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Volume 178 Number 20

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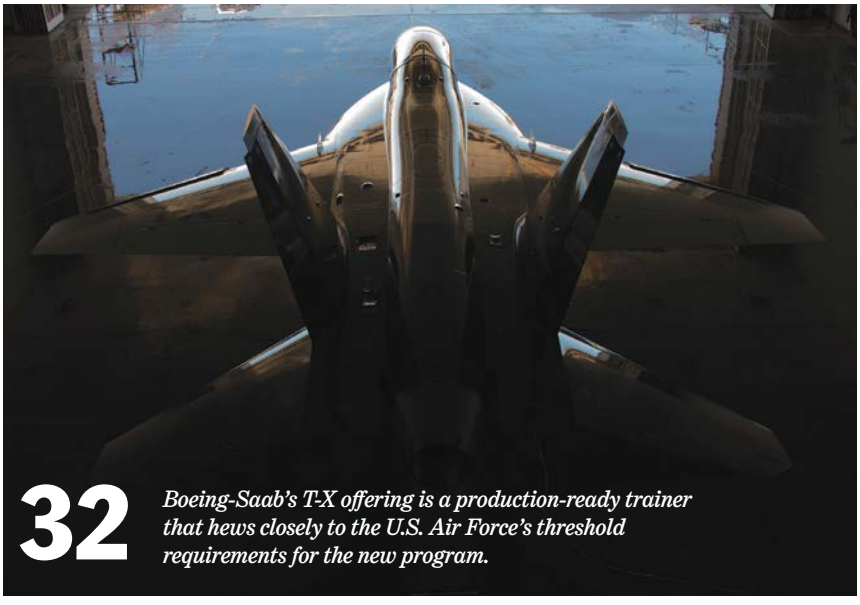

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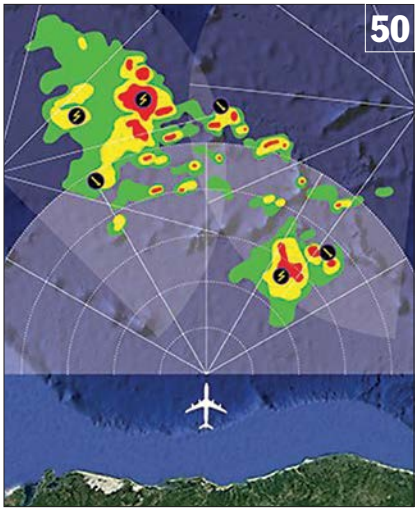
## DEFENSE



## TECHNOLOGY






## COMMERCIAL AVIATION



## SPACE



## LOW-COST CARRIERS



## AERONAUTICAL ENGINEERING




## ON THE COVER

*Dzyne Technologies' Ascent blended wing-body small airliner is one of five concepts being considered for future X-planes as NASA looks beyond established large-aircraft manufacturers Boeing and Lockheed Martin for ideas on future ultra-efficient subsonic transports (page 42). Concept image: Dzyne Technologies/Brendan Kennel. Also in this issue: Chasing breakthroughs in hypersonic propulsion (page 46), Baltic states' military buildup (page 34), new advances in cockpit connectivity (page 50) and Japan's plans to field unmanned aircraft for air combat and ballistic missile defense (page 20). Aviation Week publishes a digital edition every week. Read it at* **AviationWeek.com/awst** *and on our app.*







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# Feedback

*Address letters to the Executive Editor, Aviation Week & Space Technology, 1911 Fort Myer Drive, Suite 600, Arlington, Va. 22209 or send via email to:*
**awstletters@aviationweek.com**
*Letters may be edited for length and clarity; a verifiable address and daytime telephone number are required.*

## FORWARD THINKING CALLED FOR

In a recent In Orbit commentary (*Aug. 29-Sept. 11, p. 18*) Julie Van Kleek, vice president of Aerojet Rocketdyne's (AJR) advanced space and launch business unit, commented about the AR-1 engine, clearly illustrating the company's "legacy" mindset.

Well. I say reaching the "next level of high technology" is not what's important and "things that were developed decades ago" don't necessarily constitute a negative feature. Producing an engine that gets the job done reliably at the right price is what matters.

SpaceX has shown this with the "low-tech" Merlin 1 series of engines. AJR is counting on cost-plus procurement and a good story for its "high-tech" AR-1. ULA isn't buying it because they see the new way business needs to be done. If AJR doesn't adapt, it will disappear.

*Mike Schriber*
SAN DIEGO, CALIFORNIA

## SHORTSIGHTED ON F-35?

As a retired Royal Canadian Air Force fighter pilot, I read with great interest "Oh, Canada" (*July 18-31, p. 46*), which highlights succinctly the very points our new prime minister, Justin Trudeau, was unable to understand when, seeking election, he stated that he would terminate the F-35 purchase.

It was beyond his ken that doing so would wipe out countless high-tech jobs and establish Canada as an unreliable partner. Recently, he has stated that the F-35 "does not work."

Beware who you elect.

*Martin Abbott*
SCOTTSDALE, ARIZONA

## A SHARED DRIVING FORCE

"Sino-Bomber" (*Sept. 12-25, p. 24*) states that China, in developing a new long-range bomber, is seeking "to project force beyond ranges necessary for immediate national defense." Is this not the very same reason the U.S. is developing the B-21 Long-Range Strike bomber? And is this not what all great powers do?

For the past 35 years, the policy of incorporating China into the world economy has produced, on a purchasing power-parity basis, a nation with the largest economy in the world. We have enabled the Dragon to become rich; now the Dragon will grow strong.

Never in the history of the world has the dominant power actively pursued policies that will ensure its own displacement by another. We have.

And if continued, by the middle of the century, they will.

*Guy Wroble*
DENVER, COLORADO

JAPANESE DEFENSE MINISTRY

**On AviationWeek.com:**
***Jonblus* wonders:**
. . . if the recent reports of an An-225 agreement could be a source for engine technology for this project?

***Waldobobbi* replies:**
Antonov An-225 engine is, say most engine experts, a reverse-engineered CF6-6 but on a three-shaft architecture. China has failed to acquire Western engine technology, even via clandestine efforts.

***QuestionMark* reminds:**
Most reports coming out of China are state propaganda.

***Spectre49* opines:**
I would not discount this one.

## F-16s AND FIT EVENTS

There is a misnomer in "Collision Course" (*Aug. 29-Sept. 11, p. 33*) that reads: "During the maneuvering, a student pilot in a single-seat aircraft *blacked out* and . . . descending rapidly toward terrain. . . .." This error in terminology has persisted for decades.

"Blackout" is temporary dimming or loss of vision but not "loss of consciousness" (G-LOC). When G forces are relaxed following blackout, vision returns instantly. In a G-LOC event, post-relaxation of G forces, the pilot is severely incapacitated for up to 30 sec.

In 1970, U.S. Air Force senior staff visited the Mayo Clinic to discuss with the father of the G-suit, Dr. Earl Wood, the positioning of the ejection seat in the then-YF-16. Wood warned that the proposed tilt-back angle of the seat would increase likelihood of G-LOC events, proposing instead a more upright position, based on decades of results from several thousand instrumented runs at up to 10g on Mayo's human centrifuge. The visitors replied that a more upright seat would reduce the number of eligible pilots due to canopy spacing constraints.

Wood predicted that one or more student pilots would be lost to "flight into terrain" (FIT) every year the F-16 was in service.

The problem is apparently finally being addressed via new automation overlays in the F-16 software load. Wood, who died in 2009, would be pleased by the positive outcome from automation but not surprised by the loss of human life over decades.

*Barry Gilbert*
ROCHESTER, MINNESOTA

## FOCUS MISPLACED?

Michael Bruno's commentary (*Aug. 15-28, p. 12*) concludes there is now an emphasis on program execution, and it is driving the focus of manufacturing entities. But large companies with complex programs always have program execution as a driving force. He cites the Airbus A400M and Boeing KC-46 programs to bolster his point. Program execution is hardly an emerging risk, but the failure to properly identify and manage engineering issues relevant to these programs is.

The KC-46 and A400M have been rife with engineering issues. However, those are not an execution issue. As Bruno properly indicates, production is where the money is made and cash flow is generated. Boeing and Airbus have successfully accelerated delivery rates for their popular models. The focus on execution is not new; it is ongoing.

*Bryan F. Pepin-Donat*
KENNEWICK, WASHINGTON

## Corrections:

A table accompanying "Catch and Release" (*Aug. 29-Sept. 11, p. 57*) misstated the percentage of engineers who retired in 2016: It is 2.0%.

In "Flight Hardware" (*Sept. 12-25, p. 36*), the metric ton capability of the Block 1B vs. Block 1 launch vehicles was incorrect. It is 105 metric tons, up from 70.

# Who's Where

Charles R. Davis

Mark Leaity

Dimitri Courtelis

Kelly Murphy

Katie Thomson

Wayne Goodman

Kevin Mortensen

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

*Rolls-Royce* has appointed **Simon Kirby** chief operating officer. He has been chief executive of HS2 Ltd., which oversaw delivery of the UK's new high-speed rail network, Europe's largest infrastructure project.

*American Airlines Group Inc.* has named **Robert Isom** president. He has been chief operating officer. Isom succeeds J. Scott Kirby, who is leaving.

*Emirates* has named **Christoph Mueller** as chief digital and innovation officer. He was CEO of Malaysia Airlines.

*Polaris Industries Inc.* has hired **John M. Olson** as Polaris Defense vice president/general manager. Olson, who had been vice president-space systems at Sierra Nevada Corp., brings extensive U.S. government experience including 12 years at the Pentagon.

**Marko Enderlein** has been named president of *Telair International GmbH*. He succeeds Axel Hauner, who is retiring. Enderlein was CFO of the Airbus subsidiary Satair Group.

*L-3 Communications* has appointed U.S. Air Force Lt. Gen. (ret.) **Charles R. Davis** (see photo) senior vice president-strategy in the Aerospace Systems Division, a newly created position. Davis was president/CEO of Seabury Global Aerospace and Defense Consulting. He has more than 30 years of aerospace and defense experience.

*AJW Group* has named **Henry Game** chief strategy officer. He was CEO of Bland Group Holdings Ltd. and has held executive positions in both international finance and operational aviation.

*TenCate*, a producer of textiles, composites and systems for space and aerospace, has appointed **Frank Spaan** as chief financial officer.

*AeroMobil* has hired **Mark Leaity** (see photo) as chief engineer-structures. Leaity's composite-materials experience includes developing aerospace applications for manufacturers such as BAE Military Aircraft, Airbus, Bombardier Aerospace and Rolls-Royce Aero Engines.

*Air Berlin* has appointed **Dimitri Courtelis** (see photo) as chief financial officer, succeeding Arnd Schwierholz, who is leaving to become chief financial officer of Flixbus. Courtelis, who joined parent Etihad Airways in 2011, was Air Berlin's deputy chief financial officer.

**Noreen Kabra** has become *AAR*'s vice president-international business development for the defense-OEM aftermarket including direct sales to foreign militaries. Kabra was head of Rockwell Collins's Intertrade military distribution business.

**Kelly Murphy** (see photo) has been named director of communications/editor-in-chief of Emerald Media's bimonthly magazine *Women in Aviation*. She produced Regional Horizons, the official publication of the U.S. Regional Airline Association, and, most recently, supported the Flight Safety Foundation's *AeroSafety World*.

**Frances Williams** has been appointed to promote Emerald Media's Single-Engine Turboprop Operators Conference and Fly-In.

*VZM Management Services* has hired **Andreas Reichert**. Reichert, who was chief operating officer at Haitec Aircraft Maintenance GmbH and director of maintenance in Dusseldorf, Germany, for Air Berlin. He has 30 years of aviation experience in maintenance, training and operations.

Aviation analytics company *OAG* has named **Mark Clarkson** executive vice president-product management, heading the company's schedules and analytics portfolios. He was vice president at Airport Strategy and Marketing.

*The National Defense Industrial Association* has appointed **Alexander Frank Zemek** vice president-policy. He was an intelligence officer with the National Geospatial-Intelligence Agency and a legislative fellow with the U.S. Senate Committee on Homeland Security and Government Affairs.

**Katie Thomson** (see photo) has joined *Morrison and Foerster* as partner. She will chair the law firm's transportation group, counseling on regulatory matters, civil and criminal litigation, internal and governmental investigations, compliance issues and cybersecurity. Thomson has been general counsel of the U.S. Transporatation Department and FAA chief counsel.

*The Aerospace Corp.* has appointed **Wayne Goodman** (see photo) executive vice president, succeeding David Gorney, who is retiring. Goodman was Milsatcom general manager, responsible for high-frequency satellite communication systems support for the U.S. Air Force Space and Missile Systems Center.

*Bombardier Commercial Aircraft* has named **Francois Cognard** vice president-sales for Southeast Asia and Australasia. He was Dubai-based head of sales for Airbus for the Middle East and North Africa.

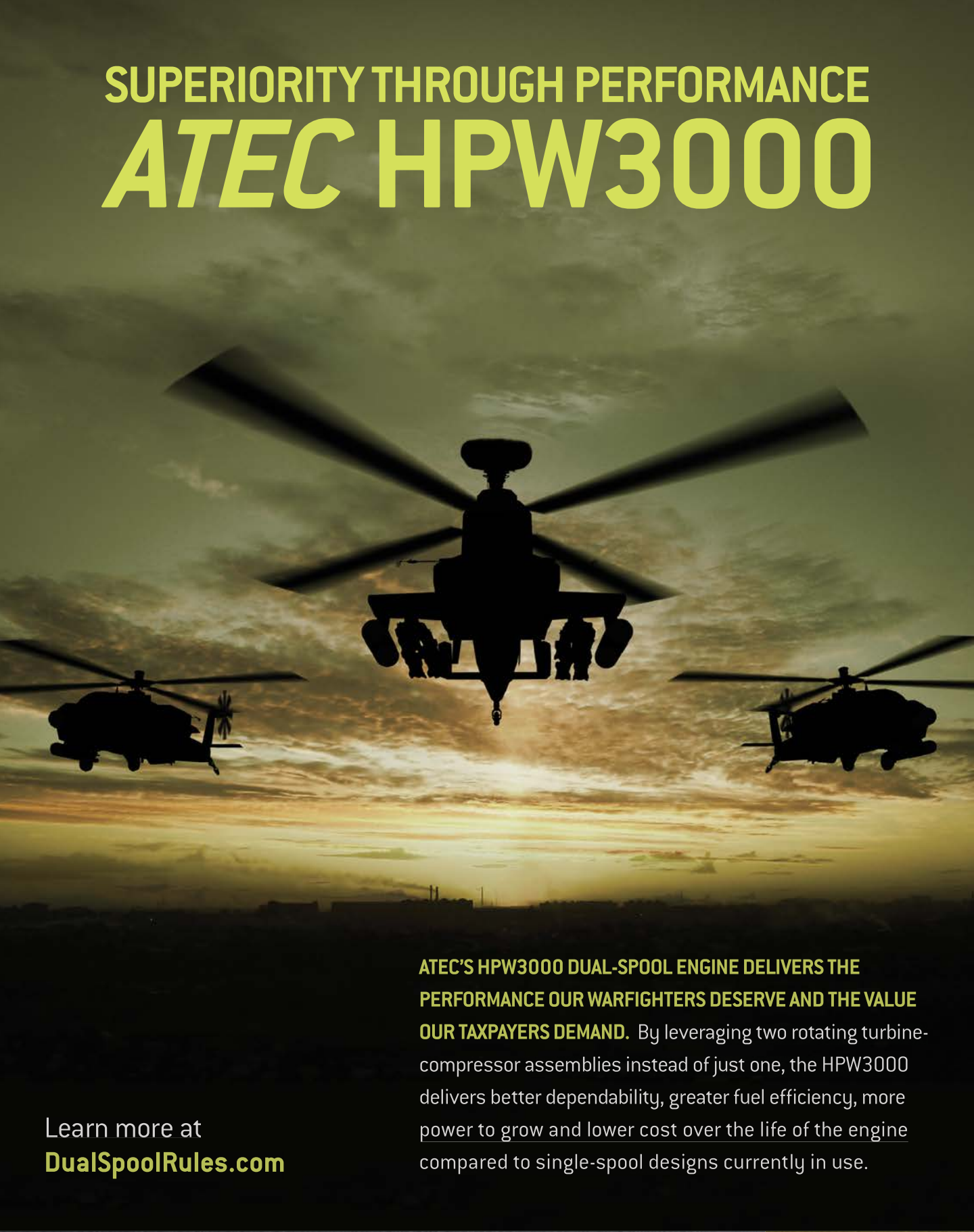
*Swedish Space Corp.* (SSC) has appointed **Kevin Mortensen** (see photo) vice president-international marketing for all business units. He was director of marketing and business development for SSC Satellite Management Services Americas.

*Tigerair Singapore* has named **Cynthia Dammerer** of Australia-based Dammerer-Nicholas PR and Marketing to handle media relations for Scoot and Tigerair, which will merge under umbrella Budget Aviation Holdings of Singapore.

Global aviation services group *Air Partner plc* has selected **Richard Jackson** as an independent nonexecutive director, serving on the audit and risk committee. Jackson had been group director of consumer protection at the UK's Civil Aviation Authority for 16 years.

# SUPERIORITY THROUGH PERFORMANCE

# *ATEC* HPW3000



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# First Take

BELL HELICOPTER

## DEFENSE

**Bell Helicopter has unveiled the V-247 Vigilant tiltrotor** it is proposing for an emerging U.S. Marine Corps requirement for a ship-based expeditionary endurance unmanned aircraft. With an 11-hr. time on station at 450-nm radius with a 600-lb. payload, the V-247 could be ready for production by 2023, says Bell (page 22).

**Northrop Grumman's B-21 Long-Range Strike Bomber** has been named the Raider, to honor the Doolittle Raiders who bombed Tokyo in 1942. The U.S. Air Force plans a minimum of 100 aircraft, which will be manned initially, with unmanned capability a future option yet to be exercised.


BOEING

**Boeing rolled out its clean-sheet contender for the U.S. Air Force T-X** advanced pilot trainer competition in St. Louis on Sept. 13. With partner Saab, two prototypes of the single-engine, twin-tail aircraft have been built, powered by an afterburning General Electric F404 (page 32).

**Lockheed Martin and the program office moved quickly** to fix faulty cooling-line insulation in wing tanks that grounded 15 U.S. Air Force and Norwegian F-35As and affected 42 more on the production line. Due to a supplier error, the insulation crumbles in fuel and can block flow.

**Japan will field unmanned aircraft for air combat** and ballistic-missile defense in the 2030s, according to a defense ministry technology-development road map. The "unmanned wingman" will fly ahead of manned fighters to locate targets, launch weapons and saturate enemy defenses (page 20).

**Boeing is disputing the Danish government's recommendation** of the F-35 to replace its F-16 fighters, submitting a legal challenge to the defense ministry. Boeing alleges the recommendation to buy 27 F-35s was based on "incomplete and possibly flawed data."

**The DragonFire consortium led by European missile manufacturer** MBDA will demonstrate a high-power laser weapon for the UK Defense Ministry under a £30 million ($39 million) contract. The system will be tested against representative targets in land and maritime environments in 2019.

MBDA

**Russia's defense ministry has approved the requirements for** a military version of the Mi-38 after Russian Helicopters failed to find commercial buyers for the Mi-8 replacement first flown in 2003. With increased weight and altitude capability, the military Mi-38-2 is expected to be ready in 2018.

**Czech manufacturer Aero Vodochody has restarted** limited production of the L-159 Advanced Light Combat Aircraft, the first time it has built a complete aircraft in 15 years. A single two-seat L-159 for Iraq will pave the way for production of the new L-39NG, to be available by the end of 2018.

**Ukrainian manufacturer Antonov is reportedly severing ties** with Russian operators in a move that could hit NATO airlift. Antonov Airlines will discontinue its Ruslan International An-124-operating joint venture with Russia's Volga-Dnepr and withdraw from NATO's Strategic Airlift Interim Solution.

## COMMERCIAL AVIATION

AIRPORT WEBCAMS/TWITTER

**The uncontained failure of the left-side CFM International CFM56-7** engine on an Aug. 27 Southwest Airlines Boeing 737-700 flight was likely initiated by a fan blade that broke off due to metal fatigue, says the U.S. National Transportation Safety Board.

**China's Comac will not meet its stated target of flying the C919** airliner this year, according to industry sources. The company says a 2017 first flight is possible; industry sources say it is likely around April 2017, which implies a delay in the undisclosed target for first delivery, which was 2019.

**The Civil Aviation Administration of China (CAAC)** has formally tightened

rules on setting up airlines just months after it made an unannounced decision to suspend authorizations. Approvals were granted for 20 new airlines in 2011–15, the CAAC says (page 28).

**Two Chinese airlines have dropped plans to buy 11 Boeing 787s,** switching to 737 MAXs because of government pressure, industry sources say. The economic-planning National Development and Reform Commission opposed Ruili and Donghai Airlines' intended moves into widebody aircraft.

**JetBlue Airlines is to buy more than 33 million gal.** of renewable jet fuel over 10 years from SG Preston. Lufthansa will purchase up to 40 million gal. of alcohol-to-jet fuel over five years from Gevo, and Virgin Atlantic and LanzaTech have produced enough fuel from industrial waste gas to support testing on a 2017 demo flight.

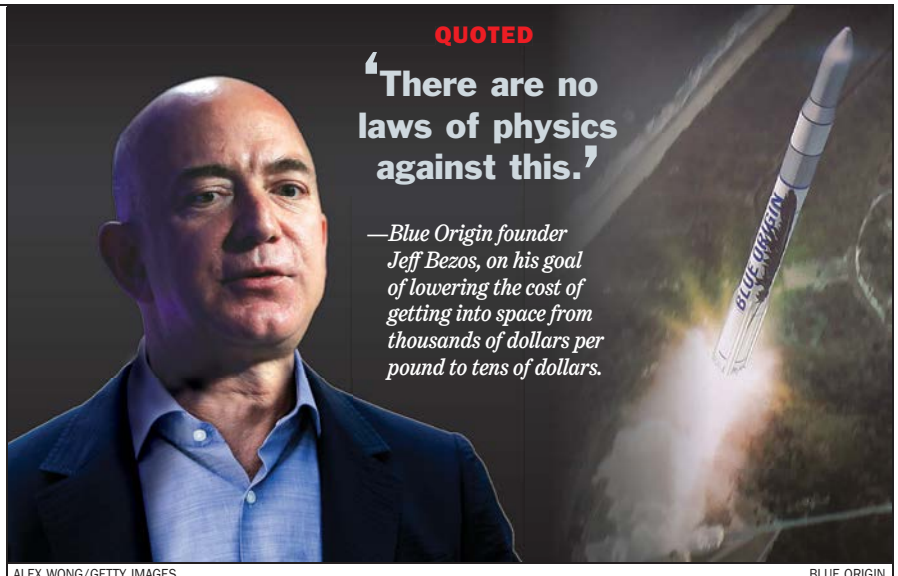
**The U.S. government has granted Airbus and Boeing licenses** to export commercial aircraft to Iran. Iran Air has signed agreements for 118 Airbus A320s, A330s, A350s and A380s and 109 Boeing 737s and 777s (page 19).

CCTV

## SPACE

**China launched its second orbital laboratory,** Tiangong 2, on Sept. 15 as a step torward assembling a space station around the end of the decade. A manned mission, Shenzhou 11, will follow to dock with the laboratory, three years after China last sent people into space.

**First flight of Blue Origin's New Glenn** human-rated orbital launch vehicle with a reusable first stage is due from Cape Canaveral by decade's end. Two versions are planned: an all-hydrocarbon two-stage vehicle for launches to low Earth orbit and a version with cryogenic third stage for missions to the Moon and beyond (page 49).




ALEX WONG/GETTY IMAGES

BLUE ORIGIN

**NASA faces delays to all three of the next non-Russian resupply** missions to the International Space Station. Return to flight of Orbital ATK's Antares has slipped to October and the planned Oct. 1 launch of Japan's H-2 Transfer Vehicle has been delayed; SpaceX aims to fly its Falcon 9 in November, after the Sept. 1 launch-pad accident, but the planned November cargo launch remains uncertain.

## DIED

**Sam Iacobellis,** who led production of 100 Rockwell B-1As over six years after the bomber was rescued from cancellation by President Ronald Reagan, has died at age 87 following a stroke. He joined North American Aviation as an engineer in 1952 and retired in 1995 as executive vice president and deputy chairman for major programs at Rockwell International.

## 38 YEARS AGO IN AVIATION WEEK

**Our Sept. 25, 1978, cover featured the rollout** of the U.S. Navy/Marine Corps F/A-18 at the McDonnell Douglas (now Boeing) military aircraft plant in St. Louis. Developed to replace the McDonnell Douglas F-4 fighter and Vought A-7 attack aircraft, the Hornet was the first tactical aircraft designed to perform both air-to-air and air-to-ground missions. It made its first flight on Nov. 18, 1978, and entered service on schedule at the start of 1983. The upgraded E and F Super Hornet variants entered service in 1999, followed by the Boeing/Northrop Grumman EA-18G Growler electronic warfare derivative in 2008.


