine, the 10-metric-ton-thrust Phoenix for its second stage. This initial version of the launcher is being designed to take a payload of 4 metric tons to low Earth orbit; the second version, with a third stage and the upgraded standard of TQ-12, generating 75 metric tons at liftoff, is intended to hurl 6 tons to the same orbit.

In developing that version and any larger ones, Landspace will be encroaching on the market of the Long March 8 launcher under development by Calt, the main rocket-builder of state space contractor Cas. The Long March 8 is being designed to throw 8 metric tons to low Earth orbit in its initial version, with two boosters; officials say a second version will lack boosters, so it may overlap in capability with even the basic ZQ-2.

Eventual reusability is a target for the ZQ-2 program, at first with vertical recovery and later with runway landing. The company has said in expendable mode, the price per launch will be 150 million yuan ($22 million). The Long March 8 is also being designed for eventual reusability, using vertical descent.

The TQ-12’s design uses the open gas-generator method of driving the engine’s pumps. In this relatively undemanding arrangement, chosen to help speed development, unconsumed propellant exhausted by the gas generator is ejected, rather than forced into the combustion chamber.

Landspace says the TQ-12 will also serve as a second-stage engine. The company has done its own design, development, manufacturing, assembly and now testing for the engine.

The test of the complete engine followed demonstration of its power pack—comprising the turbopump, gas generator, piping assemblies and valve components—in April. That test verified the design of the turbopump and valves, integration of components, the start sequence and fabrication techniques, Landspace said then. The thrust chamber was tested in September 2018 and the gas generator alone in January 2019.

A brief video of the power-pack test suggests the company is resisting any temptation for gold plating. The test rig was housed within a simply constructed frame of steel tubes supporting corrugated roofing sheets for protection from rain. The installation was obviously not intended for prolonged use.

Landspace developed a small solid propellant launcher, the ZQ-1, mostly as a pilot program to accumulate experience and introduce the company to the launch market. The first and second stages of the first ZQ-1 worked properly when the rocket was launched in October 2018, but the third stage suffered a fault, and the mission failed. Landspace has not said whether it will launch another ZQ-1.
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A NEW MARKET?

NORTHROP AND INTELSAT LAUNCH FIRST COMMERCIAL ON-ORBIT SERVICING MISSION

EARLY PROGRAMS COULD DETERMINE PACE OF ADOPTION

Jen DiMascio  Washington

The launch later this summer of Northrop Grumman’s Mission Extension Vehicle, the first commercial, in-space satellite-servicing mission, could help seed a market for on-orbit servicing and serve as the first step to unlocking manufacturing in space.

But the mission is not without risks, and its success could determine the speed with which a market for on-orbit servicing (OOS) develops.

The first Mission Extension Vehicle, MEV-1, is scheduled to fly beneath a Eutelsat satellite on a Proton rocket from the Baikonur Cosmodrome in Kazakhstan later this summer. It was built to provide four types of service—geostationary station-keeping, reductions in the inclination of orbits, relocation of a satellite within the geo-belt or into the graveyard, and satellite circumnavigation and inspection. The MEV will rendezvous with an Intelsat satellite that will conduct 30 orbital maneuvers on its way to a point over the Pacific Ocean chosen to be conservative and safe for docking.

Should the subsequent docking be successful, the MEV will extend the life of Intelsat 901, a Space Systems/Loral-made (SS/L) satellite launched in 2001 that is running out of fuel. The mission will allow Intelsat, which prides itself on early adoption of technology, to keep using that asset in its valuable orbital position.

“We would not be able to replace that satellite because the business case wouldn’t work,” says Ken Lee, Intelsat’s senior vice president of space systems.

“This will allow us to continue to provide service to our customers.”

The mission represents a step toward the larger goal of spacecraft that can service satellites in orbit—using robotic arms to repair their solar arrays. And those robots move the world one step closer to the dream of in-space manufacturing. The next hurdle will be commercial viability. “I think it’s very hard to find the right business model for these services,” Lee says.

Intelsat signed a contract in 2016 with Space Logistics, which is now a subsidiary of Northrop Grumman.