*Read our original coverage of the F/A-18 rollout in the Sept. 18 and Sept. 25, 1978, issues of* Aviation Week *at:*
**archive.aviationweek.com**

By Michael Bruno

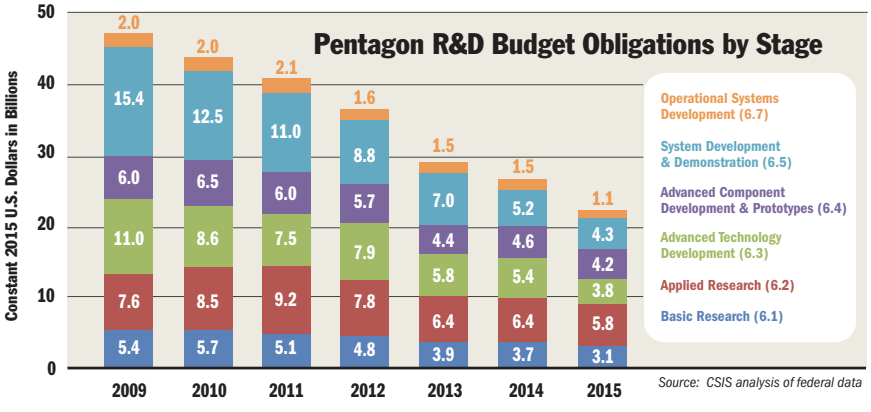
*Michael Bruno is Senior Business Editor*
*Join the conversation at:*
**AviationWeek.com/GoingConcerns**
*michael.bruno@aviationweek.com*

COMMENTARY

# Anemic Arsenal

## Both the U.S. military and defense primes could be hit by a dearth of big research

Go to most aerospace and defense events in the U.S. lately and you hear growing concerns about the bow wave of acquisition bills that will sweep over the Pentagon like a fiscal tsunami in the next decade.




Source: CSIS analysis of federal data

But officials and executives might also want to focus on the drought of new defense projects on the horizon. Increasingly, attention is turning to a looming dip in potential new weapons and systems.

According to a September report by the Center for Strategic and International Studies (CSIS) think tank, two Defense Department budget categories for mid-to-late-stage R&D saw cuts of two-thirds or more between 2009 and 2015. They are advanced technology development (budget line 6.3) and system development and demonstration (SDD, 6.5). Meanwhile, funding for early-stage basic research (6.1) also has seen a significant decline but has been relatively preserved when compared to the overall decreases in R&D.

That flips the script on what was conventional wisdom after the onset of federal budget cuts called sequestration that started in 2013. That led many analysts and observers to expect that within R&D budget lines, seed-corn research would be sacrificed disproportionately while later-stage efforts would be preserved. In retrospect, it was the reverse.

In its new report, briefed to reporters Sept. 12, the CSIS says the two main drivers of the massive budget declines in the latter two stages of R&D were the cancellation of large programs such as the Army's erstwhile Future Combat Systems, as well as the maturation of major programs from research phase to production.

At the same time, there was a dearth of new development programs for major weapons systems to replace those that have graduated into production or been canceled. "As a result, the Defense Department is facing a six-year trough in its development pipeline for major weapons systems," the CSIS reports.

Pentagon acquisition czar Frank Kendall has been saying the same thing all year, when he spoke at the CSIS in Washington in May and again in September at the ComDef 2016 conference nearby. "What I think is the real problem in the department, the thing the next administration is going to have to wrestle with, is resources," Kendall warned in September.

Looking ahead, the advanced component development and prototypes account (6.4) is even bigger than the SDD (6.5) account, because it is the right place to put limited dollars first, Kendall says. But it also means there is relatively less money in the five-year budget plan to take what demonstration efforts do exist and make them into programs, let alone to produce them and put them in the hands of combat personnel.

"It's good to have options," Kendall says. "It's better to have actual future investments."

What is more, it is not just the government that could be challenged by the lack of options. Industry—at least the legacy prime defense contractors, Boeing, Lockheed Martin, Northrop Grumman, Raytheon and General Dynamics—eventually could be in for harder times as well.

"When you look at the big five overall, they're doing OK; they're holding their market share," says Andrew Hunter, director of the Defense-Industrial Initiatives Group and a senior fellow at the CSIS. "But what's underneath that is that they are losing —dramatically losing—market share in R&D contracts."

The CSIS says within past defense budgets, the share of R&D contract obligations going to the big five has fallen to 33% in 2015 from 57% in 2009.

That is largely as a result of the aforementioned six-year dip in the Pentagon's developmental pipeline. At the same time, "there has been a marked surge in the share of R&D contracts going to small vendors," states the CSIS. Their share rose to 17% in 2015 from 10% in 2009. In the end, however, everyone is eating from a smaller budget pie than before—53% less in 2015 than in 2009.

Thus everyone still has something to complain about. Analysts and officials, meanwhile, also are left wondering what it will mean.

"We're not crying tears here for the big five, by the way," Hunter says. "But we just think it's notable what's happened in the industrial base. There's a massive disinvestment from the big, traditional defense-contracting R&D enterprise that has been there for many decades."

**By Richard Aboulafia**

*Contributing columnist Richard Aboulafia is vice president of analysis at Teal Group. He is based in Washington.*

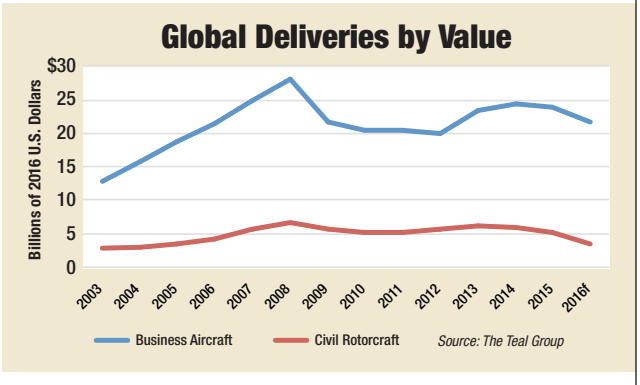
COMMENTARY

# Bear Markets

## Why business aircraft and civil rotorcraft face a cloudy future

**Business aircraft and civil rotorcraft have much in common. Both markets were transformed by unprecedented growth waves in the early 2000s, and both have spent the last eight years seeking renewed growth, with no success.**

But most of all, these two markets are now falling, largely due to the decline in energy prices and other factors. Given the volatile nature of energy prices, forecasts for these aircraft markets have become much less reliable.




The transformation of both segments took place in 2003-08, with growth rates seldom seen in mature industries: business aircraft grew at a 17.1% compound annual growth rate (CAGR) by value, while civil rotorcraft grew at an 18.2% CAGR. Both reached new peaks: business aircraft hit $28.1 billion in deliveries in 2008 (in 2016 dollars), and civil rotorcraft reached $6.6 billion. Both markets had doubled in value over the course of about five years.

After that peak, both markets deflated, and neither has recovered to their 2008 peak. Over the past 18 months, the parts of both markets that were still growing—large cabin jets and super medium twin helicopters—have been hit hard.

Last year, the civil rotor market fell 10.6% to $5.3 billion in deliveries, off from 2014's $5.9 billion. General Aviation Manufacturers Association (GAMA) first-half 2016 delivery numbers indicate a turbine market decline of 18.3% by unit from the first half of 2015. That's a serious drop, but far worse, the market's value suffered a massive 32.5% drop. This clearly shows that the market for larger, more expensive models, primarily used by the oil and gas industry, is declining at a much faster pace than the rest of the rotorcraft market. The recent history of the market reveals that this segment was also primarily responsible for the 2003-08 growth surge.

The story is the same with business jets, where the higher-priced large-cabin segment has taken all the damage. Large-cabin deliveries in 2015 fell 8.2% by value from 2014 (small- and medium-cabin aircraft deliveries actually increased). First-half 2016 deliveries of all business jets fell 11% by value from the first half of 2015, according to GAMA. Unit deliveries fell just 4.5%, indicating that again it was the larger, more expensive jets that led the decline.

Like the rotorcraft market, business jet demand was once linked to a wide array of economic indicators, especially equities markets and corporate profits. Since 2008, these links have broken down. Stock prices recovered and profits have set new records, but most business jet segments stayed flat. But as documented by Bank of America/Merrill Lynch analyst Ron Epstein, there is a close correlation between high-end business jet demand and oil prices. Even as other segments collapsed, high-end business jet demand rose after the 2008 meltdown, in line with oil prices. It is now falling in line with oil.

These high-end business jets benefit from resource-extraction company orders but, more important, resource-rich countries are a key component of demand, particularly in the Middle East and Russia. These economies, and the high-net-worth-individual wealth in these countries, have been affected by low oil prices, too. Meanwhile, the ongoing anticorruption campaign in China has hurt demand from the only BRIC (Brazil, Russia, India, China) country where demand had been holding up.

We don't know when the market will find a deliveries floor. Last year, the three top-tier producers—Bombardier, Dassault and Gulfstream—reduced 2016 output guidance significantly. Bombardier Global series output is falling to about 50 this year, from 73 in 2015. The OEMs are now talking about a market that is stabilizing, but many indicators are still in troubling territory. And in August, Bombardier said it would "pause" Global production in 2017 for an unspecified period—probably about 20 days. This implies output will fall to the mid 40s.

With civil rotorcraft and business jet demand linked to oil prices rather than the usual basket of economic indicators, we are in less well-known territory. Of all the macroeconomic indicators, oil and energy prices are easily the hardest to predict. Long-term GDP numbers, stock prices, high-net-worth wealth creation and corporate profits all have very long track records and a clear story of long-term growth. By contrast, oil prices may stay at $43 per barrel or lower or may shoot back up above $100. Their cycles are unpredictable.

For forecasting purposes, Teal Group assumes the consensus view—oil prices at $80-90 per barrel before the end of the decade—is correct. But in reality, the range of possibilities is all over the map. And therefore, these two aircraft market segments face much greater uncertainty.

By William Garvey

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COMMENTARY

# Airborne Surveyor

## A tiny, winged tool to help keep airplanes out of trees

**An innovative state bureaucracy? A more oxymoronic combo is hard to imagine. And yet, it has delivered brilliantly. Twice.**

Recognizing a need to assess land use and respective ordinances near its state's 58 public airports—especially its 52 general aviation facilities—the South Carolina Aeronautics Commission began doing so in 2011.

At the same time, the commission was directed to establish land-use zones around airports. Once completed, an airport sponsor—typically a county or municipal government—would have to notify the state when changes were contemplated within a zone. The project also involved production of detailed airport maps (see below).

To accomplish that and facilitate the process for all involved, the commission created the "Compatible Land Use Evaluation (CLUE) Tool" on its website. Any airport can be viewed in detail using the Airport Layout Plan, which includes every building and measurement, along with planned buildings and paved areas and land set aside for future aviation and non-aviation development.

The site is interactive, so the sponsor can insert a proposed building's height and location and immediately determine its compatibility.

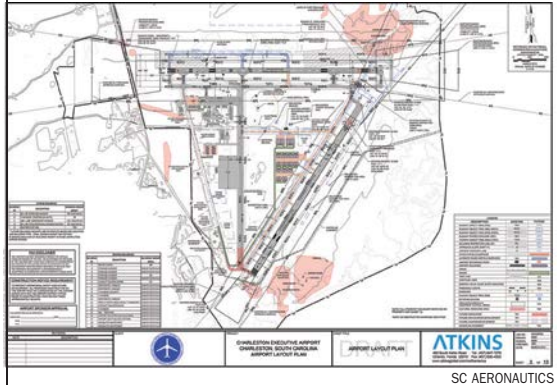
The free tool and process were deemed so clever and useful that the National Association of State Aviation Officials (NASAO) gave CLUE its "Most Innovative State Program Award" in 2014. But there's more.

Concurrently, the FAA reviewed its obstacle clearance data for airports countrywide and determined that tree growth had penetrated the maximum 20:1 approach slope areas stretching out from the ends of many runways. As a result, the agency prohibited night approaches to those airports.

Typically, the approaches are surveyed by state safety inspectors who stand 200 ft. from the runway end and, using a clinometer and 20/20 vision, determine whether anything penetrates the slope. If so, that "controlling obstacle" is reported to the FAA. The method's shortcoming is the inability to see similar obstacles behind the offending tree, or note others in the broad approach trapezoidal area.

Historically, the way to correct such data deficiencies was to conduct an aerial mapping survey. However, that service costs $8,000-10,000 per runway, involves a tedious authorization process and, once completed, can take weeks to reduce data into usable form.

The commission staff had another idea: Let an unmanned aerial system, aka drone, do it.




SC AERONAUTICS

They opted for the Swiss-made SenseFly EBee RTK (see photo). With a 37-in. wingspan, tiny pusher prop, battery power, programmable autopilot and a high-def camera, this 1.6-lb. snap-together, hand-launched, foam-construction aircraft can "produce orthomosaics and 3-D models with absolute accuracy" and absent any "ground control points." Translation: It's a self-contained surveying wonder that can quickly produce amazingly precise imagery and measurements.

While it and its Arc GIS software cost $50,000, the commission reasoned the package would pay for itself after surveying 5-6 airports. And since the money would come out of the state's Airport Inspection Fund, the service would be free to the airport owners.

Needing the FAA's blessing, the commission submitted its request to fly its EBee around South Carolina's airports in July 2015, and the "FAA choked on it," recalls James Stephens, the commission's executive director.

Flying a drone in the approach areas of public use airports was unprecedented and ripe with woe. But to their credit, the feds worked it out. With clear operational rules—NOTAM (Notice to Airmen) 48 hr. in advance, line-of-sight control, daylight ops in uncontrolled airspace only with pilot and observer required and a 700-ft. maximum altitude—the project got an initial green light last May.

So far, six airports have been surveyed. Each survey flight lasts less than 30 min., involves 200-250 overlapping photos and covers all approaches in 3-4 flights. Data can be processed overnight and produce a variety of visual presentations that precisely show the obstacles—nearly always trees—penetrating the slope. "The picture is worth a million words," says Stephens.

The target precision is uncanny—within 4 in. horizontally and 6 in. vertically. These visuals allow airport sponsors and nearby landowners to see immediately all the offenders rather than just a single "controlling obstacle," thereby obviating the need to address the same problem year after year.

The process is so successful that eight states have sent representatives to South Carolina to learn more. And other agencies within the state—from forestry to law enforcement—are interested in the EBee's potential.

Meanwhile, in September, Stephens and his team briefed those gathered at NASAO's annual convention on the drone airport survey project . . . and returned home with the "Most Innovative" award for 2016.


JOEPRISAVIATION.NET

**By Jens Flottau**

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COMMENTARY

# Painful Message

## Singapore Airlines' decision to send back its first A380 comes at a bad time for Airbus

Singapore Airlines' opting not to extend the lease for its first Airbus A380 after only 10 years of flying has provoked some heated debate. It is a facet-rich and complex move, but the bottom line remains: It is terrible news for Airbus and the lessors that own the aircraft. Singapore Airlines (SIA) has four other leased A380s which are coming up for possible contract extension between now and April 2017 and are likely to be returned.

The first few SIA A380s are of an early-build standard with some flaws and extra weight; they are not as good as aircraft that came off the production line later. One might therefore argue that it is a wise decision to replace them with more mature and lighter aircraft. So why all the excitement?

Several reasons. While it is somewhat understandable that SIA would want to get rid of the early aircraft, the airline will have to spend a substantial amount of money before doing so in order to restore the aircraft to "full life" condition, according to the agreements with their owners.

Returning the aircraft essentially to new condition in terms of systems, engine maintenance and cabins will be a very expensive proposition—and the first of its kind for the global A380 fleet. The incentive not to fly them further must be high, unless increasingly desperate lessors are willing to accept reduced terms based on the current and foreseeable market conditions. In short, the less-than-optimal build standard is only a small part of the explanation.

A bigger issue is simply that the airline does not want to expand its A380 fleet beyond the 19 aircraft it now operates and the five more on firm order. In addition, there are reasons specific to SIA and more general industry aspects that are influencing the decision. SIA no longer plays the dominant role in Asian long-haul travel. Other carriers are growing at its expense: Emirates, Qatar Airways and Etihad Airways to the northwest of its hub and the Chinese carriers to the north. The number of routes on which even SIA can operate an A380 profitably is limited, particularly if as many as 142 are flying for a competitor.

What is more, now is not the time to add significant long-haul capacity. Analysts and industry observers have been concerned about the overcapacity that the widebody market is facing based on current orders.

To be fair, the A380 is not the only long-haul aircraft that is not generating many new orders; the entire market is slowing to a crawl.

Boeing has already announced a cut in the 777 production rate ahead of the transition to the 777X and may lower the output further if demand does not resume soon. The manufacturer also is not going to increase 787 production to 14 per month from 12. Boeing recently indicated that for the first time it may end 747-8 production if it does not see a reversal of that program's fortunes.

The timing for a buoyant widebody market to stagnate could not be worse for Airbus. A380 production is already being reduced to 12 aircraft a year in 2018 for risk containment, but ultimately the European manufacturer needs the market to return. It cannot wait another five years.

But for new orders, Airbus is also competing with the availability of 11 used Malaysia Airlines and SIA aircraft, some of which are only a few years old. The capital expenditure needed for the A380 is one of two hurdles airlines must overcome when buying such large aircraft. The other is the fear of being unable to fill all those seats. If one of these hurdles becomes lower, some carriers such as British Airways or Iberia might give the A380 a try. But those possibilities will only represent a handful of aircraft. It is difficult to see how secondary airlines would want to broaden the A380 customer base.

Decisions such as the SIA return are particularly damaging to the airframers because of the signal they send to other airlines. And SIA is not the first to alter its A380 plans:

- Air France is not taking the final two A380s it has on order.
- Lufthansa has reduced its commitment by one aircraft.
- Qantas Airways does not want to take the eight in the backlog.
- Virgin Atlantic does not want the six it bought a decade and a half ago.

The market is speaking, and it is sending a painful message: We are no longer interested.

**By Graham Warwick**

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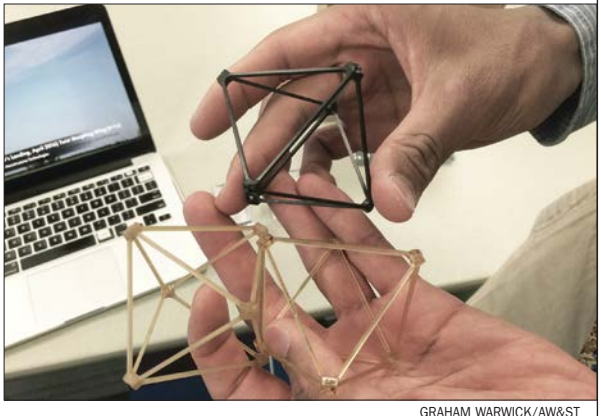
COMMENTARY

# Weird Science

## NASA's rapid feasibility-demonstration project is beginning to produce results

An unmanned aircraft dropped from a balloon that can learn to fly before it hits the ground; morphing airframes made from the structural equivalent of digital pixels; aircraft structures that store energy . . . these were just some of the ideas on show at Glenn Research Center on Sept. 7-8, where an enthusiastic group of NASA engineers—young and diverse, but with a scattering of grayhairs—gathered to showcase their progress under the agency's Convergent Aeronautics Solutions (CAS) project.

A key part of NASA's restructured and refocused aeronautics research, CAS funds rapid, 2-3-year feasibility demonstrations of early-stage ideas from in-house researchers. With about $40 million a year to spend, CAS has so far funded 15 subprojects in three annual selection rounds.



GRAHAM WARWICK/AW&ST

The restructuring focused research on six strategic thrusts, ranging from ultra-efficient airliners to assured autonomy, for which NASA has developed technology road maps. "CAS is there to challenge them," says Robert Pearce, deputy associate administrator for aeronautics. "We hope people are taking risks and looking at really innovative ideas. Some will not work out, but it is about the idea of failing forward, of taking smart risks so we are always learning. Without taking risks, CAS will not be successful, and NASA aeronautics will not be successful."

Projects must be multicenter and multidiscipline, and most have partners in academia and industry. If they prove feasible, it is hoped the concepts and technologies will be picked up by industry, a NASA aeronautics program or another of the agency's mission directorates.

First to graduate from CAS is the X-57 distributed electric propulsion demonstrator, which involves the Langley, Armstrong and Glenn centers as well as ESAero, Joby Aviation, Scaled Composites, Xperimental and Electric Power Systems on the industry side. The X-57 is to fly by 2018.

Several of the projects have key tests coming up to prove or disprove their feasibility. One of these is Madcat, which brings together cellular materials, digitized structures and morphing technology to produce a lightweight, reconfigurable airframe.

The project aims to test a tailless flying-wing unmanned aircraft with a morphing structure assembled from composite "volume cells," or voxels (see photo)—the equivalent of digital-image pixels—that are light and stiff but can deform in a controlled way to adapt wing shape.

Another is M-Shells, which aim to eliminate the weight and volume of batteries in electric aircraft by developing multifunction structures that also store energy. The project is pursuing chemistry and materials for load-bearing structures that are also hybrid battery/supercapacitors.

M-Shells is developing a sandwich structure in which the honeycomb between the carbon-fiber face sheets is a battery, made from laminated ribbons of highly conductive graphene electrodes and an ultralightweight aerogel separator impregnated with electrolyte. In 2017, the project plans to fly a small UAV with a third of its power coming from a battery that is part of the airframe, likely the fuselage.

Learn To Fly (L2F) is a CAS project that aims to combine real-time modeling of vehicle dynamics with learning control systems to emulate how birds learn to fly, reducing the time and cost of taking a novel aircraft design from concept to flight.

L2F first showed the idea by dropping a foam target drone from a balloon. The simple aircraft developed a usable model of its dynamics 3-5 sec. after being released and went on to complete a turn and land. The "graduation exercise," at NASA Armstrong in November, will involve an unconventional design.

Dropping the UAV, called Woodstock 1, from a balloon at 2,500 ft. will provide more time, about 4 min., for the system to learn how to fly the more complex aircraft, which has an arbitrary configuration with multiple flight control surfaces.

CAS is an effort to break out of NASA's process-oriented culture. "We want to show the rest of aeronautics, and the agency, that we have the in-house capability to do this. We just have to unleash our innovative minds," says Jaiwon Shin, associate administrator for aeronautics.

CAS is bringing young engineers together with seasoned researchers. "The project has reinvigorated NASA's in-house workforce," says Shin. "We emphasized from the beginning that we wanted our early career folks to be working on this. We also asked our graybeards to mentor them. I think it is working out."

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By Frank Morring, Jr.

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COMMENTARY

# Selling Space

## Germany weighs its lunar vision, 'New Space' against age-old problems

For Pascale Ehrenfreund, chair of the executive board of German Aerospace Center DLR, the glass is half full, not half empty. While European politicians struggle with the costly day-to-day problems besetting their continent, Ehrenfreund and her colleagues at other European national space agencies are providing an astronautical counterpoint.

URTHECAST

Like the world's other spacefaring nations, they see opportunities for new cooperation when the International Space Station (ISS) reaches the end of its orbital service life and suggest ways to mitigate even the most intractable of today's woes with space assets.

It is a work in progress. Europe hasn't yet signed on to NASA's push for a "Journey to Mars" that bypasses a return to the Moon's surface after a shakedown period for deep-space human spacecraft in lunar orbit, and its near-term human-spaceflight policy remains a question mark.

Ehrenfreund's predecessor at DLR, Johann-Dietrich Woerner, proposed a "lunar village" as the next step for human exploration, possibly on the radio-silent lunar far side. Woerner is director general of the European Space Agency (ESA) now, and the discussions continue.

David Parker, ESA's new director of human spaceflight and robotic exploration, has raised the possibility of a European deep-space habitat in lunar orbit or at one of the Earth-Moon Lagrangian points, which could meld with NASA's plans to test life support, radiation protection and spaceflight dynamics in the lunar "proving ground." But an international outpost on the lunar surface remains on the table.

The Moon and Mars are important to Europeans and to other players, says Ehrenfreund, who joined a panel on international cooperation Sept. 15 at the American Institute of Aeronautics and Astronautics "Space 2016" conference in Long Beach, California. "We are on the verge in Europe of building an exploration program for the future, and it will still need a consensus. How we integrate the ideas of Europe in the NASA road map is an ongoing process."

Parker's near-term goal is to persuade science ministers from ESA partner nations to fund the ISS beyond 2020. Jean-Jacques Dordain, Woerner's predecessor at ESA, led the charge to fund the outpost in low Earth orbit (LEO) until the end of its projected structural soundness in 2028. But while the other ISS partners have agreed to maintain the station at least until 2024, ESA has lagged in committing the necessary resources. A decision is expected in November.

NASA managers worry that fiscal pressures related to the onslaught of refugees fleeing war in the Middle East and famine in Africa have reached a point where Europe's ISS funds might be viewed as better spent on the immediate crisis.

"Obviously the attention is very much on solving the migration problems," says Ehrenfreund, who is sympathetic to the need but emphasizes—as do her counterparts—that cutting funds for space is a short-term fix that impedes a longer-term solution. Droughts and other disasters that have traditionally triggered migration into Europe can be monitored from space, guiding international efforts to mitigate the local effects before residents begin to move.

Cameras on the ISS and other LEO spacecraft already are tracking the growth of refugee camps in Syria and elsewhere (see photos), which helps European planners prepare.

"We try to convince the government how important solutions from space are," Ehrenfreund says. "We have disaster management. We help government in cases of migration or routes of migration. You can do a lot with Earth observation, satellite observation, in order to support the requests and needs of the government."

DLR manages space and aeronautics research for ESA, spending €1.1 billion ($1.22 billion) on space. Of that amount, €800 million goes to ESA and €270 million toward the German national space program. Big-ticket items in the latter basket include the Sophia airborne observatory in conjunction with NASA, the new Franco-German Merlin environmental satellite and smaller projects such as a university-led study to determine how to navigate a probe in the vicinity of Saturn's icy moon, Enceladus.

The agency—and others in Europe—are beginning to follow NASA's lead in partnership with private companies on the "New Space" model, hoping to use the greater efficiency of profit-driven organizations to stretch space funding and boost national economies. Germany's Ministry of Economic Affairs and Energy recently published a study on the subject.

"You have to bring people together, give incentives and create workshops to build up New Space in Europe," says Ehrenfreund. "It's not like in the U.S."

**Edited by Jen DiMascio**

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COMMENTARY

# Target FAA

## Forces favoring ATC reform prepare to woo election-year victors

Whoever is elected in November can expect an earful from proponents of removing air traffic control (ATC) from the FAA's purview. The debate over ATC privatization is one reason passage of an FAA policy bill has been stymied. Congress barely managed in July to pass a temporary extension of the safety agency's authority to Sept. 30, 2017, so it is likely it will be up to the next Congress to pass a multiyear FAA bill.

DONNA MCWILLIAM/GETTY IMAGES

**'This is a cause that is crying out for leadership.'**

—DOUG PARKER
*American Airlines CEO*

Advocates of an ATC privatization provision championed by Rep. Bill Shuster (R-Pa.), chairman of the House Transportation Committee, are regrouping for battle. At an ATC reform summit convened in Washington this month by Airlines for America, the trade association for U.S. airlines, National Air Traffic Controllers Association President Paul Rinaldi lamented that the FAA's equipment and technology lags its counterparts in other nations. "You have to shake your head," he says. And American Airlines, which has spent $3.9 million lobbying Congress this year, according to the Center for Responsive Politics, is preparing to woo a new crop of public officials. "In this distinguished audience are people on both sides of the aisle who may be able to influence the direction of the next administration," says American CEO Doug Parker. "This is a cause that is crying out for leadership from the White House and one that can be a proud legacy of the next administration for decades to come."

### EYES ON SPACE

The vulnerability of U.S. military space programs is about to receive plenty of attention from Congress. Gen. John Hyten, nominated to become the next head of U.S. Strategic Command, believes Russia and China want to be able to "cripple" U.S. operations in space.

"I believe they are building those capabilities today," Hyten testified during his Sept. 20 confirmation hearing. "They are building counterspace capabilities to deny us those capabilities in conflict." Hyten, who currently leads Air Force Space Command, adds that the U.S. should be working faster to respond. Sen. John McCain (R-Ariz.), chairman of the Senate Armed Service Committee, is already planning a classified briefing on the topic. And the House Armed Services' strategic forces subcommittee will meet Sept. 27 to discuss national security in space.

### SLOW GO

When it comes to U.S. military operations in Syria, the U.S. should employ a strategy more like the one used during the first Iraq War, according to one of the architects of airpower during that conflict. Operation Desert Storm, as it was called by the Pentagon, was a 43-day buildup and war in late 1990 and early 1991. It relied on airpower to ultimately cause the collapse of the Iraqi military, says U.S. Air Force Lt. Gen. (ret.) David Deptula. An intense 3-4-week operation in 2013 or 2014 could have prevented the refugee crisis or subsequent terrorist attacks across Europe and in the U.S., he maintains. Instead, the conflict against the so-called Islamic State is dragging on, in part because the applicable lessons of the first Gulf War are not being applied. In Desert Storm, the war was commanded from the air. In this conflict, targets are approved by ground commanders, and the process of selecting a single target can take up to two months. "Folks, that's longer than the entirety of Desert Storm," Deptula says, adding that it allows the enemy time to regroup and entrench. He argues that the Obama administration is weighing too carefully the civilian cost of the war. While the administration waits to decide, more civilians than may have died in an airstrike are dying at the hands of terrorists. "We can't conduct immaculate warfare," he says.

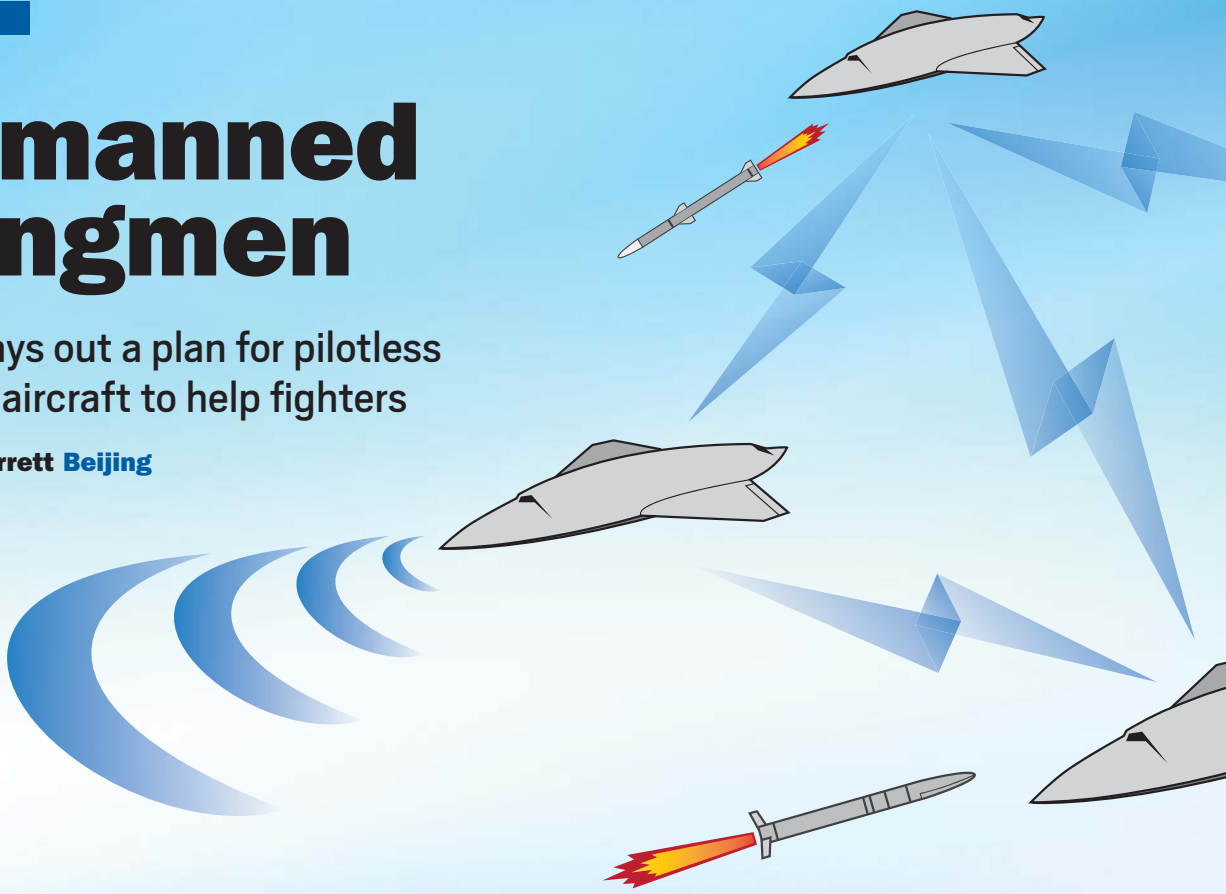
### IRAN OK

The U.S. government has issued licenses that allow Boeing and Airbus to sell civil aircraft to Iranian airlines. Iran Air has signed up for 118 jetliners from Airbus and 109 from Boeing. The aircraft builders have been working methodically all year to secure the Treasury Department licenses (Airbus needs one because of U.S.-made components on its jets). The deals were made possible by a landmark 2015 agreement in which Tehran agreed to curb its nuclear program. Airbus forecasts a need for 400-500 new commercial planes to replace Iran's existing, aging fleet and meet growing demand. But the sales still face political backlash in Washington. Several members of Congress remain fiercely opposed to any commercial deals with Iran, and Boeing's transactions could be hampered by a slew of remaining sanctions and U.S. financial restrictions on Tehran.

# Unmanned Wingmen

## Japan lays out a plan for pilotless combat aircraft to help fighters

**Bradley Perrett** Beijing



Air-combat maneuvers will be far more challenging than strike missions for artificial intelligence, so countries planning autonomous warplanes are generally looking at trying air-to-ground first.

But to many Japanese ears, unmanned strike sounds too offensive—in both senses of the word. Probably for that reason, the country's defense planners are proposing to leap directly into air-to-air automation. Limiting the challenge, they propose high-performance robotic aircraft that would fly as helpers for manned fighters; a pilot would issue commands. And at first the aircraft, called Combat Support Unmanned Aircraft or unmanned wingmen, would fly ahead as sensor carriers, only later taking on the role of shooting.

This family will appear in the 2030s, according to a technology road map for pilotless aircraft published by the defense ministry's purchasing office, the Acquisition, Technology and Logistics Agency (ATLA). The ministry previously discussed concepts for unmanned wingmen but has now advanced its plans. The road map will also include a ballistic-missile defense (BMD) type that would go into service in the 2030s.

The plan divides unmanned aircraft into five types, including the two simplest—small, portable ones and those that operate with line-of-sight communications—which Japan already has in service. A third category, which the country is still working on, are those that need relay communications by satellite, such as types the U.S. has relied on for years, like the General Atomics MQ-1 and MQ-9 and the Northrop Grumman Q-4 in various versions. Then there are pilotless combat aircraft and, lastly, aerostats and solar-powered airplanes, both for extremely long endurance.

ATLA says resources will be directed toward the third category, for ballistic missile defense, and the fourth, for air combat, meaning that they have priority.

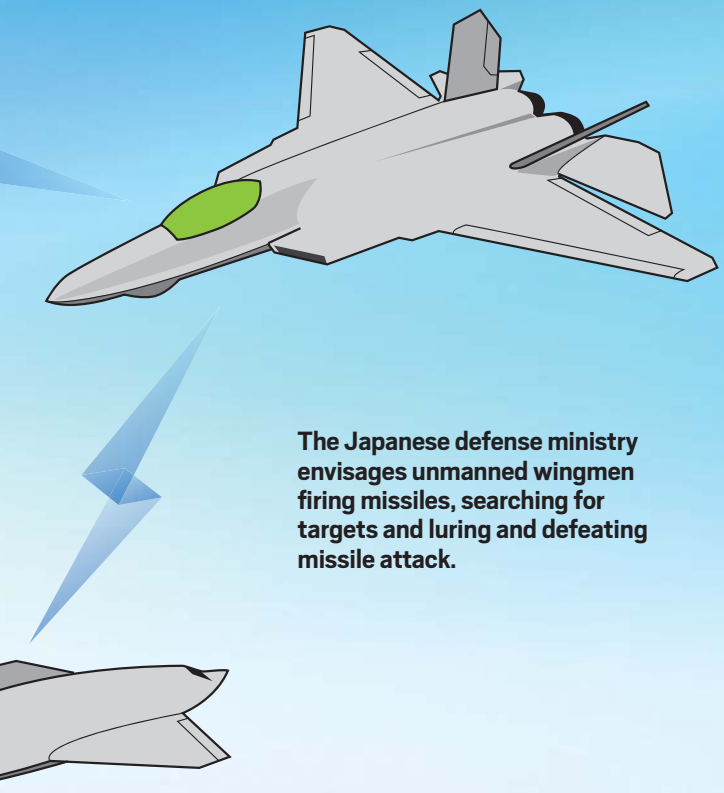
The agency makes no mention of the BMD aircraft carrying weapons. Instead, the type seems to be envisaged as a sensor carrier, presumably using an infrared detector descended from the Airboss system that was tested in 2007. A simple concept design in ATLA's road map document shows that it would be of a conventional configuration for high-altitude, long-endurance operation, with an extremely slender wing and what appears to be a twin pusher propeller-engine installation, similar to the Boeing Condor of the late 1980s. The sensor is shown in a turret in the upper nose (see concept, page 21).

The ministry's Technical Research and Development Institute (TRDI) first discussed the concept of the unmanned wingmen at least six years ago. It then conceived of such aircraft entering into service in the 2040s and working with a suitably upgraded version of the country's proposed next fighter, the F-3. The first version of the F-3 is expected to enter service around 2030.

ATLA now says Japan will "acquire high-autonomy technology to realize an unmanned wingman for manned aircraft in 15 to 20 years." Its drawings showed the F-3 as the manned aircraft. Entry into service before 2035 is probably not intended, since the agency proposes that technology be demonstrated in fiscal 2029-33. In that case, the F-3 would still get an upgrade for unmanned wingmen, but the modified version would appear sooner than was previously planned.

The first type of unmanned wingman to appear would be a sensor aircraft. ATLA's concept drawing shows three flying ahead of a fighter with which they would have a data link. This is the concept that would be achieved in 15-20 years.

More than 20 years from now, there would be a second type—or perhaps a second version, using the same airframe



**The Japanese defense ministry envisages unmanned wingmen firing missiles, searching for targets and luring and defeating missile attack.**

and engine as the first. It would fire weapons. Also after 20 years, the sensor type or version would take on the role of a missile sponge. Since the sensor-carrying wingman would have to cost much more than missiles fired at it, and could not possibly accept hits, ATLA must expect it to routinely defeat attacks in the sponge role, using maneuver and electromagnetic countermeasures.

ATLA shows two concept designs for the unmanned wingman in low-resolution pictures that may or may not bear some resemblance to what is eventually deployed. One has a broad body, blended into a stubby wing that has perhaps 45-50 deg. of backward sweep on the leading edge and moderate forward sweep on the trailing edge (see concept, above). The design is shown operating in all three roles. The other concept design, with a longer, skinnier body, has about 60 deg. of sweep on the leading edge and a conventionally aft-swept trailing edge. It looks fast, except it has the draggy and unstealthy feature of a large underslung pod extending almost to the nose, presumably carrying a radar. This design is shown only as a sensor aircraft.

The unmanned wingman would be under the control of the F-3 pilot but would devise its own tactical maneuvers, reporting back its planned moves. That suggests that the pilot would give general instructions, such as where to search or what to attack, and the drone would work out how best to execute them. It would do things that a piloted aircraft could not, the agency says, probably meaning it would pull maneuvers that a human could not withstand. That would contribute to surviving enemy missile volleys.

The progression from only searching to attacking and dodging is consistent with expectations outside Japan on the likely evolution of artificial intelligence and its capacity to choose maneuvers.

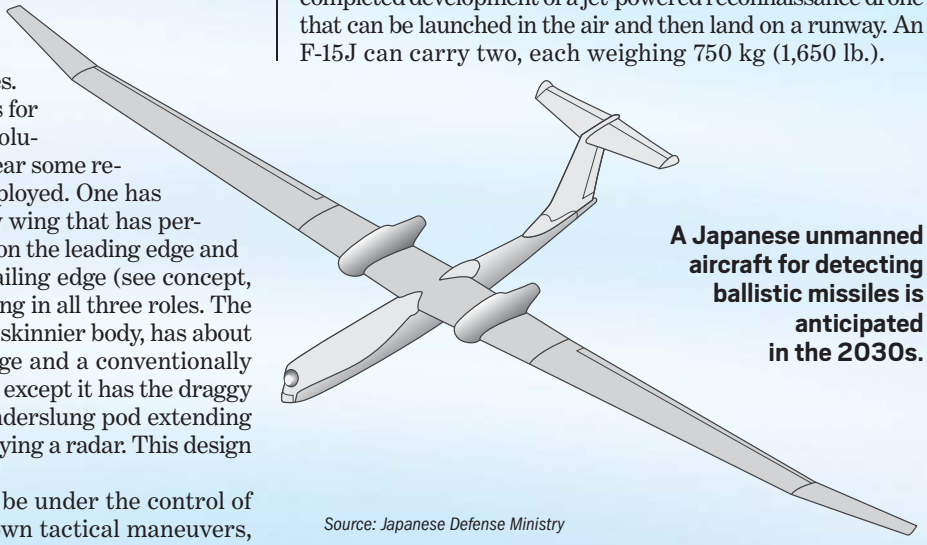
Saab, for example, has published a technology sequence in which an optionally manned Gripen E/F would progress from the current capability of automatically holding altitude and navigating by waypoints to performing "basic air traffic maneuvers" and takeoffs and landings. Later the fighter would be autonomously capable of basic maneuvers needed for maintaining a relative position with a flight leader—presumably, a manned fighter. That looks like the level that the Japanese unmanned wingman needs for the sensor role.

For the next degree of difficulty, Saab lists aerobatics, such as rolling and looping, and then tactical turns executed in relation to the flight leader. Last, and hardest, are maneuvers for beyond-visual-range combat, such as cranking and pumping. That is probably something like what the Japanese believe they need for an unmanned wingman that attacks the enemy or attracts and dodges missiles.

Power and propulsion studies for the unmanned wingmen are to begin in fiscal 2019. The technologies Japan must develop are high agility, meta-materials (with properties not found in nature) for stealth, morphing structure and bistatic radar.

With that radar technology, a transmitter is separate from the receiver, but the acquisition agency does not say which aircraft will do what. One possibility is that the sensor wingman will transmit and the shooter wingman will receive. But it would also be possible for the manned fighter to be the silent receiver, or for it to transmit safely in the rear of the drones while they silently close in for the kill.

The F-3 is likely to have much greater range than the unmanned wingmen. The sensor drones could be of moderate size, however, so they could conceivably be carried near to the combat zone and air launched. ATLA says that in 2011 Japan completed development of a jet-powered reconnaissance drone that can be launched in the air and then land on a runway. An F-15J can carry two, each weighing 750 kg (1,650 lb.).



**A Japanese unmanned aircraft for detecting ballistic missiles is anticipated in the 2030s.**

*Source: Japanese Defense Ministry*

Alternatives would be to use inflight-refueling—which could be repeated often on each mission, since there would be no tired pilot aboard—or perhaps to accept that many unmanned aircraft must be built to support frequent shuttling to and from the combat zone where on-station time would be short.

The latest concept for the F-3, devised in 2014, envisages a fighter with great endurance and armament at the expense of maneuverability.

The unmanned recon drone launched by an F-15 was a product of Fuji Heavy Industries, Japan's specialist in unmanned aircraft. The company is presumably well placed to build the unmanned wingman, too, although rival Mitsubishi Heavy Industries is the national specialist in combat aircraft.

# Rotary Rebirth

## Simpler, cheaper design breathes new life into Bell's tiltrotor franchise

BELL HELICOPTER

**With a 65-ft. wingspan, the 30,000-lb.-class unmanned V-247 is designed to operate from amphibious ships and destroyers.**

**James Drew Amarillo, Texas, and Graham Warwick Washington**

In the depths of their challenges codeveloping the V-22 Osprey, Bell Helicopter walked away from producing a civil tiltrotor, and Boeing from extending the partnership to future products. With the first production tiltrotor drawing praise from its operators, and a more affordable and capable design in development, Bell is again putting its full weight and future hopes behind the configuration.

In addition to assembling the V-280 Valor medium tiltrotor that will fly in 2017 under the U.S. Army's Joint Multi-Role (JMR) technology demonstration, Bell has unveiled the smaller V-247 Vigilant tiltrotor, aimed at an emerging U.S. Marine Corps requirement for a ship-based expeditionary, endurance unmanned aircraft system (UAS).

The company has also proposed an unmanned tiltrotor for the Army's Future Vertical Lift (FVL) Capability Set 1, which calls for an armed scout rotorcraft, and is looking at a large twin- or quad-rotor design for FVL Capability Set 5—a heavy cargo rotorcraft last looked at with V-22 partner Boeing under the Quad TiltRotor project.

"The beauty of the tiltrotor is its scalability," says Vince Tobin, vice president for advanced tiltrotor systems. The downside, with the V-22, is its complexity and cost, but Bell's latest tiltrotors have a simplified configuration and advanced composite structure that make them cost-competitive across the size range, he says.

The 35,000-lb.-class V-280 is 65% of the way through assembly at Bell's Amarillo, Texas, plant. The General Electric T64-419 engines are to be installed by November, with rotors to start turning in April. The 280-kt. tiltrotor is expected to fly in the second half of 2017.

Bell is so confident in its design that it wants a competitive flyoff against the Sikorsky/Boeing SB-1 Defiant coaxial rigid-rotor compound helicopter, also planned to fly in 2017 under the JMR demo. V-280 program manager Chris Gehler says the aircraft will be mature enough when flight tests end in 2019 to support a decision to launch engineering and manufacturing development (EMD) in 2020. This would avoid the 2021-24 technology-maturation phase planned by the Army ahead of a competition for EMD.

The Army plans to begin an analysis of alternatives for FLV-Medium, or Capability Set 3—to replace the utility UH-60 Black Hawk and attack AH-54 Apache—this October. The service's current time line calls for initial operational capability (IOC) by early 2030. Bell says the V-380 could be ready closer to 2025—an acceleration also supported by Sikorsky/Boeing.

Similarly, the 30,000-lb.-class unmanned V-247 could be ready for production in 2023 after a three- or four-year EMD phase, Tobin says.

Bell began preliminary design in response to the Marine Corps' 2016 aviation master plan, which introduces the MUX (Marine Air-Ground Task Force UAS Expeditionary). The plan envisions the MUX as a Marine Corps/Navy program, with a technology demonstration in 2018, early operational capability in 2024 and IOC in 2026.

While a production V-280 would need new high-power turboshafts in the class of GE's Future Affordable Turbine Engine technology demonstrator, the V-247 "does not need a new engine," he says. Powered by a single 5,000-6,000-shp engine, the UAS has an endurance exceeding 11 hr. and 450-nm-radius carrying a 600-lb. payload. The V-247 can carry 13,000 lb. of fuel, sensors and weapons.

Despite a 65-ft. wingspan and 30-ft.-dia. rotors, the aircraft is compatible with Navy DDG destroyers. The blades and outboard wing extensions fold inward and V-tail downward before the wing pivots parallel to the fuselage, allowing the UAS to fit the ship's hangar. Two folded V-247s would fit in the Boeing C-17 airlifter, Tobin says.

The Marine Corps' master plan illustrates the MUX capability with the Tern coaxial-rotor tailsitter ship-based medium-altitude, long-endurance UAS, which is being developed by Northrop Grumman for DARPA and the Office of Naval Research. While the V-247 is larger, Tobin says the tiltrotor has a lower disk loading, reducing the fuel burned during vertical takeoff and landing and extending endurance.

The UAS has an open systems architecture enabling "plug-and-play" payloads, says Tobin. Side bays can house fuel, sonobuoys, lidar sensor or two Hellfire or Joint Air-to-Ground Missiles. An underfuselage bay can carry a Mk. 50 torpedo, AIM-9X air-to-air missile, 360-deg. surveillance radar or fuel.

Having sold its Model 609 civil tiltrotor program to development partner AgustaWestland (now Leonardo Helicopters) in 2009, Bell is focused on military applications, but Tobin says the company always keeps an eye on the commercial market.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For a next-gen battlefield-survivable tanker, the Air Force may draw on Lockheed Martin's concept for Speed Agile.

LOCKHEED MARTIN

# Stealthy Tankers?

## The U.S. Air Force, with the KC-46 in production, looks ahead to battlefield-ready follow-ons

**Lara Seligman** Washington

As Russia and China develop sophisticated weapons that can shoot down U.S. aircraft from farther away, Air Force leaders worry that their aerial refueling tankers, the backbone of the joint force, are vulnerable to attack.

Gen. Carlton Everhart II, chief of Air Mobility Command (AMC), thinks about how to solve this problem every day. AMC is embarking on a new look at the art of the possible for the next-generation tanker fleet, often referred to as "KC-Z," he tells Aviation Week. That future KC-Z may look very different from the large-bodied, commercially derived tankers of today: They could be stealthy, carry missile-shooting lasers, or even fly autonomously.

"What is on the cusp of groundbreaking technologies? That is what we want on that airplane," Everhart said Sept. 20 at the Air Force Association's annual air and space conference. "Is it stealthy? I don't know. Is it large? I don't know. Is it medium, is it small, what is the combat offload?"

The Air Force has spent the last 15 years operating in the permissive skies over Iraq and Afghanistan, with no real need for radar-evading, armed tankers, he says. But adversaries such as Russia and China are developing sophisticated surface-to-air missiles and anti-aircraft weapons designed to foil U.S. forces' ability to penetrate, leaving the Pentagon struggling to tackle the new anti-access, area-denied environment.

A stealthy, armed tanker might be part of the solution, Everhart says. The tankers of the 2030s and '40s will need to be significantly more survivable because they may accompany the next generation of fighters and bombers into this new battlefield. In other words, a nonstealthy tanker could give away the position of the stealthiest fighter jet.

"Now that you are getting near-peer adversaries who have different technologies," Everhart says, "and they have studied the way we fight, that is starting to change our calculus of how we might execute the next war."

The Air Force hosted an industry day on the next-generation tanker concept and will continue discussions with industry in order to solicit the best ideas, he says. The KC-Z study is expected to kick off in about six months and to last about a year.

The general hopes to speak with major industry players about applying low-observable coatings, using a blended, hybrid or flying-wing design to reduce the tanker's radar cross section, or even outfitting the aircraft with lasers to defeat incoming missiles. AMC is open to an autonomous or remotely piloted tanker as well, he says.

For a stealthy next-generation tanker, the Air Force may draw on the Air Force Research Laboratory's (AFRL) Speed Agile concept demonstration, a decade-long collaborative effort by AFRL, NASA, Boeing and Lockheed Martin to develop technology for a stealthy, short-takeoff-and-landing airlifter. Boeing and Lockheed's Speed Agile designs featured stealthy shaping and embedded engines. Though Speed Agile began in 2002 to meet Air Force requirements for an efficient, survivable airlifter able to deliver loads directly to the battlefield, the program ended in 2012 without transitioning to a development program.