For three years, Northrop has been refining its MEV-1. On a recent visit to Northrop’s Dulles, Virginia, production facility, the servicing vehicle was depressurizing in a blast cage and undergoing leak testing. From there, the spacecraft will return to the thermal vacuum chamber for another test preceding final approval for launch. Northrop has secured licenses from the Federal Communications Commission as well as the National Oceanic and Atmospheric Administration, and it is insured for launch plus one additional year of operations. MEV-1 will provide station-keeping life extension for Intelsat 901 for at least another five years. Intelsat 901 is set to take on communications traffic from a nearly identical satellite, Intelsat 907, that is also timing out. Beyond that, Intelsat has signed another five-year contract with Northrop, for MEV-2, a build-to-print version of the initial spacecraft. Launch is anticipated in the spring of 2020 on an Ariane 5 rocket.

For geostationary communication satellite operators, orbital assistance can reduce inclined orbits or just provide station-keeping life extension.
Northrop has taken a conservative approach to innovation, drawing on its existing GEO communication satellite bus; it has already built 40. And Northrop's Cygnus cargo-carrying capsule for NASA has given the company experience with rendezvous and docking operations. The company developed algorithms, sensors and prototype docking mechanisms and shared them with customers. “That was pivotal to getting customers to buy in,” Anderson says.

Anderson expects new sales to begin a few years before the MEV-1 and MEV-2 missions are complete. Northrop would sell those two MEVs as a single asset or as a service in the future. The MEV itself has a 15-year design life. “I believe there is plenty of demand,” he says.

Northrop has plans for other robotic servicing missions as well. First, the company is developing a Mission Robotic Vehicle that uses a robotic arm to install a Mission Extension Pod. The concept is to install small propulsion augmentation devices onto existing satellites. Those pods would function as new propulsion elements for 2,000-kg (4,400-lb.) satellites for 5-6 years but would not conduct attitude control missions.

“We can make a business out of augmenting with pods,” Anderson says. “There is ample demand,” for this rather simple approach. He sees the pods being launched in 2023 and begin service in 2024.

Beyond this step would be the ability to execute in-space assembly, something Anderson envisions occurring in the latter half of the 2020s.

Customers are already asking what types of interfaces they can add to be able to plug into a replacement unit for data or power in the future, he says. But rapid adoption of on-orbit servicing may hinge on the success of early missions like the MEV.

“If near-term [on-orbit servicing] demonstrators suffer failures, either technical or programmatic, the market may shy away from OOS, at least until more successful demonstrations occur,” write the authors of a recent Aerospace Corp. report titled “On-Orbit Servicing: Inspection, Repair, Refuel, Upgrade, and Assembly of Satellites in Space.”

The report adds that Maxar’s recent exit from DARPA’s Robotic Servicing of Geosynchronous Satellites (RSGS) may be an indication that the market is not ready for commercial investment. Maxar, which reorganized due to losses in the geostationary communications satellite market, terminated its agreement to provide the robotic arm. The company’s CEO Dan Jablonsky says the RSGS investment of $50 million would not see returns until 2022, adding that when it comes to capital allocation decisions, he has to conclude RSGS was “an uncertain bet.”

But after two decades of investment by the U.S. and other governments, The Aerospace Corp. indicates building a market is more a question of when, not if, a market can be built.

About 1% of satellites in geostationary orbit will need servicing, says Joseph Parrish, RSGS program manager for DARPA. “We envision 20-30 satellites need to be repaired,” he says, during a mission that would last 5-10 years.

DARPA is conducting a three-part process to find a new vendor since Maxar’s departure from the program. The agency held an eligibility determination in early June, in which companies had to demonstrate they can handle export controls and other requirements. Proposals from the eligible contractors are due July 23, and DARPA expects to award an Other Transactions Agreement by the end of the year.

The industry-led Consortium for Execution of Rendezvous and Servicing Operations is funded by DARPA. But this year, industry will begin paying for the organization that is developing technical standards to enhance the safety of on-orbit servicing, says Todd Master, program manager in DARPA’s Tactical Technology Office. Given that satellite-servicing vehicles could be misused to damage spacecraft, such rules would help ensure that servicing missions do not trigger security concerns. As commercial outfits begin their own missions, he expects the expertise to move from government to the private sector, allowing DARPA to reduce its role.

According to Parrish, the technological challenges have largely been solved. The programmatic difficulty is having a community that has not designed spacecraft to be serviced. “That is one of the reasons we decided to get in front of that with RSGS and break the egg and build the service.”

"It allows them to defer capital expenditures," says Joe Anderson, vice president of business development for Northrop Grumman. Life extension can also allow satellites to start new orbital roles, identify anomalies using onboard sensors and cameras or just keep older satellites operating longer.

“We’d like to break down barriers to entry. MEV does that for existing operators or for new operators who want to enter the market,” Anderson says.
How Northrop Grumman’s MEV Will Extend GEO Satellites’ Lives

When Northrop Grumman Innovation Systems’ first Mission Extension Vehicle, MEV-1, is launched later this year, it will set the stage for more than just the first docking between two spacecraft in geosynchronous orbit (GEO).

If successful, MEV-1’s mission to extend the operational life of an existing Intelsat communications satellite by years will change the economics of the space market. MEV-1 could also be the first in a line of increasingly capable spacecraft for servicing, assembly and manufacturing in orbit.

The 2,500-kg-class (5,500-lb.) MEV-1 will be launched as one of a stacked pair of Northrop-built spacecraft, sharing the ride into orbit on a Proton-M booster from Baikonur with the Eutelsat 5WB communications satellite. MEV-2 will likewise be paired with Intelsat’s Northrop-built Galaxy 30 when it is launched on an Ariane 5 in 2020.

After separating from its rideshare partner, MEV-1 will begin its journey to GEO. Orbit-raising on electric propulsion will take 3-4 months, says Joe Anderson, vice president of business development and operations for Northrop subsidiary Space Logistics. Intelsat 901 is still operational in a 1-deg.-inclined orbit, so while MEV-1 is en route to GEO, the satellite will be raised to graveyard orbit ready for the rendezvous, a safety measure to be taken “for an abundance of caution,” he says.

“While it’s doing the orbit-raising, our 901 spacecraft will be doing maneuvers to meet the MEV,” says Ken Lee, Intelsat’s senior vice president of space systems. “We’re going to meet two vehicles over the Pacific Ocean at 150 deg. W. Long. We picked that location because it is where you have the least amount of spacecraft. Again, to be conservative and be safe.”

The MEV is based on Northrop’s GEOStar bus, more than 40 of which have been built. The spacecraft has two electric-propulsion modules mounted on booms positioned so that, once docked, their thrust acts through the center of mass of the combined spacecraft. Compared with a communications satellite, the MEV carries more xenon propellant, enough for 15 years of station-keeping and several inclination reductions.

The servicing spacecraft will deploy two solar arrays providing 10 kW of power at the beginning of life. The arrays will be aligned East-West when docked, so as not to shadow the client satellite’s North-South-aligned solar panels. And while the satellite’s arrays track the Sun to maximize power for its communications transponders, the MEV needs less energy, so its arrays will simply flip over.

Once in GEO, the MEV will be maneuvered into the client satellite’s station-keeping box. GEO satellites do not stay perfectly still, says Anderson, but instead are kept within a ± 0.5 deg. longitude region. The servicing spacecraft will then begin to spiral in close to its target. For rendezvous and docking, the MEV will use its hydrazine thrusters, which will provide six-degree-of-freedom control.

Within 1-2 km (0.6-1.2 mi.) of the rendezvous point, the MEV’s onboard sensors will be able to see the target, enabling it to approach autonomously to its first waypoint, 80 m (260 ft.) behind the client satellite in the same orbit. Here the MEV will await command from ground control, which will be receiving imagery from the sensors and data from image processing onboard the spacecraft.

“These spacecraft are 22,300 mi. away. That’s pretty far, and they have to meet at a point,” says Lee. “So some pretty interesting work has been done by both companies to make sure we can do it, because our spacecraft [Intelsat 901] was not designed to be docked like this.”

MEV-1 has multiple sensors for rendezvous and docking—stereo visible and infrared cameras with wide and narrow fields of view and two lidars. Onboard image processing identifies and tracks datum points on the client satellite to align the spacecraft for automated docking. One of things Northrop wants to find out from these first flights, says Anderson, is whether it can perform the mission with fewer sensors.

The sensors have undergone years of testing in Northrop’s Rendezvous, Proximity Operations and Docking (RPOD) laboratory on Northrop’s campus in Dulles, Virginia. Here, the sensors and docking system are mounted on a robot arm and put through their paces using full-scale models representing different client satellites—mounted on a second robot arm so the MEV and its target can be maneuvered relative to each other. The lab can simulate a range of lighting conditions, from total darkness to full sunlight, to exercise the sensors.

Having received permission to proceed, the MEV will move to the next waypoint at 20 m behind the client, where it will again stop and await a command from the ground. The spacecraft is autonomous from waypoint to waypoint, and align-
The MEV docking system (left), with a central probe and three stanchions, against the target satellite (right) with the apogee engine and adapter ring.