The Air Force may also be looking at Lockheed's Hybrid Wing Body (HWB) and Boeing's Blended Wing Body (BWB) concepts for a more fuel-efficient next-generation airlifter. The HWB combines a blended wing and forebody for aerodynamic and structural efficiency with a conventional aft fuselage and tail; BWB is a triangular, tailless design that merges the vehicle's wing and body. Neither concept is specifically designed for stealth—features such as embedded engines and aligned edges are not apparent—but such an airframe would certainly be stealthier than today's transport and tanker aircraft and could later be modified to reduce the radar cross section.

The Air Force's long-stated strategy for replacing its aging KC-10s and KC-135s begins with buying 179 Boeing KC-46A Pegasus aircraft, with delivery beginning in August 2017. The service had planned to pursue a KC-Y acquisition starting in 2024, followed by a KC-Z in 2036. However, Everhart says they are now thinking about leapfrogging KC-Y for a next-generation KC-Z. Alternatively, KC-Y could just be a modernized KC-46—a KC-46B, per se.

The KC-Z would likely come online in the 2030-40 time frame, he says—after the bow wave of modernization currently facing the Air Force has passed.

"I look at the time lines, I look at the Air Force overall budget, and I ask, 'Where can I logically not put an undue burden on the Defense Department, or an undue burden on the taxpayer?'" Everhart says. "[And] 'where is my next opportunity to introduce an acquisition program?' That is the reason we are looking at the 2035 time frame."

# Making an Impact

## FAA to receive results of initial small-UAS collision severity studies


DJI

**DJI's Phantom was selected for collision testing because it is the most popular small quadcopter.**

**Graham Warwick Washington**

U.S. researchers are flinging small unmanned aircraft systems (UAS) and their components at aircraft structures in a speedy effort to provide data on collision risks to help the FAA with future rulemaking.

Results suggest people on the ground do not need to be very concerned about injuries from falling drones, but the argument that a small UAS hitting a manned aircraft is equivalent to a birdstrike has not survived closer scrutiny.

Begun in January, the research is being conducted by Assure (Alliance for System Safety of UAS through Research Excellence), the FAA's UAS Center of Excellence led by Mississippi State University. Assure is an alliance of 15 core and eight affiliate universities with more than 100 industry partners.


OPENWORKS ENGINEERING

**Collision research is part of a layered approach to the threat of small UAS that includes ways to safely bring them down, such as this net launcher that captures the drone.**

Assure's first tasks from the FAA include two projects to assess collision severity: A3 for air-to-air, led by Wichita State University; and A4 for air-to-ground, led by the University of Alabama, Huntsville. Reports will be submitted by the end of September, and follow-on work is already planned, says associate director Stephen Luxion.

These initial studies are aimed at helping the FAA define waivers to its Part 107 Small UAS Rule, which took effect on Aug. 29. Results will help the FAA delineate mitigations enabling operations outside the rule's narrow limitations, such as flying over people or beyond visual line of sight.

The air-to-air project is assessing the impact-damage risk to a Boeing 737-class narrowbody airliner and Learjet-class small business jet from a collision with a small UAS below 10,000 ft. and at 250 kt. The most prolific small quadcopter, DJI's Phantom, and a generic fixed-wing UAS are used for these initial projects.

Detailed mathematical models have been developed of the UAS and the aircraft structures where collisions can be expected—windshield, wing, horizontal and vertical stabilizer. The impact of UAS components—battery, motor and payload camera—on these structures is then modeled. Collisions with complete UAS are also modeled, at different impact angles and speeds, and compared with an equivalent birdstrike, Luxion says.

"We are then firing components and even the whole UAS against these structures to see if the results verify the models," he says. "The goal is to model this, versus every time a new UAS model comes out having to blast it against a real stabilizer. Eventually, we will be looking at engine ingestion testing to confirm what we think will happen."

These initial studies are already driving follow-on research, including into collisions with rotorcraft and private aircraft that will share low-altitude airspace with small UAS. "Engine ingestion testing has everyone's attention, but they are taking extra due diligence to make sure the models are right and everybody is on board when we get to the testing," Luxion says. "You don't want to have to set up multiple high-bypass engines and keep firing things at them."

Assure has been tasked by the FAA with identifying time lines and potential industry partners for engine testing. "The researchers have relationships [with manufacturers], and I am sure they are going to support us with engines and expertise because they are interested, too," Luxion says.

The report submitted will detail issues found during the collision testing. Luxion expects the immediate question from the FAA to be "What kind of mitigations can take place to improve a battery, say, so it has less of an impact?" The agency has already asked for white papers and preproposals from Assure for follow-on research into mitigations, he says.

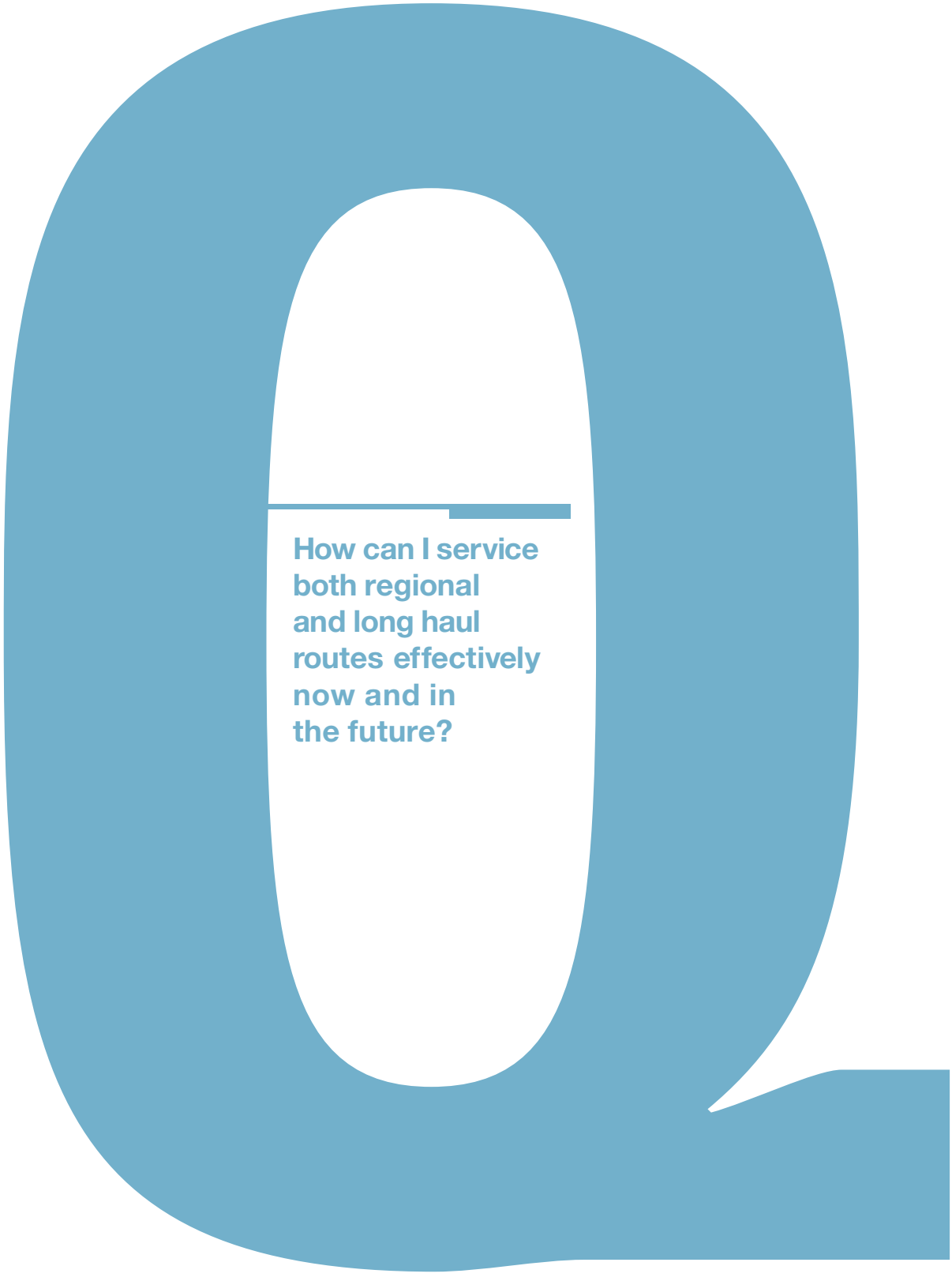
The A4 study is looking at UAS hazards to people and property on the ground. "There has been a lot of research done on the interior, on what happens to an aircraft passenger during an impact, but really nothing exterior," says Luxion. An initial look at existing research identified gaps.

"So, first, they had to define the characteristics of UAS, how do they fall and what terminal velocities do they reach?" he says. "They are looking at head and thoracic lacerations, and what happens when a payload hits someone." Initial studies are trying to define levels of safety based on factors such as kinetic energy or kinetic energy density to find the best way to establish rules.

"There is a lot of debate right now on levels of safety. As the [air-to-ground] research starts to come in, there have been some surprises—favorable ones—that there is not as much risk of damage as originally expected. This has raised more questions and research about why," he says.

Detailed results of these initial collision studies are not yet available. The air-to-ground research, Luxion says, shows small UAS tend to flutter as they fall; drag and friction reduce the terminal velocity, so the risk is not as great as thought.

On air-to-air collisions, much will be determined by how the FAA eventually defines "safe"—whether it is based on the pure kinetic energy of the impact or kinetic energy spread over an area. "Any hope these things would act like a bird when they hit something is not supported by the testing," Luxion says. "We know the characteristics are different, and you cannot use birdstrikes as a model."



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# Calling a Halt

## CAAC will severely restrict its authorizations for new airlines

**Bradley Perrett Beijing**


**Ruili Airlines of Kunming is one of 20 airlines that the CAAC authorized in 2011-15.**

From full speed ahead to slamming on the brakes: The Civil Aviation Administration of China (CAAC) has tightened rules on setting up airlines, around five months after it suspended authorizations, unannounced.

Citing safety concerns, the agency says it will severely restrict the number of new carriers it will authorize. It also is limiting investors' ability to use regional or cargo aviation companies to enter the trunkline passenger business.

Industry sources say the caution of new CAAC chief Feng Zhenglin is likely a factor behind the policy, which the agency is using to formally reverse its once-liberal approach to licensing carriers. The bureau set out its policy in a notification that was sent to the industry on Aug. 29 and has been seen by Aviation Week. "The CAAC will severely restrict airline establishment," it declares, dissatisfied with the industry's increasing fragmentation. It states that it wants to "avoid a situation in which airlines are numerous, small, scattered and weak."

Twenty airlines were approved in 2011-15, the CAAC notes. Toward the end of that planning period, the industry saw a new carrier entering the market every month or two. Provincial and city governments' eagerness to have their own airlines was the key driver behind the proliferation.

This is not the first time the CAAC has opposed industry fragmentation. For the six years until 2013, it had an official ban on new airlines—though in practice it occasionally licensed carriers that had government backing.

Aviation Week reported the unannounced shift in stance three months ago (*AW&ST* June 6-19, p. 26). No later than April, the agency ceased taking applications for new airlines and even declined to move forward some that had been accepted. More recently, the CAAC has relaxed its position a little, deciding to license one or two more airlines this year.

# Sweet Spot

## Engine throttle push and limited stretch could be key to faster-reaction Boeing 737-10X

**Guy Norris Seattle and Los Angeles**

The design space remains wide open for a potential second stretch of the 737 MAX family to counter the Airbus A321neo, says Boeing, but as assembly of the first 737-9 nears, the manufacturer appears to be leaning toward a simpler, lower-risk derivative.

Earlier this year Boeing outlined studies of a longer-fuselage MAX version dubbed the 737-10X that may be powered by a derivative of the larger-diameter CFM Leap 1C developed for the Comac C919. However, the concept requires a redesign of the main landing gear, which, added to the integration of the bigger engine, would add both time and cost to the development.

When the company first acknowledged the plan earlier this year, the initiative was targeted at entry into service around 2022 and development costs of no more than $2 billion. Now, in order to bring entry into service forward by up to three years, as well as reduce research and development costs while maintaining greater commonality with the 737-7, -8 and -9 MAX models, Boeing is considering alternate options. The leading candidate now appears to be a more straightforward -10X stretch with an uprated Leap 1B that could be available by 2019 or 2020.

The stretch concept is a "viable option and a potential opportunity in that marketplace," says Boeing President and CEO Dennis Muilenburg. "We are thinking through the business case on that right now [and] talking to customers," he said at Morgan Stanley's financial investors conference on Sept. 16.

Boeing's product development and business-case debate over the revised -10X concept boils down to four main questions. First, if it launches any further stretch variant at all, how much of a derivative will be enough to win a share of the estimated 17% bigger-capacity market? Second, will such a derivative maintain the value of family commonality while still being sufficiently different to prevent potential cannibalization of the 737-9 market? Third, depending on the level of change, can the variant be brought to market in a timely and affordable manner? Lastly, is the potential -10X market important enough to merit the disruption to the production system a new derivative might bring?

The decisions about the stretch also take place in the context of Boeing's broader strategic goals of developing a new middle-of-the-market airliner (also known as new midsize airplane or NMA) class to fill the current capacity gap between the 737 and 787. The timing and cost implications of the 737-10X options therefore could affect development of the NMA, as well as ongoing R&D spending on the new large 777X twinjet.

Although the potential 200-plus seating of a 737-10X would creep into the lower limits of the NMA market, Boeing stresses that the larger midsize aircraft will be an-all new one to address an all-new market. Its studies are focusing on an aircraft family with initial seating of up to 270 seats and range up to 5,000 nm. The aircraft will have a sixth-generation composite wing and more electric systems. A projected entry-into-service target of around 2025 is driven almost entirely by the availability of new-generation

BOEING

The proliferation of airlines over the past few years has resulted in increasingly conspicuous shortages of airspace and technicians, according to the CAAC policy notification, referring to pilots as well other specialists. "This affects flight safety, service quality and punctuality," it says. Another issue, not mentioned, may be the CAAC's ability to properly supervise the industry, since every additional carrier demands more work by the regulator's staff. Feng, who lacks an aviation background, presumably wants to proceed cautiously, as Communist officials usually do when taking over a job, say industry sources.

The country has 57 airlines—51 primarily for passengers and six for freight. "Research shows that the current airlines' capacity growth can satisfy the growing travel demands of the people," the agency says, implying that no more are needed. One victim of the policy change may be AirAsia, which wants to set up a Chinese affiliate.

In restricting market entry, the CAAC says it will stringently assess proposed airlines' use of limited capacity in the air and on the ground at their intended base airports. The qualifications of technical staff, such as flight crews, will come under heightened scrutiny. And the agency will limit the number of airlines home-based at each airport: a maximum of three at airports handling 10-30 million passengers a year, four at those handling 30-50 million and five at busier facilities.

But neither that rule nor any other in the policy specifically limits the creation of branch companies, which Chinese carriers need to establish as they expand operations. So while no more than five airlines will be able to call Beijing Capital International Airport their home, others can continue to establish subsidiaries and keep aircraft there. This means local governments still will be able to pay for expanded air services at their typically underused airports; they just will not be able to put their names on new airlines in doing so.

Some of China's mainline passenger carriers have grown out of regional airlines or been converted from freight operators. Further opportunities will now be limited. A regional carrier will need 25 aircraft and to be flying at least 3,000 hr. a month before it will be allowed to add mainline aircraft, according to the CAAC. Freight operators will need at least 20 aircraft and 2,400 hr. a month before taking on passenger business. Regional and freight aviation will continue to receive CAAC support, however. The agency views the two subsectors as undeveloped. It is particularly keen to back airlines using domestically made regional aircraft.

In issuing the new policy, the CAAC has directed its regional offices to reconsider applications for airline establishment that have not received final approval.

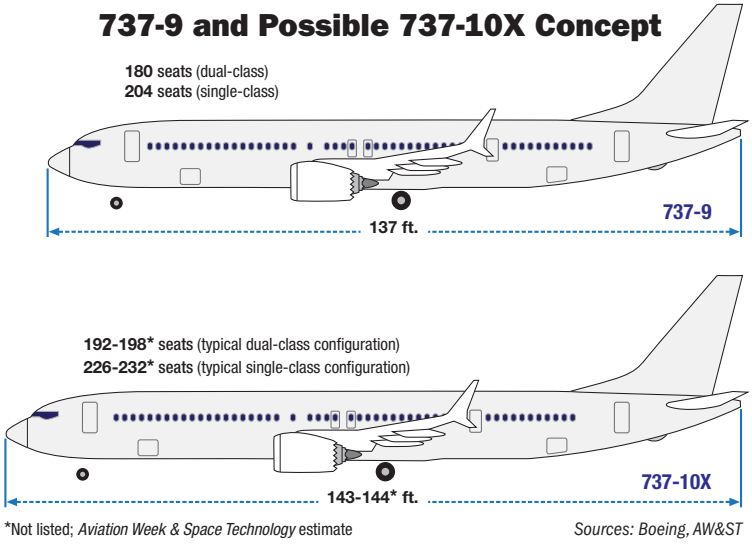
*—Research by Ryan Wang*

40,000-45,000-lb.-thrust engines.

"We can potentially do both," says Muilenburg, referring to the 737-10X and NMA. "If you were to look at a stretched MAX airplane and additional stretch, that could potentially be a 2019, 2020 entry into service and a relatively minor development program. If you were to look at a new middle-of-the-market airplane, it would be more of a 2024, 2025 entry into service, so [it is] not something that is going to significantly affect the R&D profile in the near term," he adds. Straddling the 787-10 and 777X debuts, both initiatives "would feather in very nicely and give us a nice, stable R&D profile," says Muilenburg.

Boeing declines to discuss details of the latest 737-10X stretch study, which, if approved for proposal to the board, faces inevitable compromises compared to other options with a bigger engine and taller gear. Aside from challenges to rotation angle, performance will be limited to the "thrust bump" capability of the Leap B. Rated at just over 29,000 lb. for takeoff, the Leap 1B28 is expected to be capable of a "throttle push" to over 31,000 lb. CFM has achieved this in the past. Over the life of the 737 program, from the CFM56-3B to the current CFM56-7BE, available thrust grew 24%.

For fuselage length increases, the key limitation will be maintaining adequate ground clearance from tailstrike. Assuming Boeing adopts a modest stretch of just over 6 ft., similar to the extension made recently to extend seating in the 737-7, this will likely require a simple landing gear modification to move the rotation point slightly aft. Even though Airbus offers high-density seating in the A321neo for 240 passengers, Boeing believes many carriers will require fewer seats and that stretching the MAX to an additional 12-18 seats would likely cover most of the market.




*Not listed; *Aviation Week & Space Technology* estimate

*Sources: Boeing, AW&ST*

Another, less obvious challenge facing the -10X is the logistics involved in transporting the larger fuselage from Spirit AeroSystems in Wichita to Boeing's 737 production site in Renton, Washington. The 737 fuselages are transported by rail as one major assembly, the longest of which for the 737-9/900 is more than 130 ft. long (without radome). To avoid the disruption and cost involved in reassembling complete fuselages in Renton, the stretched aircraft may also require the redesign of rail cars and careful remeasurement of trackside obstacles.

# Talking Shop

## Top space executives concur on 'mutual backup,' electric propulsion and manufacturing advances

**Thierry Dubois** Paris

The jury is still out on how the recent accident that destroyed a SpaceX Falcon 9 rocket will affect the launch service industry. But in the near term, the accident is giving competing providers an opportunity to tout their relative strengths. In the longer term, launch companies are looking to electric propulsion, an opening of the U.S. market and 3-D printing as potential game-changers.

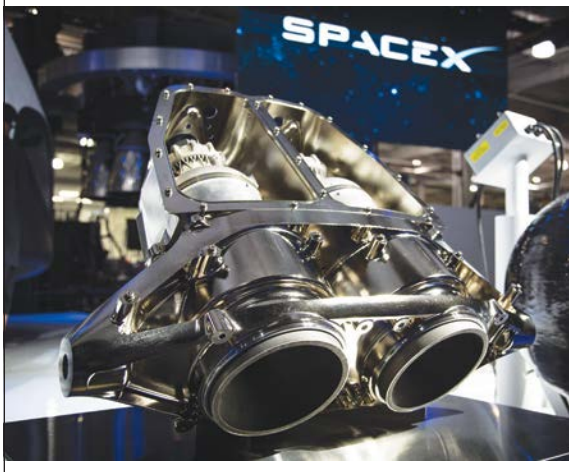
Arianespace is quick to promote its reliability: Its August launch was its 73rd consecutive successful one. And in announcing Blue Origin's New Glenn reusable launch vehicle, founder Jeff Bezos emphasized a methodical approach to development. "Our mascot is the tortoise," he stated. "We believe 'slow is smooth and smooth is fast.'"

Among the titans of the launch industry, a consensus is emerging on "mutual backup." Such agreements allow a provider, in case of a delay, to redirect its customer to a partner. "Launch service providers have an obligation to help customers have their satellites in orbit on time; we all face challenges, and . . . there is an opportunity for us to work together and still effectively compete," International Launch Services (ILS) President Kirk Pysher said Sept. 13 during a panel discussion at Euroconsult's World Satellite Business Week annual executive meeting in Paris. SpaceX and ILS have a mutual backup agreement for a number of satellites, according to Gwynne Shotwell, SpaceX president and chief operating officer. Whether it will apply to the recent Falcon 9 explosion is not clear, she added, as the company needs further discussion with the customer.

"Mutual backup makes sense, and . . . we are ready to trigger discussions with our dear competitors," Arianespace Chairman and CEO Stephane Israel said. Compatibility with two different launchers can be designed into a satellite, an official at a satellite operator confirms. The official finds it hard, however, to imagine mutual backup as part of a contract with the customer.

Quality has a cost, and there are limits to Arianespace's pricing as it prioritizes reliability, Israel said. On the other hand, it would be fair if insurance rates could take into account the proven reliability of a launcher, he suggested. The allusion to the recent accident left Shotwell unfazed, as she foresees insurance rates will not be an issue for Falcon 9.

SpaceX is now aiming to launch in November. A Falcon rocket will not fly until the company has pinpointed the cause of the explosion, Shotwell clarified, but "three months is the right amount of time to find the problem and fix it," she said.



SPACEX

**For the Dragon V2's launch escape system, SpaceX is using a 3-D-printed chamber in the SuperDraco engine. Additive-layer manufacturing, thanks to its reduced cost, is expected to become widespread in spacecraft production.**

Asked about conducting other tests with a satellite onboard, she answered: "We don't force anyone to do that. I do not want to speculate, I will not say 'never again' but probably not the next few."

The first flight of a Falcon Heavy is being rescheduled to 2017. "It depends on the results of the investigation into the anomaly; it has no impact on the rocket but on which pad we will launch from," Shotwell explained.

Launch service providers are gearing up for electric propulsion becoming widespread. Arianespace calculated that one-third of the satellites launched last year were electric or hybrid. It will reach 40% this year, according to Israel and Pysher.

"Electric propulsion is an opportunity for the customer, as it reduces mass and cost," Israel said. The in-design Ariane 6 rocket, which has factored in this evolution, will be more cost-effective, he believes. "We will have the possibility to launch two small satellites or a small and medium one, no longer having to wait for [the combination of] a small and a big satellite," he said, noting that large electric-propulsion satellites can be expected.

In Pysher's view, the typical geostationary satellite in 2020 will be powered electrically.

Several industry players, including an American, hoped for relaxation of the U.S.'s International Traffic in Arms Regulations (ITAR), which aims to prevent the transfer of sensitive technology to China. "It is a problem for us; we have good launchers but cannot get to the market easily," said Zhiheng Fu, China Great Wall Industry Corp.'s vice president and general manager. A satellite with a U.S. component may not be launched on a Long March rocket.

China is among a handful of countries that have not benefited from an ITAR relaxation in 2014. SpaceX's Shotwell and Ko Ogasawara, Mitsubishi Heavy Industries' vice president and director for space systems business development, also appear to favor further relaxation.

All three Western launch service providers expect to see growing use of additive manufacturing (3-D printing). "On Ariane 6, 3-D printing will be one of the means to cut costs," said Israel. Shotwell concurred, noting that "printers get better all the time" and the technique uses much less material. She warned, however, that metal from a conventional machining process is stronger.

Robert Cleave, Lockheed Martin Commercial Launch Services vice president for advanced programs, pointed out that 3-D printing is already playing a substantial role on the planned Vulcan launcher. ILS is not using 3-D printing and is not planning to do so, even for a launcher on the drawing board, said Pysher.

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# Boeing's T-X Moment

## Teamed with Saab, Boeing bets on affordability in U.S. Air Force's next-gen trainer competition

**Lara Seligman** St. Louis

As production of Boeing's venerated F-15 and F/A-18 fighters winds down, the company is struggling to stay in the tactical aircraft business beyond this decade. So it is taking no chances in the U.S. Air Force's T-X advanced trainer competition, which may offer St. Louis a lifeline.

Boeing and partner Saab finally lifted the curtain on their T-X offering here on Sept. 13, bringing to a close months of speculation about the clean-sheet aircraft. Boeing-Saab's T-X is a purpose-built, production-ready trainer that hews closely to the Air Force's threshold requirements for the new program. The sleek, twin-tail design focuses on affordability over performance, drawing on Boeing's secretive Black Diamond initiative to drive down manufacturing and sustainment costs.