The MEV mission control center software and displays have been tested in the RPOD lab.

ment for docking is closed-loop onboard the MEV, Anderson says. Cleared to proceed, the MEV will move in to 1 m behind the client and into the capture hold box.

The docking system uses two features on the client satellite: the launch adapter ring used to attach the satellite to its launch vehicle and the liquid apogee engine used to raise the spacecraft to GEO. Neither are needed again once the satellite is in orbit. The MEV will extend a probe that enters the nozzle of the apogee engine and is guided by the curve of the cone into the throat of the engine.

There are a dozen different designs of liquid apogee engine on communication satellites in GEO, but Anderson says Northrop's research—evidenced by several 3D-printed nozzles in the RPOD lab—shows that their throats are all within a few millimeters in size, enabling one probe system to be compatible with all variants.

The probe will pass through the throat, open a set of fingers, then retract, capturing the satellite. Four small arms, called quillions, will move forward to press against the inner curve of the nozzle cone, holding the probe in place as it retracts and pulls the spacecraft together until three stanchions on the MEV press against the launch adapter ring.

There are three standard sizes of launch ring, and the L-shaped stanchions accommodate all three, Anderson says. Forces in orbit are light, so simple push-pull tension on the probe and stanchions will keep the spacecraft firmly docked until the life-extension mission is complete, the client satellite is released, and the MEV moves on to its next mission.

Because the forces are so light, the client satellite will begin to move slowly away as soon as the MEV's probe makes contact. The RPOD lab has a frictionless air-bearing floor on which to test contact dynamics. This uses the MEV docking system, on its robot arm, and a dynamically accurate mockup of the target satellite mounted on air-cushion pucks so it is free to move. “When the MEV makes contact, the satellite starts to drift, and we need to make sure we can still capture it,” Anderson says.

Before docking, the client satellite’s control system will be deactivated to prevent it from “fighting” the MEV as they come together. After docking, Intelsat will continue to control the communications payload from its ground station. But now
the MEV, providing station-keeping and attitude control for the combined spacecraft using its electric propulsion and momentum wheels, will be managed from Northrop's mission operation center in Dulles.

“Ultimately—once attached—we will be using the MEV’s propulsion system to pull down the spacecraft from docking to service orbit. Then Northrop will operate the MEV for station-keeping and attitude control, and our team will control the spacecraft except for those two functions,” says Lee.

Northrop’s contracts with Intelsat are each to provide five years of docked life extension. The MEV is designed to provide 15 years of station-keeping time docked to a 2,000-kg-class satellite, the average dry mass at end of life for all GEO communications satellites in the 2020s, says Anderson. The servicing satellite has additional xenon fuel for inclination reduction. Changing orbit consumes much more fuel than maintaining orbit, he says, with 1 deg. of inclination reduction equaling one year of station-keeping.

The next step for Northrop’s space servicing plan is the Mission Robotic Vehicle (MRV), a development of the MEV that will use a robotic arm to attach Mission Extension Pods (MEP) to client satellites. The MEP is a small propulsion-augmentation device the MRV will install on a satellite using the same apogee-engine docking probe as the MEV. This pod will provide only orbit (station-keeping) control and will be limited to six years of life extension for a 2,000-kg-class satellite. The MEP also can be detached from one satellite and moved to another.

Later versions of the MEP will enable the MRV to add other payloads to satellites in orbit, replacing failed onboard systems or adding adjacent capabilities such as space situational sensors or an optical communications payload. “Customers like the MEP versus refueling,” he says. “It provides the same economics at lower risk. And the MRV is the MEV with a simple robotic arm that can install augmentations. It is not doing satellite surgery. Our strategy is to keep it simple and incremental.”

Solar arrays on the MEV (foreground) will be at right angles to those on the client satellite.
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ON-ORBIT SERVICING

A Growing Market?

While Northrop Grumman takes the lead with its Mission Extension Vehicle, several programs and other industry players are looking to extend on-orbit servicing capabilities and expand the emerging market.

Graham Warwick  Washington

NASA Restore-L

NASA is considering expanding the mission of its Restore-L spacecraft, which is planned for launch in December 2022 to demonstrate autonomous rendezvous, inspection and capture, teleoperated robotic refueling and relocation of an existing satellite in low Earth orbit (LEO). The client satellite will be Landsat 7.

Maxar is providing the spacecraft bus, while the NASA Goddard Space Flight Center is supplying and integrating the robotic servicing payload and will operate the vehicle in orbit. The payload includes visible, infrared and lidar sensors, a berthing system and two seven-degree-of-freedom robotic arms with interchangeable tools. NASA is establishing cost and schedule baselines for two potential additions to the Restore-L mission: the Dragonfly on-orbit assembly and MakerSat on-orbit manufacturing demonstrations. Short, 30-day studies have indicated the demos are compatible with the Restore-L mission, NASA says.

Maxar’s Dragonfly demo would use a dedicated robotic arm to assemble a large radio-frequency reflector; it is aimed at application to geosynchronous (GEO) communications satellites. Tethers Unlimited’s MakerSat demo would manufacture a meters-long thermoplastic carbon-fiber beam to validate the pultrusion process to be used in its Trusselator system to form longerons and crossmembers for large spacecraft truss structures.

DARPA RSGS

Following Maxar’s withdrawal from DARPA’s Robotic Servicing of Geosynchronous Satellites (RSGS) program, citing financial pressures, the Pentagon research agency is seeking another industry partner with which to create a commercial dexterous robotic servicing capability in GEO.

RSGS is planned as a public-private partnership under which a U.S. satellite builder and operator will provide the GEO bus and integrate a DARPA-supplied payload to create the Robotic Servicing Vehicle (RSV). The partner will procure the launch and, after the DARPA on-orbit demonstration, continue to operate the RSV commercially for several years to service government and commercial customers.

“The end state is a U.S. commercially owned and operated RSV in GEO, carrying the government-furnished robotic payload,” says DARPA. Developed by the Naval Research Laboratory, the payload will have sensors, tools and two dexterous robotic arms with which to grapple and service the client satellite. Payload hardware and software assembly and integration and testing are now underway.

Notionally planned for launch in the fourth quarter of fiscal 2022, RSGS would rendezvous with and grapple a cooperative satellite, then conduct inspection, orbit adjustment, anomaly resolution and the installation of “on-orbit attachable capabilities” — DARPA-speak for small payloads that would be delivered into orbit on routine GEO satellite launches and retrieved by the RSV for robotic attachment to client satellites to replace failed components or expand capability.
**Effective Space**

UK startup Effective Space plans to launch the first two of its Space Drone vehicles in 2020 to extend the lives of two GEO communications satellites for an unidentified operator. Backed by Israel Aerospace Industries, the company is developing a 400-kg-class (900-lb.) spacecraft that will dock with the client satellite to provide station-keeping and attitude control, orbit correction, relocation and deorbiting using its electric propulsion. Space Drone is designed for multiple missions over a 15-year design life.

**Astroscale**

Japanese startup Astroscale has raised $132 million to develop technology to remove orbital debris from LEO using a robotic servicer satellite that would track, grapple and deorbit large objects such as spent upper stages and defunct satellites. Tokyo-based Astroscale also plans to provide a service to actively deorbit satellites, particularly in large LEO constellations, at the end of their lives. An end-of-life demonstration mission, ELSA-d, is planned for launch in 2020.

**Weintraus**

A U.S. startup formed to tackle the growing space-debris problem, Weintraus is still in stealth mode but has discussed plans to develop the Phasor space tug and Hercules servicing vehicle. Phasor, which is planned for a first flight in 2022, will provide orbital placement, orbit boosting, inclination changes, satellite refueling and debris mitigation over a 15-year life. Hercules, to follow in 2023, will have two robotic arms for servicing satellites in all orbits between LEO and GEO.

**Altius Space Machines**

Altius is working to develop the Bulldog microsatellite-class spacecraft for robotic servicing and end-of-life disposal of satellites in large LEO constellations. The company is developing required technologies such as the Gecko Gripper grasping tool, MagTag magnetic servicing interface and cooperative servicing valves under small-business research contracts from the U.S. Air Force Research Laboratory and NASA while it tries to raise investment to develop the complete system.

**Airbus O.Cubed Services**

Airbus has created O.Cubed Services to pursue development of the Space Tug family of robotic spacecraft for GEO inspection and maintenance, GEO spacecraft delivery, LEO constellation deployment and active debris removal. Airbus participated in Europe’s Remove-Debris mission to demonstrate debris capture and removal technologies. This was a precursor to the European Space Agency’s expanded Deorbit mission to demonstrate both on-orbit servicing and removal of a defunct satellite.
Bringing Commercial Space Into the Mainstream

The FAA advances its Space Data Integrator system

SpaCeX’s CRS-8 Dragon is the first vehicle tracked

Bill Carey Pomona, New Jersey

Engineers are watching the growth of the commercial space industry from a second-floor laboratory at the FAA William J. Hughes Technical Center with an eye toward minimizing the impact on the routine operation of the U.S. national airspace system (NAS).