BOEING


**Boeing and Saab announced during the unveiling of their joint T-X advanced trainer offering that they already have two production-ready aircraft on hand.**

Boeing is the last of the four competing prime contractors to show its hand in the competition. The 350-aircraft program is a coveted prize for all four of the competing teams, but Boeing arguably has the most to lose. In a major blow, the company lost the next-generation bomber competition to Northrop Grumman last year; meanwhile, any work on the U.S. Air Force and Navy's sixth-generation fighter will likely come too late to keep Boeing in the tactical aircraft business. Absent new orders from the U.S. military or its allies, production of Boeing's Strike Eagle and Super Hornet will end by 2020.

"St. Louis will never close, but the fighter business that was the heart of the enterprise is in danger," warns Loren Thompson, an analyst with the Lexington Institute. "To be out of that business is a wrenching prospect, and T-X is one way they might be able to keep a toehold."

Richard Aboulafia, an analyst with the Teal Group, is blunter: "When Super Hornet and F-15 go, St. Louis goes," he says.

So there is no question the stakes were high last week when Boeing finally unveiled its T-X offering. In perhaps the biggest surprise of the day, company officials revealed they have two production-ready aircraft on hand—in contrast to Northrop Grumman's clean-sheet T-X demonstrator, which made its unannounced first flight from rapid-prototyping subsidiary Scaled Composites' plant in Mojave, California, on Aug. 26. The first Boeing aircraft, displayed during the rollout event, has already started ground tests and will complete its first flight by year-end, company officials say.

The Boeing-Saab design certainly looks the part of a purpose-built next-generation trainer. But does it have what it takes to win?

The Sept. 13 rollout ceremony revealed a single-engine T-X design that looks like a hybrid of an F/A-18 Super Hornet and a Saab Gripen. The aircraft features a shoulder-mounted, shallow-anhedral wing and fuselage-mounted landing gear. The wing has F/A-18-style leading-edge root extensions, under which appear Gripen-style pitot inlets.

The aircraft can be most obviously distinguished from the competition by its twin vertical tails, which officials say add maneuverability and control. While most modern fighter jets are twin-tail, the other three T-X proposals feature a single tail. Boeing's is powered by an afterburning General Electric F404—the same engine used by Lockheed Martin and Korea Aerospace Industries' offering, the T-50, and, in nonreheated form, in Northrop's T-X demonstrator.

Boeing appears to have concluded the competition will come down to affordability, with officials promising to "shatter the cost curve"—a reference to the Air Force's cost-cutting initiative dubbed "Bending the Cost Curve." The Boeing-Saab proposal prioritizes affordability over exceeding performance requirements, says Boeing Phantom Works President Darryl Davis—a decision that comes as a bit of a surprise, as the Air Force in its latest draft request for proposals (RFP) incentivized competitors to submit high-performance bids.

"The No. 1 mission is to meet the threshold requirements of the Air Force advanced pilot training," says Davis. "If you are going to control cost you have to drive how you actually meet all those requirements."

Boeing may have concluded the performance incentives in the RFP were not enough to offset the price of increasing the aircraft's power and G-capability, Aboulafia hypothesizes.

Meanwhile, Byron Callan of Capital Alpha Partners questions how much the service will be willing to pay for increased performance at the end of the

day, particularly given the bow wave of modernization bills coming due in the 2020s.

"The Air Force has an 'eyes bigger than its stomach' problem right now," he says. "They may be looking at Porsches, but they are going to end up buying Fords."

Officials revealed after the rollout that the T-X design goes beyond Boeing's Black Diamond initiative, with engineers 3-D-printing certain components of the jet to lower manufacturing costs. In order to bring down life-cycle costs, the aircraft also features large, conveniently positioned access panels so that technicians can more easily perform maintenance.

Experts read Boeing's emphasis on affordability as an indication the company sees Lockheed's T-50 as its main competition for T-X. Like Boeing's offering, the T-50 can easily meet the Air Force's performance parameters, but Lockheed may struggle to bring down the cost of the existing airframe. As to the T-100, a version of Leonardo's M-346 offered by Raytheon, Honeywell and CAE, its main advantage is the companies' simulation and training expertise. However, there is still some question about whether the T-100 can meet the stringent performance requirements.

But while Boeing is seen as a leading contender in the competition, the company's partnership with Saab may pose a problem, Aboulafia says. While officials declined to say what parts of the jet were developed by which industry partner, experts believe Saab did much of the design and engineering work. Ulf Nilsson, president of Saab Aeronautics, says Saab is responsible for the mid- and rear-fuselage sections, according to a recent news report. Meanwhile, a large Russian cargo aircraft believed to be carrying portions of the new aircraft flew from Sweden to the U.S. in June.

The disconnect between the design and manufacturing of the Boeing-Saab T-X may add risk—something the Air Force is seeking to avoid, Aboulafia speculates. He contrasted the team's three-year design effort with Northrop's, whose Scaled Composites subsidiary quickly built its own T-X demonstrator after the company, in February 2015, abandoned plans to propose an updated version of BAE Systems' Hawk trainer.

But Callan points out that two of the three other competitors are in the same boat, as Raytheon is relying on Italy's Leonardo for the T-100 airframe and Lockheed's T-50A is based on South Korea's Golden Eagle fighter-trainer.

The Boeing-Saab team is still discussing where the aircraft will ultimately be assembled, but the engineering and manufacturing development phase of the program will be completed at Boeing's St. Louis factory, Davis says.

The Air Force is planning to release a final RFP to industry in December, with a downselect to a single vendor planned in 2017. Initial operational capability is expected in 2024.

**Gallery** *See more on the Boeing-Saab team's next-generation T-X trainer:* **AviationWeek.com/Boeing-SaabT-X**

# Baltic Boundaries



**NATO countries have been policing the airspace of the Baltic states since 2004, but this presence has been enhanced since the Russian annexation of Crimea.**

## Baltic states work together to solve defense issues posed by their 'pesky' neighbor

**Tony Osborne** **Malmen Air Base, Sweden**

Militaries around the Baltic are reconsidering defense plans, with years of defense cuts being reversed as they ponder how to counter and deter a more powerful, capable Russian armed force equipped with advanced fighters, standoff weapons and advanced long-range ground-based air defenses.

As the nation with the largest Baltic coastline, Sweden is at a strategic juncture of great interest to both NATO and Russia, said Col. Oscar Hull, head of the Swedish armed forces capabilities section, speaking during an airpower seminar before its air force's 90th anniversary celebrations at Malmen air base.

"Access to Swedish borders, territory and airspace is a strategic advantage for NATO, therefore there is also a Russian natural interest in Swedish waters and airspace," he said.

While Sweden had one of Europe's largest armed forces during the Cold War, its assumption of a "peace dividend" has left its forces a fraction of that size. Politicians chose to convert a well-equipped force ready to defend the country from invasion into a lightly equipped expeditionary power fitted to respond to world events, a pattern followed by numerous Western countries.

But Russia's moves have seen Swedish armed forces revisiting a national defense role.

"The Baltic region has become less secure," says Swedish Defense Minister Peter Hultqvist, noting that the situation is "more challenging and harder to predict than before," he notes. He says Russia is increasingly willing to use violence to achieve its political goals and that even tactical nuclear weapons play a part in its military exercises.

Swedish defense officials point out that Russian anti-access/area-denial capabilities, such as long-range ground-based air defenses, have been firmly established in the Kaliningrad Oblast, the Russian exclave on the Baltic, along with tactical ballistic missiles. The siting of such capabilities just over 500 km (310 mi.) from Stockholm is roughly the same distance as Kiev to Crimea, where similar defense capabilities have also been established.

The Swedish government has raised defense spending, approving the building of new submarines and a new fleet of latest-model Gripen fighters, although currently just 60 jets are planned. Politicians are pondering increasing that to 70 aircraft. There are also plans to give the jets a long-range strike capability through the integration of a cruise missile, but there is no decision on which weapon this will be. The air force is in the process of training to use the long-range Meteor air-to-air missile.

Swedish air force commander Maj. Gen. Mats Helgesson says the air force has noted significant changes in the capabilities of Russian aircraft based in the region. Types such as the long-range Mikoyan MiG-31, once a rare sight over the Baltic, are now seen more regularly, often in a "refurbished and modernized" state, he says.

Helgesson has no doubts the Russians will follow by basing the Su-34 "Fullback" strike aircraft, Su-35 "Flankers" and new types such as the T-50 Pak-FA in the Baltic region .

"The threshold to use these forces has been lowered," says Helgesson. "With new [Russian] fighters and ships and ground-based air defense systems, we must be ready to handle that."

The smallest of the Baltic states, Estonia is one of the few countries in Europe that regularly meet NATO's target of spending 2% of its gross domestic product (GDP) on defense, but as a small nation the spending levels do not equate to much in real terms, particularly compared to its giant neighbor to the east.

Yet Estonia has always tried to punch above its weight in terms of deploying troops and assisting in international operations. It regularly sent rotations of 150 troops to Afghanistan, and nine Estonian soldiers died there. As a proportion of its population, its casualties were nearly twice those of the U.S., and that support has earned it strong defense alliances.

"The Estonian people appreciate why we sent troops to Afghanistan. . . . When they see the NATO fighters in Estonia, they feel safer," says Col. Jaak Tarien, commander of the Estonian air force.

The country is dependent, as are the other Baltic states, on the rotation of NATO fighters as part of the Baltic Air Policing (BAP) program. BAP missions were usually solely concentrated from Siauliai in Lithuania, but the spike in Russian operations in the Baltic prompted NATO to bulk up the mission, and now fighters are also regularly operated from Estonia's Amari air base. That base also regularly hosts U.S. fighters and ground attack aircraft and has seen deployments of F-22 Raptors and MQ-1 Predator unmanned air systems.

But for equipment, Estonia has largely been dependent on other NATO countries and its neighbors to supply surplus kit—much of its fleet of aircraft and helicopters is focused on providing training to its army so that


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it is ready to work alongside its NATO counterparts.

"Our air force is about maintaining our aviation competency, in airfield operations and battlefield support," says Tarien.

Recent plans to induct former U.S. Army C-23 Sherpa transport aircraft were abandoned because of the high cost of support and pilot training, while the purchase of four Robinson R44 helicopters was supposed to be the precursor to a buy of more advanced helicopters with an anti-armor capability, but this also did not proceed. The air force is now examining other options to fill its transport aircraft needs.

In order to expand its defense capabilities, Estonia is looking to its partnership with the other Baltic states, Lithuania and Latvia. High on its shopping list is the purchase of a medium-range air defense system to supplement the short-range missiles already in service in the three countries, but Estonia may struggle to afford the capability.

Tarien says both Lithuania and Latvia have enjoyed significant increases in defense spending and have surpluses available allowing them to purchase such a system.

Lithuania's defense budget rose to 1.5% of GDP in 2016 from 1.1% in 2015, while Latvia has committed to spending 2% of GDP on defense by 2018.

Discussions on the proposed air defense system are embryonic, but Lithuanian ministers have already selected the Norwegian Advanced Surface-to-Air Missile System (Nasams). These would be surplus Norwegian systems, as Oslo looks to introduce the new Nasams 2. In the Baltic states, the Nasams would be commanded by each respective air force.

For Lithuania, the introduction of Nasams would be just one element of a major defense modernization program. This year, Vilnius has ordered Boxer armored fighting vehicles and purchased surplus self-propelled artillery from Germany. And to boost troop numbers, conscription is being reintroduced this month.

"Russia is an unpredictable neighbor . . . but from a military point of view, we are thankful in this situation because our politicians have put national security and defense as a top priority in the national budget, to 2% of GDP," says Col. Audronis Navickas, commander of the Lithuanian air force.

His force, one of the smallest in Europe, has grown rapidly in recent years, and what it lacks in airpower it makes up for in mobility, equipped with a trio of C-27J Spartan airlifters and nine medium helicopters for search-and-rescue and troop transport.

The air arm also flies four Aero Vodochody L-39 jet trainers—three of which are leased—but these are primarily used for the training of fighter controllers and forward air controllers. Navickas says his ultimate aim is to give the country its own airpower capability.

"It has to be a step-by-step process," he told delegates at the Swedish air force's air power conference. "We are not looking at fifth-generation or fourth-generation fighters. It is not so easy to make airpower the top of a national procurements list; sometimes it almost seems impossible."

All three Baltic states have taken steps to boost air surveillance and share primary and secondary radar information through the Baltic Air Surveillance Network; however, some nations are frustrated by the level of information-sharing between NATO and non-NATO countries.

"We are in a boxing ring with five friends and five enemies, and our eyes, nose and ears are shut; if we take a swing, we don't know who we will hit," says Tarien.

"We really need to move onto unrestricted sharing of data. . . . This is about safer airspace in peacetime and about having a fair chance [versus] losing in a crisis," he says.

There are other concerns. As more NATO countries purchase more advanced fighters, such as the F-35, their high cost and smaller available numbers may discourage some nations from deploying them on air policing operations.

"There will be less of them, and [they will be] more expensive to fly," says one official from the Baltic states.

During a visit to Estonia in 2014, President Barack Obama promised a more regular U.S. military presence in the country, while the new European commander for the U.S. Air Force has said he wants to bolster training in the region by broadening the scope of the existing Arctic Challenge aerial exercises.

Gen. Tod Wolters, commander of the U.S. Air Forces in Europe, says there was a "premeditated game plan" to take the exercises to "another level," building up training, and adding new capabilities for regional allies to help deter what he called the "pesky aggressive folks that sit off to the east," a clear reference to Russia.


**Since President Obama's visit to Estonia in 2014, the U.S. has sent to the country numerous aircraft and troop deployments, including F-22s and MQ-1 Predator UAVs.**

U.S. AIR FORCE/TECH. SGT. DANIEL HEATON

# Barriers to Entry

## The world's lowest-cost airline is looking at China

**Bradley Perrett Beijing and Melbourne, Australia**

"Come to China, make lots of money—and tell us how you do it." Although never stated quite so baldly, this is the typical invitation extended to foreign companies who possess certain expertise China lacks.

AirAsia certainly has extraordinarily valuable expertise: By its own reckoning, the budget airline group has the lowest costs in commercial aviation. Meanwhile, the Civil Aviation Administration of China (CAAC) has been encouraging airlines to adopt the low-cost model. And now AirAsia says it wants to set up a Chinese subsidiary with a local partner.

The problem may turn out to be that as currently planned the partner would not be an airline. So all the country's current carriers would only have reason to complain to the protectionist CAAC about the proposal from what will be seen as a foreign company.

AirAsia's ambition to set up a Chinese subsidiary has been spelled out to Aviation Week by the group's newly appointed president for North Asia, Kathleen Tan. Potential Chinese partners have approached AirAsia, and while the talks should produce results soon, the group cannot yet reveal what those might be, she says.

The potential for cutting costs in China is one factor behind the ambition to set up there, the executive says. That means an AirAsia China, if Beijing allowed the creation of one, would benefit the Malaysia-based group's current airlines while also opening access to the Chinese domestic market.

In China "our aim is to find a partner that believes in the AirAsia model, deeply appreciates low-cost aviation and is compatible with our culture," Tan says. The partner would not be an airline, adds another AirAsia official. No doubt AirAsia would prefer not to teach its tricks to a Chinese competitor, but that is exactly what Beijing prefers to see.

In early July, AirAsia was subject to speculation that it was considering setting up a Chinese joint venture or establishing a dual listing on the Hong Kong stock exchange. It responded on July 12, saying it "does, from time to time, receive proposals to establish airline joint ventures in various jurisdictions" but "currently AirAsia is not pursuing any new joint venture proposals." Tan is not necessarily contradicting that statement, however, since "not pursuing" may have meant that the group was not negotiating a specific deal at the time.

Chinese local governments, airports and airlines are interested in working with AirAsia, Tan says, without naming them. The possible role of an airline that would not be a joint shareholder is unclear. "We should have a final result soon, but we cannot now make any revelations," she says. That sounds like there will be a revelation to make.

AirAsia and other airline groups in Asia and Australia have created chains of franchisee carriers that share a brand and such operations as booking systems. Typically, the group parent company owns up to 49% of the equity of each franchisee—but no more, to preserve the branch's local nationality and therefore access to its home country's domestic market and international air-service rights. The local equity partner need not be an airline.

According to Tan, AirAsia would like to own 49% of a Chinese subsidiary, with the partner holding the rest. Under such circumstances, the branch company could achieve higher efficiency. But that raises another obstacle: The Chinese government has never allowed foreigners to own anywhere near 49% of a Chinese passenger airline. Delta Air Lines' stake in China Eastern Airlines, less than 4%, is typical of foreign participation in the equity of Chinese carriers.

Yet Chinese low-cost carrier Spring Airlines owns 33% of a Japanese subsidiary that flies under its brand, while HNA Group owns 48% of French carrier Aigle Azure.

In China, AirAsia cannot use its own information-technology systems nor install its own check-in equipment at airports, says Tan. Instead it must use suppliers, which hurts efficiency. Implicitly, she believes AirAsia's costs would be lower if it handled its own ground operations there.


Spring Airlines has been prevented from growing as fast as it would like.

AIRBUS

A peculiarity of the Chinese market will inhibit efficiency even if AirAsia has a local branch, however. CAAC insists on a minimum 1-hr. turnaround time between flights, probably to minimize delays. Budget airlines elsewhere aim to keep their aircraft at airport gates for much less than that, even less than 30 min.

There are other obstacles, too. The CAAC is currently reluctant to approve the establishment of new airlines because of safety concerns. It could give the go-ahead but then restrict growth to limit damage to favored airlines, notably the three big ones that belong to the central government: China Southern Airlines, Air China and China Eastern. Spring Airlines would have many more than its current 61 aircraft if the CAAC had been more willing to let it grow, industry sources say.

On the other hand, the big airlines appear to have lost influence, say other industry sources. Notably, they do not have close and long-standing ties with the new chief of the CAAC, Feng Zhenglin. Feng, appointed in January, does not have a background in aviation.

*—With Adrian Schofield in Auckland; research by Ryan Wang*

# New Horizons

## Long-haul LCCs eye Europe as the model matures

**Adrian Schofield Brisbane, Australia**


**The AirAsia X group has grown its Airbus A330 fleet to 31 aircraft and has 66 of the successor A330neos on order.**

The Asia-Pacific region still serves as a Petri dish for the long-haul, low-cost carrier (LCC) concept. However, there is no longer any question about whether the experiment is sustainable. Airlines in this category are growing rapidly as they spread their networks across Asia, and they are now beginning to set their sights further afield.

While long-haul LCCs have appeared elsewhere, they are most prevalent in Asia. The vast distances and less mature markets are well suited to this business model. Most of these carriers have struggled to break even, leading many observers to doubt their viability. But this perception is changing as the former upstarts come of age.

Malaysia-based AirAsia X (AAX) is regarded as the standard bearer for long-haul LCCs. The airline is finally out of the red and launching new routes within and beyond Asia. AAX has repeatedly said it intends to fly to Europe, although it appears that fast-growing Singapore LCC Scoot will beat it to the punch.

Scoot plans to introduce service from Singapore to Athens, Greece, on June 20, 2017, using Boeing 787-8s. The carrier asserts this will not only be its longest route, at over 10,000 km (5,400 nm), but also the longest flight operated by any LCC.

The current Scoot network encompasses destinations across Asia and Australia. It began flying to Jeddah, Saudi Arabia, in May, which is now its longest flight. It also introduced its first flights to India in the same month.

Scoot was launched by Singapore Airlines (SIA) in 2012 as a wholly owned subsidiary. SIA's intention is to combat the proliferation of Asian LCCs by creating its own budget brands, in much the same way as Qantas has done with its Jetstar subsidiary.

The Athens flight is a good example of the SIA group's approach. The parent, which already serves many business hubs in Europe, assessed that an LCC model would best fit the Athens route. SIA has already transferred some of its own routes—including Jeddah—to its subsidiary.

Scoot has grown its 787 fleet to 12 aircraft, comprising six of the -9 version and six -8s. It took delivery of its latest 787 in September, leaving eight remaining on order.

While its fleet is expanding, Scoot is also looking at other ways to extend its reach. It has helped form a long-haul LCC in Thailand in partnership with local short-haul carrier Nok Air. The Bangkok-based joint venture, branded as NokScoot, flies three Boeing 777-200ERs on six routes.

NokScoot has ambitious growth plans of its own. Nok Air CEO Patee Sarasin says the joint venture wants to add seven more used 777s and is looking for potential sellers. The carrier intends to use the extra aircraft to launch its own flights to India, he said on the sidelines of the recent CAPA Australia Pacific Aviation Summit.

**"There are different schools of thought within AirAsia X about flights to Europe, and that is healthy"**

Competing with the much larger AirAsia group is one of the challenges facing LCCs such as Scoot, Nok and NokScoot. This has led them to form an Asia-Pacific LCC coalition with five other airlines, known as the Value Alliance. The members intend to offset some of AirAsia's network advantages by interlining with each other.

AirAsia's network reach is increasingly based on its growing stable of offshore affiliates, most of which are narrowbody short-haul operators. AAX is a separate company but has common ownership links with AirAsia and is part of the broader group. It draws on feed from the other AirAsia brands and has established long-haul joint ventures of its own in Thailand and Indonesia.

AAX achieved a milestone with its first-ever net profit for the second quarter. It reported a profit for the first half, too, turning around a sizable loss from the same period last year. While lower fuel costs are helping, it is also attracting more business in key markets.

Revenue from its Australia routes was up 56% in the second quarter, with an increase of 47% on Chinese flights. The AirAsia group has more capacity into China than any other non-Chinese carrier, and AAX plays a major role in that, says Arik De, AAX's head of commercial operations. The group has already gone beyond primary and secondary cities in China and is now looking at tertiary markets.

The long-haul LCC sees further growth potential in Australia and New Zealand, De says. AAX generally offers double-daily flights to Australian cities Sydney, Melbourne and Perth, and it also has service to Gold Coast and Darwin; in New Zealand it serves Auckland.

MEDHI NAZARINIA/WIKIMEDIA

The carrier has little scope to add more flights to Australia's largest cities under existing bilateral arrangements and it would like to see a further relaxation of limits, De says.

Europe is certainly on AAX's agenda as well. The airline previously flew to London and Paris using Airbus A340s, before discontinuing the routes in 2012. In recent years, it has repeatedly signaled that it intends to resume flights to Europe, with London being the destination most discussed by AirAsia Group CEO Tony Fernandes.

AAX is likely to wait until it begins receiving Airbus A330neos in 2018 before launching European nonstop flights. However, the carrier has also said it could fly to Europe using its existing A330ceos, by operating a one-stop service via an intermediate destination. De says there are "different schools of thought within the organization [about flights to Europe], and that is healthy."

The carrier gave a hint about one possible option when it briefly listed a Kuala Lumpur-Istanbul-Barcelona, Spain, route in its reservations system and on its online route map in August. However, AAX later released a statement to "clarify that we have no immediate plans to operate those routes." According to the airline, "the routes appeared on our website as part of internal testing." Since then, senior airline executives have said they intend to launch an Istanbul flight next year.

AAX has been growing its overall capacity dramatically this year. While it has been taking some new deliveries, it has also been transferring aircraft back from its charter operation and increasing the fleet's average utilization rate, says De.

Four A330s have been added this year, three allocated to the core Malaysian operation and one to the Thai affiliate. This gives the carrier and its two affiliates a total of 31 A330s. AAX has no more A330ceo deliveries due this year or in 2017, and its next scheduled deliveries are in 2018, when its 66 A330neo orders are due to start arriving. However, AAX may still decide to source more A330ceos in the interim, says De.

# NASA's Next X-plane
# The Options

**Graham Warwick** Washington

Under its New Aviation Horizons initiative, NASA proposes building a series of large-scale X-planes over 10 years to demonstrate technologies for future ultra-efficient subsonic transports. To get a head start, the agency has awarded six-month contracts to develop the system requirements for flight demonstrators in five different configurations. The next step, funding permitting, will be a competition to take the first X-plane to a preliminary design review. These are the five configurations under consideration.

## Aurora Flight Sciences Double-Bubble D8

Aurora is proposing the D8 concept originally developed for NASA by the Massachusetts Institute of Technology (MIT) for an aircraft that could enter service in 2030-35 with 50% higher efficiency than today's 180-seat narrowbodies. The design combines three key innovations:

- A lifting fuselage, allowing a smaller wing for lower drag, with a twin-lobe or "double-bubble" cross-section enabling a twin-aisle cabin in a Boeing 737-class aircraft.
- Engines embedded in the aft fuselage to ingest the slower-moving boundary layer over the broad fuselage and reenergize the wake for reduced drag.
- Advanced composites manufacturing of the noncircular pressure vessel and complex-curved aft fuselage and pi-tail to enable light weight.


Aurora, with engine manufacturer Pratt & Whitney and MIT as partners, is proposing an X-plane that would demonstrate boundary layer ingestion (BLI) in flight. Wind-tunnel tests of the D8 suggest system-level fuel savings of 15% from having the engines embedded in the aft fuselage.

BLI will require engine fans that can operate in distorted airflow with minimum efficiency penalty and acceptable aeromechanical performance, an area on which United Technologies Research Center is working. Aurora will ground-test its fuselage structural concept under an FAA research contract.

## Boeing Transonic Truss-Braced Wing (TTBW)

Slender, high-aspect-ratio wings generate less lift-induced drag, and an extreme example is the Transonic Truss-Braced Wing. The configuration was originally developed by Boeing in 2008-10 under a NASA contract to identify new designs for fuel-efficient airliners entering service in 2030-35.

With a glider-like wing, but a traditional tube-style fuselage, the TTBW has the potential to reduce fuel burn by 5-10% over today's 180-seat narrowbody airliners with conventional cantilevered wings. The configuration takes its name from the strut or multimember truss that supports the long-span wing.


The most recent design tested has a wing span of 170 ft., compared with 118 ft. for the Boeing 737, and an aspect ratio (span squared divided by area) of 19.55 compared with 11 for the Boeing 787 and 9 for the 737. Bracing reduces weight, but the long wing is flexible. Wind-tunnel testing at NASA Langley Research Center in 2014-15 confirmed wing weight is acceptable and evaluated active flutter suppression techniques.

Wind-tunnel tests at NASA Ames Research Center in early 2016 assessed high-speed aerodynamics and the potential for interference where the strut and wing come together. The truss design that was tested comprised a primary load-bearing strut with a single stabilizing jury member. Results were promising, says NASA.

## Boeing Blended Wing Body (BWB)

Under investigation by Boeing and NASA for more than two decades, including flights of the X-48B/C subscale unmanned aircraft in 2010-13, the Blended Wing Body is the most mature of the large-scale X-plane options (see page 42).


Under NASA's Environmentally Responsible Aviation (ERA) program, completed in 2015, extensive wind-tunnel tests of the BWB showed up to a 53% fuel saving over today's 300-seat widebody airliners and a noise reduction of more than a cumulative 40 dB below the Stage 4 limit.

A BWB X-plane would demonstrate the integration of technologies including:

- A configuration with high aerodynamic and structural efficiency that provides significant additional internal volume for cargo, passengers and fuel.
- Engines mounted above the aft fuselage and between the vertical tails to provide airframe shielding of fan and jet noise.
- A lightweight, noncircular pressure vessel manufactured using Boeing's Prseus (pultruded rod-stitched efficient unitized structure) technique.

Under the ERA program, Boeing built a demonstrator-scale BWB center section using the carbon-fiber composite Prseus. The 30-ft.-wide multibay box exceeded its design goals for damage resistance in structural testing to destruction.

A BWB X-plane potentially would have dual uses, as the U.S. Air Force Research Laboratory has funded research into the configuration as a future military tanker-transport.

## Dzyne Technologies BWB Small Airliner

Studies show blended wing bodies (BWB) work well for large aircraft but not smaller regional airliners or business jets. A double-deck fuselage with passengers on top and cargo and landing gear below results in a deep center-body and a blended wing that is too thick on a smaller aircraft for efficient transonic cruise.

Dzyne Technologies has a design for a regional/business-jet BWB in which the landing gear and cargo are moved out from under the cabin to enable a single-deck center-body with thin wings. The gear is moved outward, and baggage and cargo are stored in the wing roots, outboard of the passenger cabin.

As a business jet with a 100,000-lb. gross weight, the limit set by key airports such as Teterboro in New Jersey, the small BWB offers three times the floor area for the same performance as today's purpose-designed, long-range, large-cabin jets, says Dzyne. As a 110-130-seat "super-regional," essentially the same configuration offers twin-aisle seating and a 20% fuel saving over existing aircraft.


DZYNE

Dzyne plans to use Prseus composites technology for the structure, and the proposed full-scale X-plane would use the stitched carbon-fiber for a section of the upper center-body that includes the skylights, which provide natural light to the cabin in both business and regional configurations (see page 42).

## Lockheed Martin Hybrid Wing Body (HWB)

Questions most frequently asked about blended wing-body designs center on how such aircraft would fit into established commercial and military infrastructure and procedures for loading and unloading, evacuating passengers or airdropping cargo.

Lockheed Martin's answer is its Hybrid Wing Body (HWB) configuration, which combines a blended wing and forebody for aerodynamic and structural efficiency with a conventional aft fuselage and tail compatible with existing cargo-handling equipment.

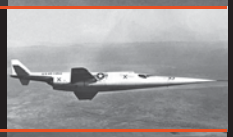
LOCKHEED MARTIN

Conceived as a future airlifter, the HWB has in wind-tunnel tests shown potential to burn 45% less fuel than the Boeing C-17 while carrying outsize cargo of the kind now transported by the Lockheed C-5. The Air Force Research Laboratory and NASA have funded studies of a dual-use demonstrator for a commercial freighter and military airlifter.

In addition to the drag-reducing blended wing and forebody, the HWB features engine nacelles mounted above the trailing edge of the wing. This facilitates installation of fuel-efficient large-diameter ultra-high-bypass or open-rotor powerplants. Wind-tunnel tests show the overwing nacelles are 5% more aerodynamically efficient than conventional underwing engines.

Lockheed has tested both transonic half-span and low-speed full-span models of the HWB. The latter model is now being prepared for flight as a subscale unmanned aircraft to assess the configuration's handling and performance in cruise mode.

## Key NASA X-planes

| | | |
|---|---|---|
| 1946 | **Bell X-1** supersonic flight |  |
| 1954 | **Bell X-2** swept wing |  |
| 1952 | **Douglas X-3** trapezoidal wing |  |
| 1948 | **Northrop X-4** semi-tailless |  |
| 1951 | **Bell X-5** variable-geometry wing |  |
| 1959 | **North American X-15** hypersonic flight |  |
| 1984 | **Grumman X-29** forward-swept wing |  |
| 1997 | **Boeing X-36** tailless agility |  |
| 2007 | **Boeing X-48** blended wing body |  |
| 2006 | **Boeing X-53** active aeroelastic wing |  |
| 2012 | **Lockheed Martin X-56** active flutter suppression |  |
| 2018 | **ESAero X-57** distributed electric propulsion |  |

**Gallery** *See more on these NASA X-planes*
**AviationWeek.com/NASA-X-Planes**


# Alternative Blend

## NASA looks beyond established transport aircraft makers as it seeks ideas for ultra-efficient X-planes

**Graham Warwick** Washington

NASA's research contracts with Boeing have been called government handouts for the last U.S. manufacturer of large commercial aircraft. But as the agency seeks ideas for new X-plane flight demonstrators, it is casting the net more widely.

Boeing has won contracts to study two potential configurations for future ultra-efficient subsonic transports, and Lockheed Martin has received one, but NASA has also awarded studies to two newcomers to commercial-aircraft design: Aurora Flight Sciences and Dzyne Technologies.

Boeing will study both the Blended Wing Body (BWB) and Transonic Truss-Braced Wing configurations as candidates for a large-scale X-plane that could fly by 2021, funding permitting. Lockheed Martin will study its Hybrid Wing Body concept for a dual-use military airlifter and commercial freighter (page 40).

Aurora has been working with engine developer Pratt & Whitney on the Massachusetts Institute of Technology's "double-bubble" D8 configuration for several years, but the Ascent concept for a BWB small airliner from design and prototyping house Dzyne is being unveiled for the first time.

Established in 2012, Dzyne has worked on design projects ranging from the RotorWing vertical-takeoff-and-landing unmanned aircraft to the M10 light aircraft for Mooney International. Founding partner Mark Page, Dzyne vice president and chief scientist, is co-inventor of the BWB and was technical program manager on the original NASA/McDonnell Douglas program in the 1990s.

"No commercial BWB has come into existence," says Page. "We wondered whether a smaller business jet would be easier to do and wanted to understand what it would take to break through the barriers to entry." Those initial studies evolved into an aircraft than can be both business jet and small airliner. But first the BWB's inherent challenges had to be overcome.

Studies show the configuration, with its aerodynamic and structural efficiency, works well for large aircraft, offering fuel savings of more than 50% over today's widebody airliners. But on smaller BWBs a double-deck fuselage, with passengers above and cargo and landing gear below, results in a deep centerbody and a blended wing that is too thick for efficient transonic flight.

Dzyne has developed a design that moves the main gear out from under the cabin, allowing a single-deck fuselage and thinner wing. The gear is moved outward, and baggage and cargo are stored in the wing roots, outboard of the cabin. "This is a breakthrough that allows any size of BWB," says Page.

As a corporate aircraft with a 100,000-lb. gross weight—the maximum allowed at key business aviation airports such as Teterboro, New Jersey—the small BWB has three times the floor area of existing purpose-designed long-range, large-cabin jets like the Gulfstream G650. This allows room for features such as a conference room, gym and multiple bedrooms.

"The question is, does the customer value floor space? We find they do, significantly, given the number of Airbus and Boeing business jets that sell against high-performance Bombardier and Gulfstream aircraft with the same payload/range performance," says Page. "We have the floor space of an Airbus A319 in an aircraft that can fly 18 people 7,000 nm from Teterboro. There is no other way to do that."

**Single-deck fuselage, skylight windows and semi-embedded engines distinguish Dzyne's small-airliner Blended Wing Body.**

As a "super regional jet" seating 110-130 passengers, essentially the same aircraft will provide a 20% fuel saving over existing aircraft. "Our super-regional has about 20% more floor space per passenger than today's regional jets," says Page. "The price for 20% more floor space is about 2% in fuel, so we're investing 1/10th of the BWB's 22% fuel savings in passenger comfort."

Dzyne had decided an all-up demonstration was needed to gain acceptance for a business-jet BWB when NASA began looking at X-planes for ultra-efficient airliners. "That really caught our attention, because everything you could learn with a full-scale X-plane would knock down the remaining technical barriers, real or perceived. This could finally allow BWB technology to reach the public," he says.

"We believe there's a clear market for BWB technology, but no one is servicing that interest. So we created a business construct to fund BWB development now. This will allow meaningful discussions with the airlines and bizjet owners," says CEO Darrell Gillette. "To our knowledge, the major incumbents have not engaged the air-

lines about BWB introduction. We want to have those discussions and promote timely adoption of this technology."

Dzyne is pursuing development of the business-jet BWB through private investment and the super-regional though NASA's X-plane plans. "We're aiming to introduce the bizjet first since we believe it's easier to fund and certify," says Gillette. "The bizjet design will be informed by airliner requirements. We're aiming for a 2025 introduction.

"The 110-130-passenger airliner would fly a few years later, followed by 160- and 210-passenger growth models. Once the airline discussions commence, we can adapt the timing, performance and capacity to suit them," he says. "As development progresses, we'll decide between teaming with a major airframer or creating a consortium. Either way, we'll use the same supplier base as the major airframers."

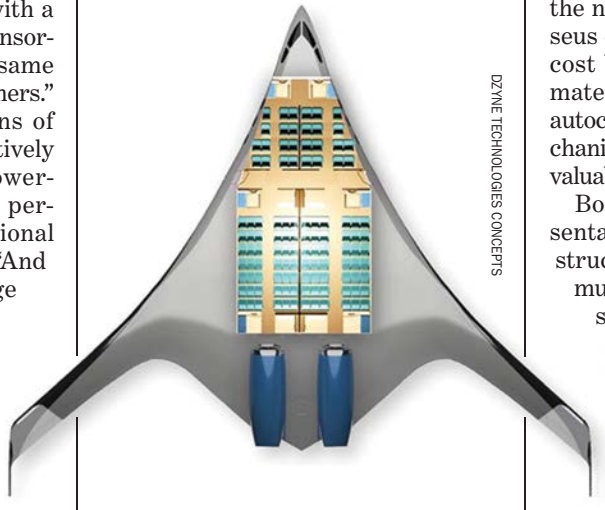
Differences between versions of the 118-ft.-span aircraft are relatively small. The business-jet has lower-bypass engines for high-speed performance, where the super-regional has high-bypass for efficiency. "And we move a bulkhead to change the balance between cargo and fuel," says Page. Dzyne is looking at Rolls-Royce BR725-class engines for the business jet and 23,000-lb.-class CFM Leap or Pratt & Whitney PW1100G engines for the super-regional.

In the airliner version, passengers enter a vestibule via a door about 40% of the way along the cabin, then turn left for business class or right for economy. The business cabin has twin aisles and large windows on the fuselage sides. Economy is two six-abreast single-aisle cabins side-by-side, separated by a structural wall running the length of the cabin and with overhead skylights for natural lighting. Emergency exits are forward near the cockpit and at the rear of the cabin, opening onto shallow ramps.

"The BWB benefit is large enough that some can be spent on passenger comfort," says Page. "We wanted to be economically competitive with a 34-in. pitch in coach. Since the coach cabin is only eight rows long, adding another row reduces pitch to a still comfortable 30 . . . [and] that's as far as you can go." The outer bulkheads are spaced to allow all middle seats to be 3 in. wider than the others.

"There are only eight rows between the most remote seat and the exit. That's two-thirds fewer than in today's airplanes. The distance from the most remote seat and the exit is halved," he says. "The vertical sidewalls allow much deeper overhead bag racks. This will nearly eliminate delays caused by gate-checking overflow baggage. Combined, these benefits are estimated to reduce turn time 15-20 min. at a minimum."

Boeing has completed substantial NASA-funded research on the BWB, data that is made publicly available after a five-year hold. "Within 18 months, all the BWB data through to the X-48B/C flights will be available," says Page. But all the technologies needed to develop an aircraft have not yet been flown together. The BWB is the ultimate integration challenge; all of the pieces have multiple roles," he says.



DZYNE TECHNOLOGIES CONCEPTS

**The Ascent 1000 has twin-aisle seating for 110-130 passengers. A structural divider runs the length of the cabins.**

"You can't demonstrate wing performance without integrated engines flying from 100 kt. to dive Mach number—engines that must operate behind a shockwave above the cabin," Page says. "You need a proof of concept with a pressurized cabin to give people the flight experience in this entirely new airplane. And how else can you demonstrate community noise benefits unless you can actually fly takeoffs and approaches?"

Under Boeing's BWB work for NASA, the wingtip vertical tails were moved inboard to increase airframe shielding of engine noise. Dzyne's BWB retains the wingtip surfaces, and the engines are semi-buried in the upper fuselage to place their exhaust closer to the beavertail for greater shielding. "We hope the full-scale X-plane will validate that," Page says.

Dzyne is not looking at boundary-layer ingestion to reduce drag, which would require the development of engines with distortion-tolerant fans. "We want to make a real product. There is no unusual inflow to the engines. The flow is diverted, and we use tricks with external compression to coax the boundary layer away from the inlets." Page explains.

The company plans to use the Boeing/NASA Prseus (pultruded rod stitched efficient unitized structure) concept for the airframe, particularly the noncircular pressure vessel. "Prseus offers extremely low fabrication cost because there are no pre-preg materials that need freezers, and no autoclaves," Page says. "The added mechanical damage tolerance is especially valuable in the pressurized centerbody."

Boeing and NASA tested a representative BWB center section to destruction and the 30-ft.-wide Prseus multibay structure exceeded its design goals. For the X-plane, Dzyne proposes a Prseus demonstration on a 24 X 10-ft. part of the upper pressure vessel that includes cutouts for the skylights. "The rest of the airplane will be made using traditional composites that are well-known to our major suppliers," Page says.

NASA's contract is for a six-month study to define the system requirements for an X-plane. Results will inform the agency's plans for a series of X-planes under its New Aviation Horizons program. For one or more of the five configurations, the next step would be to take the concept to a preliminary design review.

Dzyne, meanwhile, has engaged a "respected business aviation professional" to validate market interest in a business-jet BWB. "A fairly large number of investors have approached us, but we are not ready to commit," says Gillette. "We will get the initial results [of the validation study] soon and will then initiate negotiations with investors." And if they need an incentive to invest? While the airliner version of the BWB has been named the Ascent, Page says naming rights for the business-jet variant will go to the first investor to commit $50 million to the project.

# Better Blend

## Modified blended wing is 'superior' for airdrop, says Boeing, as new wind tunnel tests begin

**Guy Norris Los Angeles**

Testing that could pave the way for a short-takeoff version of Boeing's blended wing body (BWB) is underway at NASA Langley Research Center as part of work to calibrate the facility's refurbished 14 X 22-ft. subsonic wind tunnel.

For Boeing, the tests could be a small but important stepping-stone toward further development of the BWB concept as a military tanker-transport. Having originated the integrated fuselage-wing configuration more than 20 years ago, Boeing is studying a modified variant with a large aft cargo door as a pathway to a potential first real-world application.


NASA LANGLEY/DAVID C. BOWMAN

The test campaign, which is scheduled to end by early October, will compare data obtained in 2015 using a 13-ft.-span model in the 40 X 80-ft. National Full-Scale Aerodynamics Facility (NFAC) wind tunnel at NASA Ames. This same 6% scale model was built for NASA's recently completed Environmentally Responsible Aviation (ERA) program and was initially evaluated at Langley before the tunnel suffered mechanical failure and the balance of the testing was transferred to Ames.

"As part of the process of bringing the 14 X 22-ft. wind tunnel back online, we had the opportunity to go back in with the same model and do tunnel-to-tunnel comparisons," says Boeing BWB chief engineer Norm Princen. "The data will be used to compare the tunnel now with how the tunnel was before, as well as compare the 14 X 22-ft. with the 40 X 80-ft." Testing will include using particle imagery velocimetry (PIV), a technique in which a particle-seeded flow is illuminated with a laser sheet to visualize and map airflow around the aircraft.

"The laser illuminates the particles, and their movement can be optically tracked and recorded frame by frame by cameras," says Boeing BWB test director John Bonet. "The 14 X 22-ft. tunnel is better for doing that than the NFAC because it is smaller and the model is closer to the optical test window. One of the reasons we want to do it is to measure the vortical [vortices] flow off the airplane surfaces, and we don't want intrusive pressure rakes or pressure probes. This will produce a three-dimensional map of the separation and vortex flow at high angles of attack.

"We will see where it originates from and compare that with the predictions from computational fluid dynamics [CFD]. PIV is really looking at the off-board flow field generated by the fan, aft section and overwing by the leading edge devices," Bonet notes.

"We are hoping if we get extra time we can do some more control-surface testing," says Princen. "We've been thinking about shorter field performance, mostly for military missions, but from a commercial aircraft perspective, the BWB already had good field performance," he says. "However, the military wants short-takeoff-and-landing, like a C-17 or C-130, so we'd need shorter field performance, and the control-surface testing is part of that."

The work will focus on scheduling the movement of the surface to enable the aircraft to rotate at a slower airspeed, enabling quicker climb to higher altitude. Test results will augment Boeing's extensive control-surface database amassed during flight tests of the X-48 demonstrator. The work will also build on the 2015 NFAC campaign, which demonstrated that pitch moment could be increased by blowing the exhaust of the large, upper-fuselage-mounted engines across elevons mounted on the trailing edge. Boeing is also studying other options for augmenting pitch control varying from a belly-mounted flap and altering the gaps between the leading edge and the BWB's Krueger flap to changing the flap angle for takeoff and landing.

**Boeing's 13-ft.-span blended wing body model will undergo flow visualization tests in NASA Langley's subsonic tunnel using particle imagery velocimetry techniques.**

However, just as important to make the airlifter vision a reality is development of an unusual cargo door configuration that would be incorporated into the trailing edge of the aft fuselage. Since first revealing details of its concept to Aviation Week earlier this year (*AW&ST* Feb. 1-14, p. 58), Boeing says it is making significant progress.

"We have been looking at a clamshell cargo door for military applications, and we think we have a good solution for that," says Princen. "We've done recent CFD work, and the flow quality looks good behind the aircraft. It is potentially better than the conventional fuselage ramp because of the upwash you get around the fuselage close out. That's why we think it's a superior solution for the airdrop mission. We believe this is the path forward for the BWB, and in the next 10 years or so we can develop it into some kind of military transport, freighter or tanker."

# Iridium Reborn

## Next-generation satellites are ready, but SpaceX is not

**Joseph C. Anselmo McLean, Virginia and Thierry Dubois Paris**

In 1998, Iridium switched on the world's first global telephone service, utilizing a constellation of 66 interconnected satellites operating in six low-Earth-orbit planes. Less than a year later, the company went bankrupt and took its place in history as one of the worst business blunders of the 1990s.

But Iridium's satellites have proven more resilient than its original business plan. Designed by Motorola to last five years, most of the spacecraft are still operating or have been replaced by on-orbit spares, providing highly profitable communications and tracking services to 823,000 subscribers. And now the reconstituted company is poised to replace its aging system with an equal-size constellation of much more capable satellites.

The new L-band spacecraft—built by France's Thales Alenia Space and assembled at an Orbital ATK factory in Gilbert, Arizona—look a lot like their predecessors: 10 ft. long, 4 ft. wide and 2.6 ft. tall. But each will have far more memory and processing speed, expanding the Iridium system's capacity more than fivefold. Designed to last 12.5 years, they also will carry a secondary payload that provides satellite-based air navigation connections and tracking of aircraft and ships anywhere on the globe.


**Iridium's new satellites, pictured being mated to a launch dispenser, carry a payload that will be able to track airliners flying over oceans and remote areas.**

THALES ALENIA SPACE

While McLean, Virginia-based Iridium has been able to raise the $3 billion needed to build and orbit the new system, which includes spares for backup, getting back to space has been a challenge. SpaceX is under contract for seven missions with its Falcon 9 launcher, each carrying 10 Iridium satellites. The first batch of 10 satellites was in place for launch at Vandenberg AFB, California, on Aug. 25. But a mysterious explosion on a launch pad at Cape Canaveral seven days later destroyed a Falcon 9 and its payload and has grounded SpaceX until at least November, raising doubts about Iridium's plan to have the new system fully operational by the end of next year. "We're encouraged by SpaceX's November target for a return to flight, but all is based on a successful root-cause determination" of the Sept. 1 explosion, says an Iridium spokeswoman. "We're ready to launch when our rocket is ready."

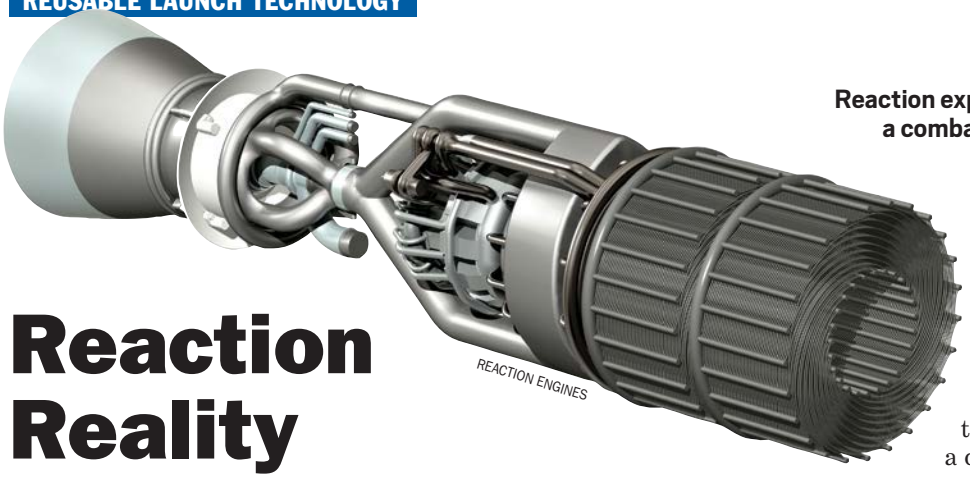
Iridium insists it will "continue operating as we are today" until the new system is in place, but the clock is ticking on its 18-year-old satellites. The interconnected network has developed two minor gaps in its global footprint that could, in the worst case, delay signals for 6 min. The longer it takes to get replacements in place, the higher the chance that more of the original satellites could fail.

When Iridium signed on with SpaceX in 2010, entrepreneur Elon Musk's launch company was a fledgling startup dismissed by skeptics. "We took a chance on them," says Iridium CEO Matthew J. Desch. With that chance came a good deal: Desch says SpaceX's price of $450 million for seven launches is less than half what other launch providers would have charged.

Iridium's initial business model failed because it was based primarily on a pricey telephone service that attracted only a tiny fraction of anticipated subscribers. Its backers also underestimated the rapid emergence of terrestrial cell phone networks in the late 1990s.

The new Iridium, which went public in 2009, relies on telephony for only about half its revenues. The other half comes from data, tracking and machine-to-machine (M2M) communications sold to the U.S. Defense Department and a long list of customers in aviation, maritime and other industries. An on-orbit software upgrade in 2003 added the M2M capabilities, long before machine-to-machine communications were referred to as the "Internet of Things." The new formula seems to be working: Iridium reported profit margins of 57% in the quarter ended June 30.

The new Iridium satellites also will carry a secondary payload, manufactured by Harris Corp., that will relay Automatic Dependent Surveillance-Broadcast (ADS-B) signals from airliners anywhere on the globe to ground controllers, allowing for reduced horizontal separation between aircraft over oceans and providing real-time, satellite-based tracking of aircraft flying over oceans and remote areas. The system will be operated by a spinoff-venture, Aireon, whose investors include Iridium, Nav Canada and the air navigation service providers in Italy, Denmark and Ireland (*AW&ST* Feb. 29-March 12, p. 56). "We will be able to see every commercial aircraft in the world that is broadcasting ADS-B," says Desch. "We think we are going to be the predominant player in the cockpit."




Reaction expects to procure first parts for a combat aircraft-size SABRE ground demonstrator following a design review later this year.

# Reaction Reality

## SABRE demonstrator will be scaled for smaller-scale hypersonic and reusable launch needs

**Guy Norris Culham, England**

Freshly infused with government and industry funding, and riding a wave of interest in Europe and the U.S., Reaction Engines Ltd. is firming up plans to build a fighter engine-size ground demonstrator of its reusable hypersonic propulsion system.