The FAA in late 2014 contracted Millennium Engineering and Integration Co. to develop the Space Data Integrator (SDI) as a proof-of-concept system to automate the way it monitors space launch-and-reentry vehicles as they transition through the NAS. The SDI ingests telemetry data provided by space vehicle operators during their missions and feeds it into the agency’s Traffic Flow Management System (TFMS) for display to traffic management coordinators.

The TFMS is a strategic tool that collects flight-plan, traffic-flow, surveillance and weather data from remote sites to create a nationwide map of predicted air traffic demand.

As its name suggests, the SDI integrates space vehicle missions in real time with traditional air traffic flows, increasing “situational awareness” and supporting dynamic management of the airspace. The SDI connects to the TFMS via a TCP (transmission control protocol) port, but testing includes publishing SDI data via the FAA’s System Wide Information Management (SWIM) flight-data publication service, which would make it available to the TFMS as a subscriber system.

Commercial space operators SpaceX and Blue Origin have participated in development of the SDI by providing the FAA with real-time launch and reentry vehicle data through a secure internet connection.

The data they provide, including vehicle state vector (position and velocity), mission status and vehicle health information is piped by the tech center to the FAA’s Air Traffic Control (ATC) System Command Center in Warrenton, Virginia.

At the command center, missions are being monitored in “shadow mode” by a Joint Space Operations Group of traffic managers, space operations specialists and engineers who make air-space management decisions involving launch and reentry operations.

“When we built the SDI prototype, we wanted the ability to use it here at the tech center where the technology is developed, but also to be able execute it in a shadow mode at an operational facility,” says Daniel Murray,
space transportation development division manager with the FAA’s Office of Commercial Space Transportation.

The command center accesses the SDI feed on a research network “that doesn’t touch operational systems,” Murray adds. “But we can put the [display] hardware next to operational hardware and monitor live operations, having the people who will operate the system in the future on a regular basis participating in its development.”

In 2014, the FAA developed a Hazard Risk Assessment Management (HRAM) prototype system to demonstrate that the time required to calculate and display an aircraft hazard area (AHA)—airspace that is segregated from other air traffic to accommodate unexpected events such as a space vehicle breaking apart—could be reduced from minutes to seconds.

The HRAM prototype, a separate system the agency has integrated with the SDI at the Tech Center, serves toward development of an AHA Generator that will provide rapid identification of affected airspace during nominal and off-nominal space missions—operations that proceed according to plan and ones that do not.

The SWIM data exchange is a candidate for disseminating dynamic hazard area data to the En Route Automation Modernization (ERAM) system that en route controllers use and the Standard Terminal Automation Replacement System (STARS) platform at terminal radar approach control facilities. “We’re looking at pulling hazard areas in a similar way into ERAM and STARS and TFMS downstream,” says Murray.

At the tech center, the systems are manifested on two 60-in.-diagonal overhead displays in the Commercial Space Integration Lab, which last year became part of the center’s NextGen Integration and Evaluation Capability (NIEC) lab complex. The NIEC is a research platform for rapid prototyping and simulation of new ATC, cockpit, unmanned aircraft and other concepts in an integrated environment.

One space lab display is a conventional Traffic Situational Display, similar to what a traffic management coordinator at an en route center or the ATC Command Center would use for strategic planning and traffic-flow monitoring. Space-vehicle data is depicted as a chain of AHA boxes and an icon for the vehicle as it progresses on a trajectory. The existing display updates once per minute, which would not suffice for tactical decision-making about a specific launch, Murray explains.

The main user interface for the SDI is an Enhanced Space Data Display, which updates once per second and can be segmented by different windows. Vehicle location can be shown on a three-dimensional map with predicted and actual trajectory lines traced with time markers for critical events such as a booster separation or deorbit burn. A “Status Lights” box indicates by green or red lights whether the SDA is receiving data from the vehicle and its operator or if data is not being received.

The FAA initially planned to demonstrate key requirements of the SDI using an interim version of the system during the SpaceX Cargo Resupply Service (CRS)-7 mission to the International Space Station (ISS). But the Falcon 9 rocket carrying the Dragon cargo capsule the FAA planned to track broke up after liftoff on June 28, 2015, dashing plans to run the system when the Dragon capsule returned to Earth.

The agency says it first integrated and displayed live data from a space vehicle on orbit and reentry using the SDI during the return to Earth of SpaceX’s CRS-8 Dragon capsule on May 11, 2016, following a resupply mission to the ISS.

The FAA first integrated live data from a launch vehicle, its complete suborbital trajectory and multiple vehicle elements (booster and capsule) on July 18, 2018—the ninth mission of Blue Origin’s New Shepard reusable suborbital rocket system.

On Aug. 3, 2018, the FAA applied HRAM for the first time during a live operation to calculate a dynamic aircraft hazard area for display on a test Traffic Situational Display while monitoring the reentry of SpaceX’s CRS-15 Dragon capsule. It used the HRAM prototype for the first time on a suborbital launch during the 11th mission of Blue Origin’s New Shepard on May 2.

As of Aviation Week’s visit in mid-May, the tech center had monitored 17 space missions with the SDI: nine SpaceX Dragon capsule reentries, five SpaceX Falcon 9 and Falcon Heavy rocket launches, and three Blue Origin New Shepard flights.
Next on the schedule was the SpaceX launch of 60 Starlink satellites by Falcon 9 rocket May 23 from Cape Canaveral AFS, Florida.

The FAA’s commercial space integration program is a four-phase effort that started by merging space data from operators with other air traffic information, then introduced rapid identification of affected airspace using the HRAM prototype.

Phase 3 calls for integrating decision-support tools for space operations with the TFMS, ERAM and STARS systems; the fourth is to deliver hazard-avoidance guidance to pilots via Data Comm text messaging, network voice communications or as an automatic dependent surveillance-broadcast (ADS-B) “In” application. Research is underway to adapt ADS-B “Out” position reporting to rockets, says Murray.

“The ultimate goal is [to] have all of these things in place. That’s where you get full integration,” he says. “You could have a launch pretty much any time from any place. The airspace would be managed dynamically throughout the entire operation and therefore the impact on the other [airspace] users would be minimized. The ability of the system to respond to off-nominal scenarios would be maximized.”

The FAA is preparing a commercial space integration concept of operations covering 2025-35 that it expects to release for comment later this year, according to Murray.

Routine commercial space operations would replace the way the Joint Space Operations Group manages the NAS during launch and reentry events, a process the FAA describes as slow, manual and labor-intensive. Before the start and over the duration of an operation, the agency closes off AHAs around a vehicle’s launch point or landing point, where the risk of a failure that could cause falling debris is relatively high, and in areas where debris is expected to fall from planned hardware jettisoned from the vehicle.

Real-time situational awareness of the airspace and dynamic hazard-area generation will allow the FAA to reduce the amount of airspace closed for an operation and the duration of the closure.

“Our elevator speech is ‘reduce, respond, release.’ Reduce the airspace you need to close in advance of the operation by having situational awareness and being able to manage it more dynamically; respond in the event that something doesn’t go as planned; and then release” the airspace, says Murray.

With the tempo of commercial space operations increasing, air traffic management improvements to accommodate launch and reentry vehicles will be welcomed by controllers as well as by other airspace users—namely airlines—that view the FAA’s current flight restrictions around space operations as disruptive. Last year, the FAA licensed a record 32 launches and three reentries; this year it expects as many as 44 such operations.

“As it stands now, we’re doing the best we can with the tools we currently have, but that’s not going to suffice much longer,” warns Paul Behan, a controller at the Jacksonville Air Route Traffic Control Center in Hilliard, Florida. “The future is here, and the NAS as it stands today is not prepared for it.”

Behan is the National Air Traffic Controllers Association national commercial space representative and a participant in the Joint Space Operations Group. During a panel discussion at the Air Traffic Control Association Technical Symposium in Atlantic City, New Jersey, he said the FAA needs to improve decision-support tools to manage space launch activity strategically and tactically.

He says the airspace region for which he is responsible as a controller, which abuts an area north of Cape Canaveral managed by the FAA’s Miami en route center, has been affected heavily by launches and reentries.

“We segregate large portions of airspace,” Behan says. “The impacts on the NAS are seen in the form of...
ground delays, miles-in-trail [between aircraft], extra miles flown, extra minutes flown—it has huge impact.”

Sharon Pinkerton, senior vice president for legislative and regulatory policy with Airlines for America, says the influential trade organization is pushing the FAA to advance the SDI and HRAM systems because of their potential to deconflict airline and space operations.

“I do think the FAA faces a resource issue when it comes to commercial space activities,” Pinkerton said during a roundtable event hosted by the U.S. Chamber of Commerce in early May. “Right now, when you talk to them about some of the technologies like SDI and HRAM, you hear pushback in terms of budget concerns.”