As that rarest of beasts, a powerplant concept combining the air-breathing efficiency of a jet engine with the power and vacuum operating capability of a rocket, the SABRE (Synergistic Air-Breathing Rocket Engine) cycle is a potential game changer for the overlapping worlds of reusable space and hypersonics. Assisted by bypass ram-burners for boost, the engine is designed to power a vehicle from a standing start on the runway all the way to about Mach 5, at which point it will transition from air-breathing to an onboard liquid oxygen source for the remainder of the flight to orbit.

However, while scientists at both the U.S. Air Force Research Laboratory and the European Space Agency are among those who have verified the theoretical capability of the SABRE and the innovative precooler design at its heart, the UK-based developer knows only a successful full-size demonstrator will prove the concept is real.

Reaction originally targeted a full-scale demonstrator capable of more than 150,000 lb. thrust, but the engine size has been scaled back to reflect the slower-than-expected rate of funding. As a result, the demonstrator will now be rated at about 20 metric tons (44,000 lb.) thrust in air-breathing mode, or about 25% of the ground-test version originally envisioned.

Reaction CEO Mark Thomas believes the move to a smaller demonstrator is serendipitous. "It is now more affordable, more rapid to execute and will potentially find its first application quicker," he says. Comparable in overall size to Pratt & Whitney's F135 engine for the F-35 Joint Strike Fighter (JSF), the smaller SABRE could more easily find its way onto a multistage vehicle or hypersonic X-plane size vehicle, suggests Thomas.

"It's a quarter of a SABRE, effectively. In an application for something like Skylon [the single-stage-to-orbit spaceplane for which the cycle was originally conceived] the engine would have four combustion chambers connecting to the single nozzle, a bypass system and the same large turbomachinery, intake and heat exchanger," says Thomas. "There is a view that you could modularize the engine to a far higher degree, so that you could have four compressors and still have a large heat exchanger. From this point onward you could go completely modular, so if you could demonstrate one element, then it is all about integration."

There are other advantages, too, says Thomas: "Being a JSF-size engine, it also gives us the ability to do a rapid demonstrator that can use off-the-shelf components. So you do not have to develop everything such as pumps, compressors and other elements." The change in scale has "been good and refreshing," he notes. "Now we are saying, 'Let's get this thing done and moving!'"

Although the demonstrator could have been smaller, Thomas says, "We think we have found a sweet spot with utility, where you can still see extrapolation to an end product. We are still in the design phase at the moment, and before the end of the year we aim to go through a design review that allows us to procure the first parts of the demonstrator."

Reaction's demonstrator road map is divided into three main phases, the final part of which culminates with flight testing early next decade. The first phase, from this year to 2020, focuses on proving the core of the SABRE and the heat exchanger. "We are bringing together the core system as a dedicated demonstrator, which will allow us to prove that the thermodynamic cycle actually stacks up and that the helium-based cycle is capable of generating thrust," says Thomas.

The basic principle of the SABRE cycle depends on a precooler that chills the incoming air from more than 1,000C (1,800F) to −150C (−240F) in less than 1/100th of a second, before passing it through a turbocompressor and into the rocket combustion chamber. Here it is burned with subcooled liquid hydrogen fuel. To chill and dry the incoming air, the SABRE uses a closed-cycle helium loop consisting of miles of tightly packed, thin-walled tubing that cools down the air only to the point where it forms a vapor. The vaporized air is then injected by the turbocompressor at high pressure into the combustion chamber. For higher-altitude operation and speeds over Mach 5 for the acceleration to Mach 25 and orbital velocity, the engine switches to onboard liquid oxygen supply and runs as a semiconventional closed-cycle rocket engine.

"We are looking to do the first test within the next 12-15 months, and after the heat exchanger the core test is the one we are positioning for in the 2019 time frame," says Thomas. Tests would focus on the low fuel consumption potential of the cycle, as well as operability work covering transients, startups and shutdowns. Key tests will validate the performance of the all-important heat exchanger system, which flows

a mix of methanol and water forward through the matrix of tubes against the direction of the airflow. "So there is a drumbeat demonstration over the next few years, and in parallel we will develop the rocket elements of the system," he adds.

The second phase will focus on integrated engine tests in 2020-2021. "At a point in time, we will integrate the whole lot and test that early in the next decade. This side of 2020, we will demonstrate the first two elements, and then [later in] 2020 integrate the full system and put it to test," Thomas says. The full-up evaluation will therefore link up precoolers and thrust chambers and take the engine through the full operating range with heated inlet air.

Sea-level testing of the high-Mach number SABRE cycle is representative because the atmosphere is both the source of its energy and the reaction mass, says the company. Using the heat exchanger, the test team plans to modulate the air entering the engine. Higher velocity air will be simulated by heating the air flow and, as the temperature of the air entering the engine will remain ambient thanks to the precooler, Thomas says, "we can simulate that on the ground all the way from Mach 0-5." In addition, inlet tests will be conducted in wind tunnels to evaluate flow conditions.

This ability to ground test to the equivalent of Mach 5 is one of the cycle's key attributes, according to Reaction. "Scramjets are a fantastic concept, but they are very expensive to develop because you have to fly them to get a few seconds of data," says Thomas. "But the SABRE looks more like a jet engine, and you can do a lot of testing on the ground because of the heat exchanger, which gives you stable entry conditions throughout the whole operating regime."

MARK WAGNER/AVIATION-IMAGES.COM

**Helium at 200 bar pressure is passed through the red-capped ports into the precooler tube matrix, which is made up of about 2,000 km (1,240 mi.) of 1-mm-dia. tubing with wall thicknesses of 20 microns.**

For the third phase covering flight testing, Reaction is "looking at various concepts, whether it is an X-plane or a flight demonstrator aircraft, or a combination of those assets," he adds. "The X-plane feels like the right territory for something like that." Targets for the flight-test engine include inlet and bypass demonstrations, complete propulsion integration, maintainability and reliability. As the hypersonic engine will be closely integrated into whatever airframe it powers, the flight test will also include a liquid-hydrogen-fueled demonstration and evaluation of an integrated airframe structure concept and high-temperature materials.

Reaction is currently committed to testing the SABRE core in the UK. "That means we have to build a test facility, and that is a big infrastructure project," says Thomas. "We are a few weeks away from submitting planning applications for a test facility close to Culham [England]," he adds. The site will incorporate a hydrogen/air-breathing preburner to condition the air for core tests. Evaluation of the rocket nozzle continues at Airborne Engineering's test facility at nearby Westcott, while parts for the complex heat exchanger are made by Reaction at Culham, as well as by Crossman Engineering and Brite Precision, two Didcot, England-based companies.

Sustained through its formative years by $75 million of backing from private investors, Reaction's growth is accelerating through the injection of $90 million in UK government investment as well as $31 million from BAE Systems, which acquired 20% of the company in 2015. "BAE brings lots of expertise and capability we can deploy on the program," says Thomas. "They have great systems integration capability and knowledge of how to work partnerships with industry and governments. They ticked all the boxes for us and their approach is very refreshing."

Reaction says it is "seeking European partners for some of the building block technology" for the demonstrator. Initial prospects include ramjet developer Bayern-Chemie, part of missile manufacturer MBDA, as well as Spanish engine-maker ITP—recently acquired by Rolls-Royce.

However, Reaction is also eagerly developing its potential interests in the U.S. through a recently established Colorado-based subsidiary led by former Lockheed Martin Space Systems architect Adam Dissel. "This enables us to have more constructive discussions with U.S. agencies," says Thomas. Treading a careful path in terms of export control, Reaction is "being as careful as we can possibly be," he notes. "Designing and making an article here in the UK for testing may result in that article remaining in the U.S., and we are fine with that. If that gets the job done and puts results in the hands of decision-makers, that is a price we would be willing to pay."

# Alternate Approach

## NASA/industry teaming evolves to demonstrate Vulcan engine recovery and reuse technology

**Guy Norris Los Angeles**

While both Blue Origin and SpaceX have demonstrated the feasibility of recovering and reusing boosters as part of an industry-wide push to cut the cost of access to space, United Launch Alliance (ULA) is taking the first steps along an alternate path involving recovery of only the first-stage engines—the highest-value element of the booster.

ULA's sensible modular autonomous return technology (SMART) reuse concept, first unveiled in 2015, is based on the premise that it is more economical to use full booster performance to deliver additional mass to orbit rather than reserve fuel to return the first stage to the landing site. ULA argues the reusable first stage approach in particular incurs up to a 60% performance loss. Even though ULA concedes that reusable boosters can work with lighter payloads, the company believes in these cases the business case is undermined by the loss of potential revenue with each launch.

The SMART concept is predicated on development of the Vulcan rocket and ACES (Advanced Cryogenic Evolved Stage) launch system, the combined version of which should be in service by 2023. The first reusable launch is targeted for 2024 and involves detaching the main engines (either the baseline Blue Origin BE-4 or alternate Aerojet Rocketdyne AR-1) from the base of the stack after burn out. Separated by a shaped explosive charge built into the thrust structure between the engine mounts and the base of the stage, the device will sever the large feed pipes supplying oxygen and fuel to the thrust chamber, be it methane or kerosene.

The engines will be protected during reentry by a hypersonic inflatable atmospheric decelerator (HIAD) that in turn will be detached to enable deployment of a parafoil. Supported by the parafoil, the engines will be recovered in midair by a helicopter and flown to a waiting vessel downrange.

To perfect two key elements of SMART—the HIAD and MAR (midair recovery)—the launch company has teamed with other industry players and NASA through Space Act Agreements. Although midair recovery systems have retrieved payloads from space since the 1960s, none have yet been developed to manage the 21,000-lb. class of load that will be needed for the Vulcan engines. "We needed partners in this endeavor," says ULA reusable systems principal investigator John Reed.

ULA teamed with NASA Armstrong Flight Research Center in California for the third-generation MAR test, the initial recovery method for which was demonstrated in July when a 1,100-lb. article was dropped by one helicopter and caught at a lower altitude by a hook apparatus attached to an Airbus Helicopters H125 (formerly Eurocopter AS350) over the dry lakebed at Edwards AFB. The test, which was run three times, may be extended to include higher loads, say NASA officials.

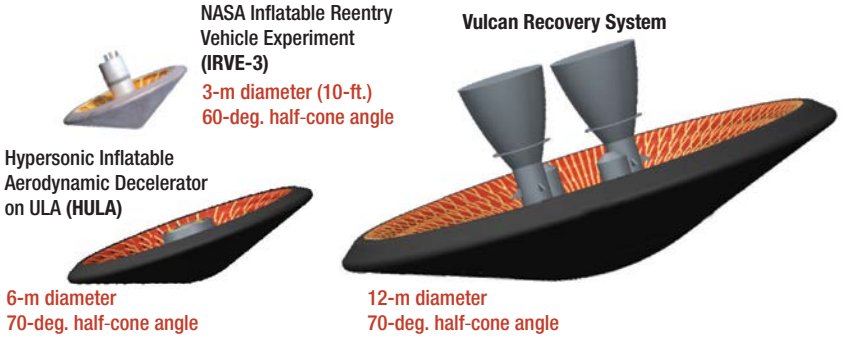
Partners included California-based Airborne Systems, which developed a conceptual design for a scalable system of parafoils and load-limiting grapples, and Erickson Aviation of Oregon, which evaluated the operational aspects. Massachusetts-based Charles Stark Draper Laboratory also developed a road map for guidance, navigation and control development, as well as autonomous systems for the parafoil, helicopter and grapple. Based on initial testing, follow-on demonstrations of 5,000- and 20,000-lb. systems are planned by ULA. Reed, who updated the status of SMART at the American Institute of Aeronautics and Astronautics Space 2016 conference, says testing shows "our entire approach is viable."

For decelerator work, ULA's teaming arrangement with NASA builds on the agency's continuing HIAD studies and results of the Inflatable Reentry Vehicle Experiment (IRVE-3) in 2012. Designed to enable larger payloads to be inserted into the atmospheres of other planets, or the recovery of fast-moving spacecraft to Earth, the HIAD consists of a set of concentric doughnut-shaped rings. Each inflatable ring, or torus, is made of braided Zylon and held to its neighboring torus by Zylon straps.

"NASA was studying HIAD, so seeing this as synergy with their efforts we set up a Space Act Agreement with Langley to mature that technology and burn down risks associated with our application," says Reed. Unlike IRVE-3, which was 3 m in diameter and decelerated up to 20g, the Vulcan engine recovery system will be scaled up to around 12 m to provide a nominal entry of 3g.

As an interim step. ULA is working with NASA on flight demonstrations of a 6-m-dia. HIAD. Dubbed HULA (HIAD ULA), the experiment will be the largest blunt body reentry ever flown and be boosted by a Centaur Atlas V second stage. The plan includes launching several secondary payloads mounted in NanoRacks and on an adaptor before the Centaur performs a reentry burn and spins up the HULA prior to separation.

### Vulcan Engine Recovery Aeroshell Size Comparison




SOURCE: ULA

**Studies indicate that a 12-m-dia. (40-ft.) HIAD aeroshell will enable recovery and reuse of Vulcan engines with minimal or no refurbishment.**

# Another Reusable

## Blue Origin details orbital launch vehicle

**Frank Morring, Jr. Washington**

The powerful new space launch vehicle outlined by Blue Origin owner Jeff Bezos could give partner United Launch Alliance (ULA) a run for the money in the 2020s, positioning "Blue" to support a burgeoning economy in low Earth orbit (LEO) and beyond.

Named in honor of retired Sen. John Glenn, the first U.S. astronaut to orbit the Earth, the launcher—identified informally as the "very big brother"—will generate 3.85 million lb. thrust at liftoff. It will burn seven of the BE-4 hydrocarbon-fueled engines Blue is developing with ULA, which intends to fly them two at a time on the Vulcan to produce 1.1 million lb. thrust off the pad. New Glenn and Vulcan are planned to begin routine operations in the coming decade, when U.S. government and private-sector spaceflight managers hope to see an off-planet economy developing in the region between Earth and the Moon.

Other U.S. launch vehicles also could play into that marketplace. The new Blue Origin launcher will be more powerful than the Delta IV Heavy (2.13 million lb. thrust with three RS-68A liquid-hydrogen engines), but will not generate as much thrust as SpaceX is saying its upcoming Falcon Heavy will deliver with 27 Merlin hydrocarbon engines (5.13 million lb. thrust at sea level).

Two versions of New Glenn are planned—an all-hydrocarbon two-stage version for launches to LEO, and a three-stage iteration for launches to the Moon and beyond. The third stage will use a single cryogenic "vacuum-optimized" version of the suborbital New Shepard vehicle's BE-3 engine that will be "capable of flying demanding beyond-LEO missions," says Bezos, who revealed more details about the new vehicle Sept. 12. Like New Shepard and the SpaceX Falcon core stage, the New Glenn first stage is to be reusable.

"Building, flying, landing and reflying New Shepard has taught us so much about how to design for practical, operable reusability," Bezos says. "And New Glenn incorporates all those learnings."

Still to be revealed are the payload masses the two New Glenn variants will be able to handle. Both versions will have a 23-ft. diameter. The two-stage version will stand 270 ft. tall, while the three-stage vehicle will measure 313 ft., comparable to NASA's Saturn V Moon launcher (see illustration).

The Kent, Washington-based company Bezos is bankrolling privately with his Amazon.com billions is developing the BE-4 in partnership with ULA to use liquified natural gas as a fuel. Other rocket engines in its class, such as the Russian RD-180 and Aerojet Rocketdyne's planned AR-1, burn refined kerosene.

Liquified natural gas is less expensive, but it requires larger fuel tanks for the same performance as kerosene. The New Glenn will use seven of the 550,000-lb.-thrust BE-4s in the first stage, with a single BE-4 optimized for vacuum operations powering the second stage. The three-stage variant will use the same configuration in its first two stages, Bezos says.

The BE-4 will be produced at the Kent factory, where the reusable BE-3 is manufactured. The latter burns liquid hydrogen as fuel. The cryogenic upper-stage engine has already proved its mettle in tests of the New Shepard, flying repeated missions without costly and time-consuming refurbishment.

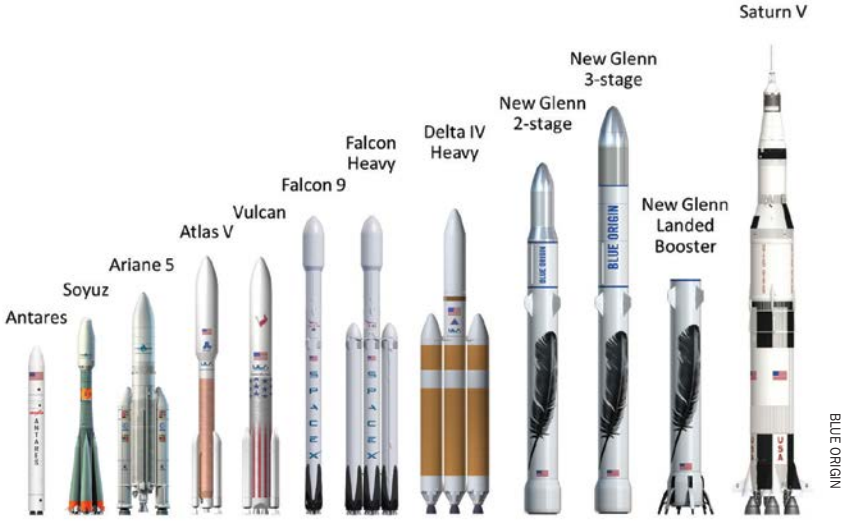
Blue Origin has started construction on facilities at Cape Canaveral AFS, where it has taken over Launch Complex 36 for orbital operations and plans to spend $220 million on improvements. Also in the works is a manufacturing plant in a nearby state industrial park (*AW&ST* Sept. 28-Oct. 11, 2015, p. 66).

In October, the company is planning a fifth flight of the same New Shepard booster with the same engines at its remote West Texas facility for an ascent-abort test designed to validate the solid-fuel pusher-type escape engine that will separate a crew capsule from a failing booster during ascent.

Because of the forces that separation of the crew capsule will place on the rising booster when it ignites at about 16,000 ft., company engineers do not expect the booster to survive its fifth flight. If it does, Bezos has said, it will be displayed in a museum.

Like the New Shepard and the Falcon 9 core stage, the New Glenn first stage will return to a tail-down deceleration and landing for reuse. Bezos has said Blue Origin prefers the vertical-landing approach over a runway landing with wings or a lifting body because it can be scaled to larger vehicles. The company already has plans for ever-larger launch vehicles, and in announcing the New Glenn details on Sept. 12 Bezos also revealed the name for the next vehicle in the sequence.

"Our vision is millions of people living and working in space, and New Glenn is a very important step," he states. "It won't be the last, of course. Up next on our drawing board: New Armstrong. But that's a story for the future."

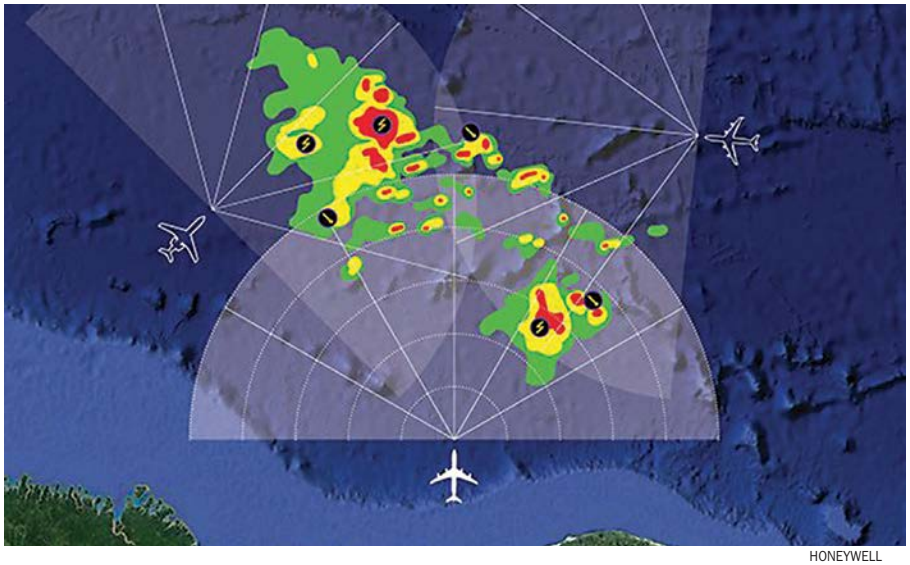



**The planned Blue Origin orbital launch vehicle, compared to other launchers.**

# Working Data

## Small equipment additions promise large benefits for connected airlines

**John Croft** Washington



HONEYWELL

Advances in connectivity systems, and some creative thinking, hold the promise of a broad new slate of applications and services that will benefit airline operational efficiency and safety.

Fueling the trend are the increasing number of airliners being fitted with broadband systems and small, lightweight cabin and "crew services" network hardware and software dedicated to the flight deck and operations. Pilots will benefit in part through new electronic flight bag (EFB) applications that tap into onboard and offboard data, while airlines will see efficiency gains through movement of operational data at lower costs, both on the ground and in the air.

Top avionics companies including Honeywell, Rockwell Collins and Thales are investing heavily in the hardware and software components, and the data pipes that deliver the information to and from the cockpit, as they compete to become end-to-end service providers for data-hungry avionics and EFB applications.

An increasing number of connectivity subsystem providers building servers or aircraft interface devices are jockeying for potentially lucrative contracts outfitting legacy aircraft designs—primarily the Airbus A320 and Boeing 737—with connectivity equipment. Key competitors include Astronautics Corp. of America, Astronics Corp., Avionica Inc., Esterline CMC Electronics, Teledyne Controls and Thompson Aerospace.

Rockwell Collins, which purchased Arinc in 2013 and rebranded the operation as Information Management Services, predicts a boom time for applications and services as broadband connectivity slowly but surely becomes ubiquitous in the airline fleet. Kent Statler, executive vice president and chief operating officer of Rockwell Collins's Commercial Systems division, says a key focus is to position the company for "the inevitable move into the information management side."

Management in this context involves not only moving data from the aircraft to the airline operations center and back, but also using the data to help carriers save money. Statler says a top priority of airlines is to be able to use connectivity to minimize fleet disruptions due to weather or other unplanned circumstances. He says the company is involved in "disruption management" studies with both Airbus and Boeing to determine how to "fix" a disruption and communicate the solution to the fleet.

Honeywell, the main distributor and satellite communications terminal provider for Inmarsat's new broadband $K_a$-band Jet ConneX service, is taking a holistic view of connectivity across its entire avionics and auxiliary power unit portfolio. "We are looking at what connectivity does to the front of the aircraft and under the floorboards," says Carl Esposito, vice president of marketing and product management for Honeywell Aerospace. "We have strategies and plans around using it in innovative ways to improve operations, maintenance, reliability and the fundamental business models of our clients."

As an example of out-of-the-box thinking, Honeywell recently certified

**Honeywell has certified a software modification to its 3-D weather radar that allows for crowdsourcing among connected aircraft.**

a software upgrade for its RDR-4000 weather radar that will downlink the radar's output to the company's Global Data Center (GDC), where forecasters will be able to boost the capabilities of Honeywell's Weather Information subscription service. "Airborne weather radar was never designed to share its information," says Esposito, arguing the development is revolutionary rather than evolutionary. "There are no design standards for that."

The GDC will merge the downlinked weather—sent every 5 min. from participating aircraft—with data from other connected weather radars and traditional sources to create, with enough aircraft transmitting data, what could be the first near-global, near-real-time snapshot of weather from the ground to 60,000 ft. (the RDR-4000 looks ahead up to 320 nm at a swath of airspace between the ground and 60,000 ft. in a 240-deg. arc).

The crowdsourced weather will be sent to subscribers, including airlines, business aviation and general aviation pilots, as well as atypical paying customers including forecasters and insurance companies. "That kind of information, particularly over oceanic regions, Africa and the Middle East, has never existed before," says Esposito, adding that Honeywell is "working incentive details" with RDR-4000-equipped airlines that sign up to get the software upgrade and provide the crowdsourced data.

Honeywell is also drasticaly increasing the number of cockpit applications that can take advantage of its connected weather information service. Kiah

Erlich, Honeywell's director of flight support services, says application developers for Honeywell's GoDirect service have increased their output rate from one new application launch per year to one per month. One of their latest developments is a new tool to optimize flight plans in the vertical dimension in real time based on the latest wind and temperature data, a move Erlich says could save airlines 88 lb. of fuel per flight. Trials underway with a "major international airline" will be finished by year-end. Future work includes optimizing flight plans in the horizontal direction.

Weather data for pilots is in somewhat of a unique category, as it can be sent back and forth from the aircraft using the broadband connectivity systems installed for passengers in the cabin, providing that the pilots are authorized by the FAA to connect to the network. With a larger volume of data, the cabin network is usually a lower-cost option than the "crew services" network, a more secure and generally lower bandwidth network for flight-related information.

Airlines are increasingly tapping into broadband systems in the cabin so pilots can receive real-time weather and flight planning updates through the airline itself or from third-party providers such as Honeywell and Rockwell Collins. Delta Air Lines pilots are tapping into the cabin network to link their EFBs through the Gogo connection system to run an application that graphically shows turbulence reports assembled by forecasters using downlinked ride-quality parameters from hundreds of aircraft in the fleet.

While cabin networks can passively monitor certain avionics parameters—such as aircraft position for the inflight entertainment system displays—the interactions are one-way for security and safety reasons. Crew networks, with dedicated servers, sometimes called aircraft interface devices, that require more rigorous software certification are capable of more access and are the focus of a great deal of development work, given the benefits the data can yield for EFB applications and airline operations.