During testimony on May 8 before the Senate Commerce, Science and Transportation Committee, Eric Stallmer, president of the Commercial Spaceflight Federation (CSF), described the space launch risk analysis and ATC tools the FAA now uses as obsolete, overly conservative and “not dynamic,” resulting in inefficient use of airspace around launch and reentry events.

The trade organization representing the commercial space industry also is calling on the FAA to implement the SDI and further develop HRAM capability among a set of recommended actions and investments for the agency. New decision-support tools and capabilities should be integrated in the automation systems used by controllers and traffic managers, the CSF says.

“Instead of closing large blocks of airspace for hours, it should be possible to dynamically manage air traffic around a launch or reentry,” Stallmer stated in written testimony. “That requires real-time safety area calculation and information flow, including the current position and velocity of the launch vehicle, to individual en route air controllers, so they can release airspace immediately behind the launch vehicle as it flies.”

At the same Senate hearing, Wayne Monteith, who started in January as associate administrator of the FAA Office of Commercial Space Transportation, said the SDI is at the initial stages of acquisition.

Asked about the system’s status, Murray explains: “We have progressed through the investment analysis readiness decision, which is where we have preliminary requirements and we work toward a final investment decision with a full set of detailed requirements. We’re in between those two states right now.”

Use of the SDI to monitor space missions will expand to include other operators. The FAA expects to receive data from an October launch of Northrop Grumman’s Antares rocket with Cygnus cargo spacecraft on a 12th resupply mission to the ISS. The Pacific Spaceport Complex-Alaska on Kodiak Island, will be the first spaceport to participate in sharing data, Murray says, and plans call for Virgin Orbit to provide data during missions of the LauncherOne air-launched rocket from the Mojave Air and Spaceport in California.

“Some of the things we didn’t know coming into this are how hard it would be to onboard these new operators—what does it take on their end to make this happen? It’s actually been pretty smooth,” relates Murray. “We’ve found that we can bring in a new operator like Blue Origin and get it right the first time, with a minimal impact on their end.”

The aspect of the SDI effort that has been most successful and of greatest value, says Murray, “is the ability to run [the system] in shadow mode at the command center. When the final system gets fielded and is operational, that is where it’s going to be. We have already got the people who will be using the system in the future using it now.”

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**FAA Commercial Space Integration Program**

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AN APPRECIATION

ROGER BETEILLE
1921-2019

For many years, Roger Beteille never really talked about his wildest dream. From the time he joined Felix Kracht and Bernard Ziegler in founding Airbus, he was convinced that if the new manufacturer was to have a chance to be established on the world market, it had to aim to develop a family of aircraft. “I was convinced that Airbus would never take off with a single aircraft,” he said, looking back.

Yet initially he could not really talk about it too much. Launching a single aircraft was a task daunting enough for the relatively small European aerospace companies that joined forces for the Airbus project in 1969. Raising the prospect of even more investment from industry and government would not have been prudent. Beteille’s view was not common at the time, when many standalone aircraft—particularly in Europe—were developed with little or no commercial success. But his pursuit of this vision throughout his career at Airbus was one of the most important reasons for the company’s success over the decades.

Beteille also played a crucial role in getting the A300B project off the ground. He was at first chief engineer for the project at Sud Aviation and later became chief engineer at Airbus Industrie. He secretly worked on revising the original concept for the A300 and turned it from a 300-seater into a smaller 250-seater, the A300B. The new design, he found, would fit the airline’s needs better and solve the problem of finding a right-sized engine for the aircraft. One evening just months ahead of the formal Franco-German agreement to launch the A300, he sat down with Ziegler to make the decision that shareholders and governments later followed.

Eight years on, when Beteille was general manager at Airbus, he convinced Eastern Air Lines to order the A300, giving the airframer its first breakthrough in the U.S. and a much-needed boost following some extremely disappointing years. A year later, in 1978, he made the first big steps toward realizing his dream of offering a family of aircraft by launching the A310. More important, he oversaw the launch of the A320 family in 1984 before retiring the following year.

“Roger Beteille is such a huge part of the Airbus story, from the creation of the A300B in 1969 right up to the launch of the A320 in 1984—to say he made a lasting impact would be an understatement,” Airbus CEO Guillaume Faury wrote on June 25. “The man with the white tie will be greatly missed.”

Beteille passed away on June 14 at age 97.
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