Rockwell Collins is providing Airbus with a new generation of "smart" servers (or routers) that is being offered as an option for the A320 and A320neo and A330 new aircraft, with the first A320neo delivery expected in December to launch customer Azul. Located in the avionics bay, the 6-lb. EFB interface and communications device (EICU) electronics box connects to avionics data buses as well as to several discrete signals, storing flight operations quality assurance (FOQA) data from the flight data recorder in memory and providing the flight deck with access to the data using Wi-Fi connectivity. Airlines have traditionally collected FOQA data by physically retrieving the memory from the cockpit at the gate and postprocessing the data to monitor how well pilots adhere to standard operating practices.

The EICU, however, is connected to 4G cellular and Wi-Fi antennas that connect with airline operations Wi-Fi systems or hot spots at airports to download FOQA data wirelessly. Given that Wi-Fi hot spots are typically not available at most airports, particularly internationally, the 4G connection is key to retrieving the data, with satellite connections as a backup. The EICU—marketed as the SSR7000 by Rockwell Collins—has four subscriber identification module (SIM) cards that airlines can program for different cellular providers, with the router selecting the appropriate provider based on GPS position and other factors.

For the flight deck, Rockwell Collins is providing software that will allow airlines or their third-party providers to develop applications for EFBs, taking advantage of the connections to the avionics data captured by the server. The company is building a similar system as part of the "avionics gateway" for the Boeing 777X.

A competing third-party server offering for the Boeing 737NG and MAX family is Avionica's Onboard Network System, selected by FlyDubai and Eastern Air Lines. The small lightweight electronics stack includes a remote data concentrator, which reads data from the avionics buses and other inputs; a quick access recorder to capture FOQA data; a 1 TB server for storing FOQA and other information; and 4G cellular and Wi-Fi links that give an airline remote capabilities to move data on and off the aircraft. The server provides information to the EFBs and can host applications, including electronic logbooks.

The small form factor is critical for the 737, particularly when the aircraft is outfitted with a cabin broadband system. "There's really no more rack space available [in the electronics bay]," says Sean Reilly, vice president of business development for Avionica. The company also builds Iridium satcom units and is developing a lightweight Bring Your Own Device Wi-Fi-based inflight entertainment system.

To retrieve FOQA data, airlines have the option of using Avionica or another mobile service provider. Avionica has partnered with GigSky to create seamless global connectivity through the GigSky network. After landing, the network connects to GigSky's 3G/4G networks using a single SIM card and transfers the data to Avionica's ground network servers, which validates the data and distributes the results to airline customers.

Avionica has proven that the system works in remote locations: Reilly says he has successfully downloaded data from a 737 on a recent charter flight to Cuba.

**Rockwell Collins reveals the small form factor of the company's new server for the A320neo.**

JOHN CROFT/AW&ST

**Check 6** *Aviation Week editors discuss how the connected aircraft works :* **AviationWeek.com/podcast**

# Turn On Your Devices

## Satellite constellations ramp up to meet growing need for airline passenger connectivity


APSTAR

**Amy Svitak Paris**

Surging demand for airline cabin connectivity has spurred the advent of new satellite suppliers hoping to tap into the market, ranging from established geostationary Earth orbit (GEO) fleet operators to startup companies planning global internet constellations in low Earth orbit (LEO).

Inflight connectivity service provider Gogo is boosting investment in its 2Ku technology, with 10 aircraft fitted for the satellite-enabled Wi-Fi capability as of June, split among AeroMexico, Delta Air Lines and Virgin Atlantic.

Gogo President and CEO Michael Small says he now plans to equip up to 100 aircraft by the end of 2017, and ultimately at least 750 annually with the service.

In the near-term, Small says Gogo expects to sign a capacity agreement with OneWeb LLC, a startup based in Britain's Channel Islands that is among a handful of companies planning new low-circling constellations of internet satellites capable of covering the globe with bandwidth.

"These satellite constellations will have tremendous advantages in terms of latency and coverage," Small told investors earlier this year, adding that the company is not gambling on a single closed system that ties it to a few satellites.

"Instead, we are betting on an open architecture that will allow us to take advantage of whatever greater innovations Google, OneWeb, SpaceX, SES . . . and others will bring to the market," he said, referring to the slate of players, old and new, that are developing satellite-based connectivity solutions for the aeronautical and maritime markets.

OneWeb, which in June 2015 raised $500 million in equity for what is expected to be a multibillion-dollar system of more than 600 small $K_u$-band satellites in low Earth orbit, is working with Airbus Defense and Space (ADS) to build the new system. As prime contractor for the satellites under a joint venture between Airbus and OneWeb, ADS will build the majority of the spacecraft at a clean-sheet facility in Florida, though the first 10 satellites will be constructed at Airbus in Toulouse.

Using the OneWeb constellation, Gogo could potentially extend its coverage beyond what is currently provided by Intelsat's fleet of communications satellites in GEO, adding high-throughput capacity for air-traffic routes over the poles.

At the same time, Intelsat, which has invested in the OneWeb constellation, says incorporating the LEO broadband network will offer customers seamless connectivity from both low-circling satellites and geostationary spacecraft.

**Hong Kong-based Apstar, a nascent provider of aeronautical broadband, will launch its first high-throughput broadband satellite by the end of 2018.**

In Asia, satellite fleet operator APT Satellite of Hong Kong is forming a partnership with the Chinese government to develop a network of mobile broadband satellites serving aeronautical and maritime platforms. The combination, formed as part of an agreement between China Aerospace Science and Technology Corp., a major shareholder in APT, and the Shenzhen regional government in July, will launch China's first high-throughput broadband satellite by the end of 2018.

According to the terms, APT Mobile Satcom Ltd. (Apstar) will manage construction of the new satellite system, which will also feature two additional high-capacity satellites to round out the broadband network by 2020.

In the meantime, rival Panasonic Avionics, with its EXConnect service, has been using a global $K_u$-band satellite network to deliver broadband connectivity to aircraft around the world.

Panasonic recently announced a memorandum of understanding with United Arab Emirates-based Yahsat to explore new ways of offering broadband connectivity to mobile markets in the Middle East over the next 3-5 years.

In addition, the agreement allows both parties to explore the launch of a Yahsat satellite constellation that would serve Panasonic's general mobility needs in aviation, maritime and ground transportation, while giving Yahsat the ability to use Panasonic communication technologies and services.

Yahsat currently has $K_a$-band satellite capacity over the Middle East. Under the terms of the memorandum, the companies will study the frequency to be used, coverage and capacity needed to serve flight routes in the region, the type of antenna and radome, and certification requirements.

In July, Panasonic announced an increase in its commitment from China Eastern Airlines for global broadband connectivity, growing from the 20 aircraft announced last November to 84 aircraft.

The extended agreement includes 35 line-fit aircraft with an extensive retrofit program covering an additional 49 aircraft.

Panasonic has been among the most aggressive inflight-connectivity providers in terms of buying and leasing $K_u$-band satellite capacity to provide seamless coverage over major airline routes.

# Destination Driven

## Avionica builds foundation for connectivity future

**John Croft** Miami

Raul Segredo discovered at an early age three guiding principles essential to creating an aerospace business in the highly competitive connectivity niche: Put the customer first; put yourself in the customer's seat; teach your employees to fly.

Segredo, co-founder, president and CEO of Miami-based Avionica, has incorporated that wisdom into the DNA of his company, which builds ground support equipment, data recorders and connectivity systems for the global aviation industry. The 25-year-old privately held business has 60 employees servicing more than 750 customers globally and is growing at about 15% per year on revenues of about $15 million a year. Customers include United Airlines, FedEx, UPS, Delta Air Lines, FlyDubai, Emirates, Gol, China Airlines and Malaysia Airlines.

That growth is based not only on the relevance of legacy products—largely ground support equipment and recorders—but the increasing need for ubiquitous connectivity on the flight deck as a fundamental aircraft capability. The company's latest product line features both "gatelink" capabilities—connecting the cockpit to the airline at the gate to take advantage of low-cost broadband data transfer through Wi-Fi and 4G—and satellite connections, data and voice, over the Iridium constellation.

The confluence of Segredo's three principles began during his 10-year stint at Gables Engineering, a builder of avionics and controls. He began at age 14 as the kid "sweeping up the floors and tidying the labs." By the time he turned 16, he was learning to write machine code for the microcontrollers that were just starting to emerge in electronics. "I noticed there were no pilots there," says Segredo of his coworkers at the time. "[We] built controller panels for cockpits, and none of us knew what they were for."

Segredo decided to put himself in the customer's seat, figuratively, earning his private pilot's license and becoming "very passionate" about flying. "I have an ethic of hiring people that are aviators as well, because pilots are destination-oriented people," he says of Avionica. Along with subsidizing flight training for employees, the company has on occasion had its own flying club and company aircraft, including a PZL Koliber, a license-built version of the Socata Rallye on which Segredo says about 20 employees learned to fly. While there is currently no company flying club or aircraft, Segredo, who now flies the company's Cessna Citation 501SP business jet, says he recently brought in an instructor to hold a ground school "to get people back into it."

He and a fellow graduate of the University of Miami, Stylian Cocalides (now retired), started Avionica in 1992 based on a common-sense idea to help airlines with the required annual readouts of digital flight data recorders (FDR). Carriers either ship the actual recorder to a readout facility or download and send the data. At Avionica, technicians verify that the recorded data meet certain performance thresholds, investigate any exceedances and, for legacy tape-based machines, make sure that certain commands (speed up, slow down) operate correctly. United Airlines, one of the company's largest readout clients, downloads its recorders and sends the data to Avionica.

When Segredo first looked at the issue, airlines were using disparate tools to read out recorders made by different companies. "What if we took the download software and put it into a regular laptop and changed the cables?" he wondered. "That's the genesis of our ground support line. We take a generic laptop, plug in the right cable and run the software that will operate any of these FDRs."

That simple concept introduced in 1993—applying ingenuity and technology to make life better for the customer—served Segredo well as word-of-mouth led to a building-block approach to other opportunities that ultimately expanded the company's product lines into quick access recorders (QAR) and connectivity equipment.

The company's start in the QAR


**Eastern Air Lines is equipping its Boeing 737s with an Avionica flight deck network system that includes a server, Wi-Fi and 4G wireless gate connection.**

JOHN CROFT/AW&ST

business came the late 1990s when Delta Air Lines—which used Avionica for FDR readouts—asked for help with a problem. The industry was in the early stages of a seismic shift in safety culture, moving from forensics (wait for an accident then fix what caused it) to predictive safety, where airlines and the FAA would analyze flight data to root out trends pointing to a potential accident.

Delta needed an easy way to read out the flight performance data, called Flight Operations Quality Assurance (FOQA) data, from the aircraft's digital flight data acquisition unit, the device that taps into the various data buses and sends information to the FDR box.

"We had been kicking around this concept of a tiny data recorder that would plug into the provisions Boeing already had in the aircraft, just to test the system and see if it would work," says Segredo. He notes that engineers

**Avionica President/CEO Raul Segredo at the controls of his Cessna Citation 501SP business jet.**

AVIONICA

came up with a variety of prototypes that were round, square or oblong. For the Boeing 737, the device would plug into a connector at the back of the forward closet.

After meetings with the FAA at the aircraft certification office in Atlanta, Segredo was given the green light to treat the device as a thumb drive (not requiring certification) and was allowed to try it on a small number of Delta aircraft for a few months. With the miniature QAR, Delta could download the FOQA data using a laptop plugged into the mini QAR. The test went well, and the FAA allowed Delta to equip its entire 737 fleet with Avionica's QAR using a "field approval" rather than a formal supplemental type certificate (STC), a move Segredo says spared the company from having to generate a 3-ft.-tall stack of approval documentation.

He says Delta flew the first-generation recorders for three years and 600,000 flight hours with only one failure before upgrading to the second-generation version, for which Avionica in 2002 gained an STC (that now covers almost 250 aircraft types in an "approved model list") and put all the necessary quality controls in place for a production facility. "We have never looked back in the 17 intervening years," says Segredo. To date, the company has sold about 8,000 mini QARs.

The second-generation mini QAR came about because FedEx wanted more capacity but the same download time, a request that led to a USB port and an Ethernet connection. FedEx later asked for changes that would result in the third-generation mini QAR in 2009, initially with Wi-Fi connectivity and later with 3G and 4G wireless connections over cellular links. Along the way, Avionica built a military version of the mini QAR, which was used for a time by the U.S. Navy to record flight parameters for post-flight playback on Boeing F/A-18 fighter jets based at Patuxent River and Miramar NAS, in Maryland and California, respectively.

While the QAR was evolving, airlines in the mid-2000s were also interested in increasing the usefulness of electronic flight bags (EFB), which were largely being used to hold electronic documents. Miami Air International, a charter operator based in Miami, called on Avionica to connect its EFBs to the external world via satellite, in large part to update charts from anywhere in the world. The resulting "Satlink" product, which connected the aircraft via the Iridium satellite network, took the next step in evolution when Continental Airlines needed communications help for its fleet of 737s in Micronesia.

Because of issues with the legacy communications system—HF—pilots would sometimes have no voice contact to tell controllers in California that they needed to divert around weather. The solution was to use Avionica's system for voice calls over Iridium. In 2013, Avionica came out with its next-generation Iridium satcom (called Satlink Max), which included approval for FANS 1/A capability, meaning aircraft could use the datalink and voice for "safety services" and qualify for lower separation minimums over the ocean. United was the first customer, equipping a Boeing 777. Anthony Rios, Avionica's vice president of sales, says the company has 850 "classic" satcom systems in service and has sold about 200 Satlink Max systems.

A request by Gulfstream during development of the G650 around 2008 set the path for further evolution of the mini QAR. Rios says the airframer had heard about Avionica's ability to connect EFBs to aircraft data via Ethernet and wanted to see if the same configuration could be used to sample data from a group of hydraulic filters that otherwise would require a bundle of wires running to the health-monitoring system at the front of the aircraft. "Three months later, we went to Gulfstream to demonstrate the mini QAR on steroids," says Rios. The beefed-up QAR, with additional inputs, memory and capability, was officially named the remote data concentrator and became a standard component on the G650.

The culmination of recorder and connectivity evolution is housed in Avionica's Onboard Network Server architecture (AviONS). The smal-footprint electronics package includes a remote data concentrator topped with the Wi-Fi and 4G units and an Ethernet connection to the Satlink Max electronics box in the crown of the aircraft, near the L-band antennas.

While Avionica has come far, it does face challenges,; the latest of which is an ongoing lawsuit with Teledyne Controls. According to court documents, the suit revolves around claims that Avionica's connectivity systems infringe on a 2001 patent by Teledyne for "wireless transmission of aircraft performance data, from an aircraft to the ground once an aircraft has landed." Teledyne builds Ground Link, a competing system. Avionica denies the allegations and has asked for a jury trial. Absent a settlement, which could possibly involve Avionica paying a license fee to Teledyne for AviONS, the two will face off in court starting in May 2017.

As with any turbulence, Segredo navigates like a pilot, always keeping his sights on the destination. "I'm an engineer with no formal business training," he says. "I need to cling to pretty simple tenets: If I take care of the customer, the customer will take care of me. Going on 25 years, that theory has always proven out."

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**Oct. 18-20**—MRO Europe. Amsterdam.

**Oct. 26**—Aviation Week Program Excellence Symposium and Awards Banquet. Scottsdale, Arizona.

**Oct. 26-27**—Airline Engineering & Maintenance: North America. Charlotte, North Carolina.

**Oct. 27-28**—2nd Annual AerospaceDefenseChain Conference. Scottsdale, Arizona.

**Nov. 9-10**—Airline Engineering & Maintenance: Central, Eastern and Southern Europe. Zagreb, Croatia.

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**Oct. 1-Dec. 3**—AOPA Flight Instructor Refresher Course. Various Locations. See aopa.org/forms/event-calendar/FIRC_ONSITE

**Oct. 4-5**—U.S. Air Cargo Industry Affairs Summit. Capital Hilton. Washington. See iata.org/events/Pages/usacia-2016.aspx

**Oct. 4-6**—Royal Aeronautical Society 5th Aircraft Structural Design Conference. Manchester Conference Center. Manchester, England. See aerosociety.com/Events/Event-List/1980/5th-Aircraft-Structural-Design-Conference

**Oct. 4-6**—SAE 2016 Aerospace Manufacturing and Automated Fastening Conference & Exhibition. Messe Bremen. Bremen, Germany. See sae.org/events/amaf/

**Oct. 12-13**—12th Annual International Symposium for Personal and Commercial Spaceflight. New Mexico Farm & Ranch Heritage Museum. Las Cruces, New Mexico. See ispcs.com/

**Oct. 17-18**—Royal Aeronautical Society Delivering Sustainable Growth in Aviation. Royal Aeronautical Society. London. See aerosociety.com/Events/Event-List/2005/Delivering-Sustainable-Growth-in-Aviation

**Oct. 17-20**—$K_a$ and Broadband Communications Conference/AIAA International Communications Satellite Systems Conference. Marriott Renaissance Hotel. Cleveland. See kaconf.org/index.php

**Oct. 18-21**—6th EASN International Conference on Innovation in European Aeronautics Research. Crowne Plaza Porto Hotel. Porto, Portugal. See easnconference.eu/

**Oct. 25-27**—Wernher von Braun Memorial Symposium. University of Alabama in Huntsville. Huntsville, Alabama. See astronautical.org/events/vonbraun/

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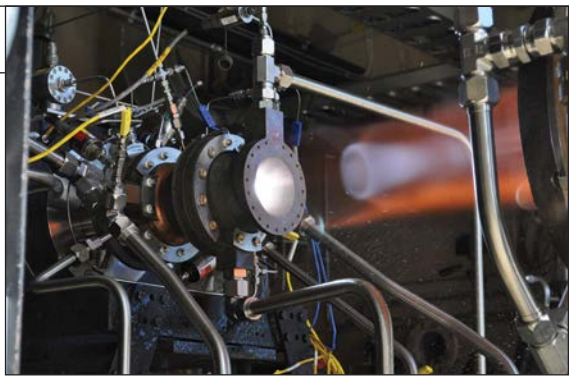
# Positioning for Digital Disruption



AEROJET ROCKETDYNE

BY MICHAEL GOLDBERG AND DAN SCHWARTZ

When it comes to technical innovation, few industries can match the achievements of aerospace and defense (A&D). But, ironically, many A&D companies are not on the cutting edge of using digital technology to create business models and transform their operations. When A&D executives look at digital opportunities, too many still use the traditional technology lens for developing or improving products without sufficiently evaluating the related business model impacts.

The effects of digital disruption are prevalent across industries. The confluence of connectivity, big data and leaps in computing and software capabilities are disrupting old business models and enabling digital-savvy startups and other competitors to push into new markets. In industrial goods, which include those produced by A&D, startups raised $40 billion in venture capital to build new businesses in 2015. Leading-edge incumbents also are using digital innovation to fundamentally change their offerings. John Deere, for example, is shifting from selling farm equipment to providing data-enabled "agricultural solutions" (which include smart tractors). Some A&D incumbents are getting into the game, too. Aerojet Rocketdyne used 3-D printing to reduce the parts in a core injector to two from 100, reducing time to market to eight weeks from a year. Pratt & Whitney and its tech partners analyzed the "exhaust" data from engine sensors to develop a more profitable power-by-the-hour program.

> "Too many executives still use the traditional technology lens for developing products."

With digitization marching through sector after sector, incumbents will continue to disrupt or be disrupted, and A&D, despite its long lead times and product cycles, will not be an exception.

A good first step for A&D leadership teams is to build a "digital road map" for their companies. While the breadth of technical innovations to consider on the road map can be quite broad, the business model questions quickly become paramount. For example:

■ If the customer is no longer buying hardware (such as a satellite) and is now buying an outcome (say, ubiquitous communications), then how does that change the way we develop and price our products?

■ If the money invested in autonomy is 1,000 times greater outside the company than within, how should we develop better partnering capabilities?

■ If we can predict product performance, access maintenance data from anywhere and 3-D-print spares on site, how should we retrain and redeploy employees?

■ If we use better analytics to optimize supply chain flows and provide a more stable demand forecast, can we translate this knowledge into greater investment and risk-sharing by suppliers?

After defining and prioritizing these business model needs, how do we implement the required changes? For example, how do we develop or access the talent and create the IT infrastructure to execute? What do we have to change in our management approaches and go-to-market processes? The difference between success and failure in digitization often comes down to how well a company can adapt its model. The best performers get at least four things right:

■ They embed digitization in their strategies versus developing a digitization strategy. Digitization should inform and enable execution of a core business strategy. Successful digitization strategies focus on helping companies better serve the needs of core customers and increase differentiation in their offerings.

■ They allocate meaningful R&D time and energy outside the company. Successful companies look beyond traditional organizational boundaries for ideas, innovations and funding. A broader lens helps combat resistance to ideas that would disrupt legacy businesses.

■ They build capabilities in partnering. The most successful companies will repeatedly source and screen potential partners in nontraditional places. They will build partnerships that rest on a strong deal thesis, have clearly defined partner contributions as well as clear governance mechanisms and exit options.

■ They recruit digital thinkers and create a culture of risk acceptance. New talent is required to compete in a digitized world. Top innovators will attract and hire new talent in part by creating a more open, collaborative and risk-taking culture.

Digitization does not represent a wholesale change in every industry and is not required in every operation or product. But where disruption's risk and opportunity are real, management cannot afford to ignore the power of digitization or simply to apply new technologies using today's business model. Being prepared and willing to evolve models to capitalize on innovation will place companies on the right side of digital disruption.

*Michael Goldberg, a Bain & Co. partner in Los Angeles, leads its global A&D practice. Dan Schwartz is a Bain partner in Washington and a member of its A&D practice.*

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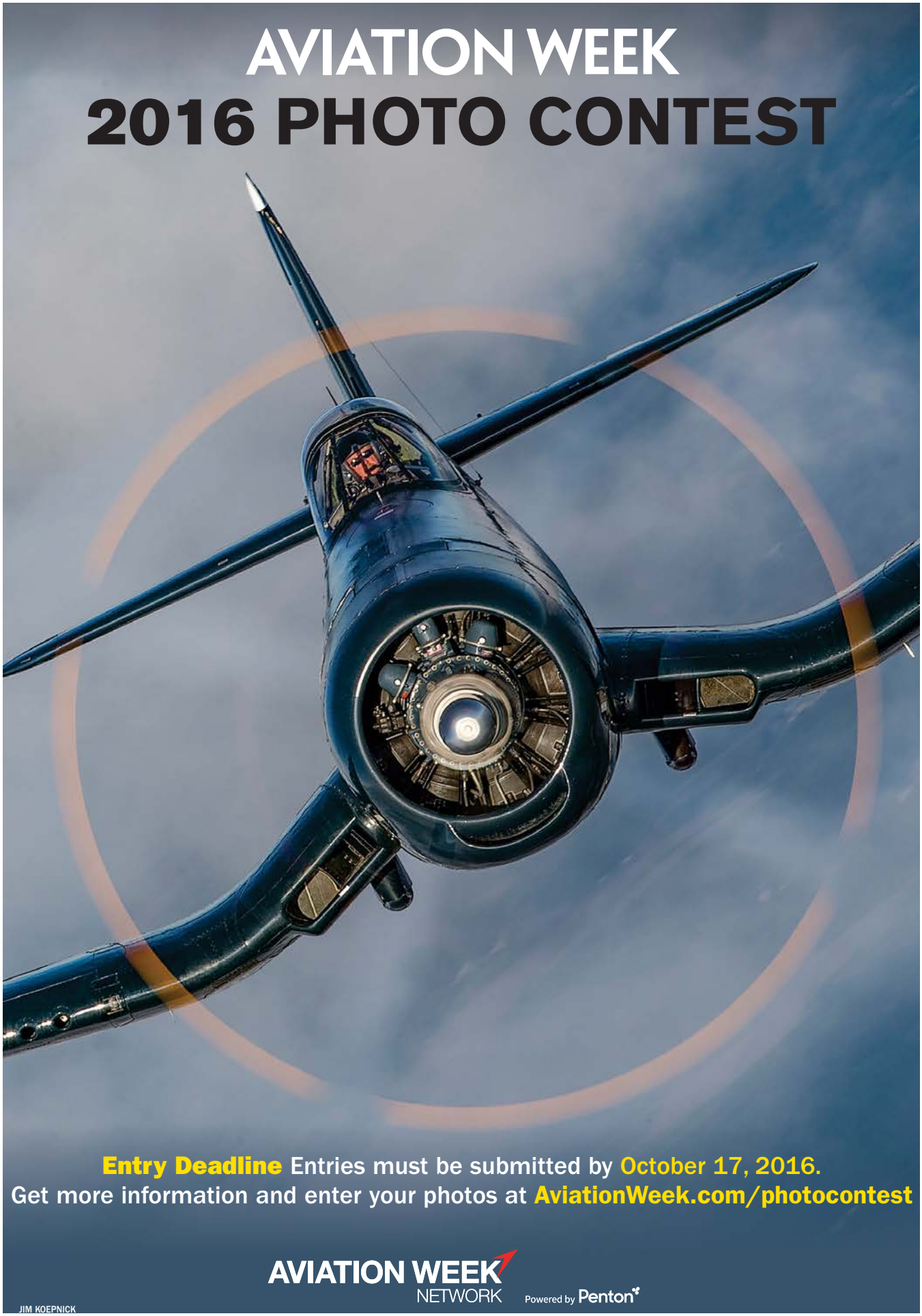

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