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PAGE MRO 4

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PAGE 30

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AVIATIONWEEK & SPACE TECHNOLOGY

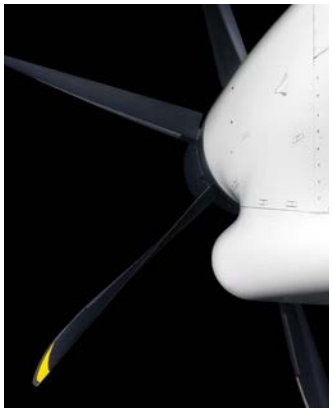
Digital Extras Tap this icon in articles in the digital edition of *AW&ST* for exclusive features.

51 *Virgin Galactic has reverted to an improved form of the original rubber-based fuel for powering its suborbital SpaceShipTwo (SS2), the second version of which is nearing completion in Mojave, California. Glide and powered test flights of SS2 are expected to resume in 2016.*

ON THE COVERS

This week, Aviation Week publishes two print editions. On the cover far left is a 2008 image of Earth captured by the U.S. Air Force's first Space-Based Infrared System (Sbirs) scanner in a highly elliptical orbit (see page 64). The missile-warning satellite image, which was degraded for national security purposes, was declassified and released exclusively to Aviation Week along with another on page 15. Also in both editions are reports on Canada and the Joint Strike Fighter (page 21) and the European Commission's inquiry into competition in the maintenance, repair and overhaul sector. On the cover of our MRO Edition, the core of a PW100G geared turbofan engine is guided toward mating with the fan case in its structural guide vanes. Pratt & Whitney photo. Aviation Week publishes a digital edition every week. Read it at **AviationWeek.com/awst** *and on our app.*

C Series



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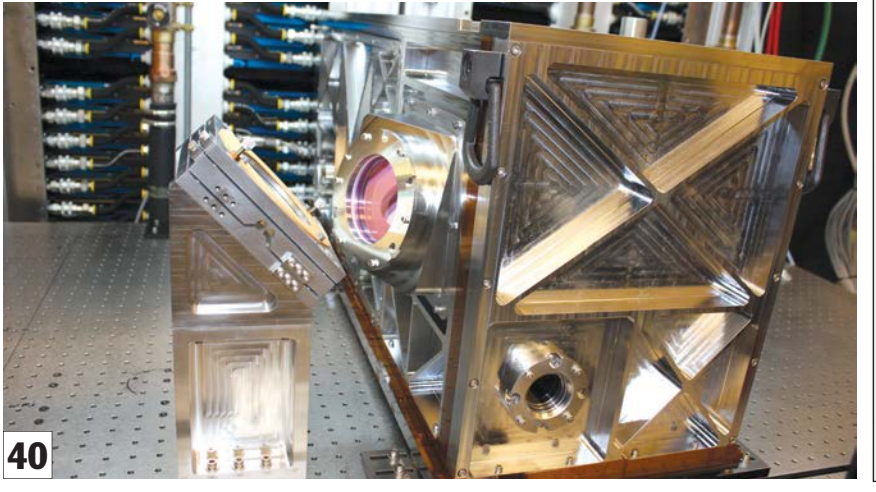
BOMBARDIER
the evolution of mobility

24



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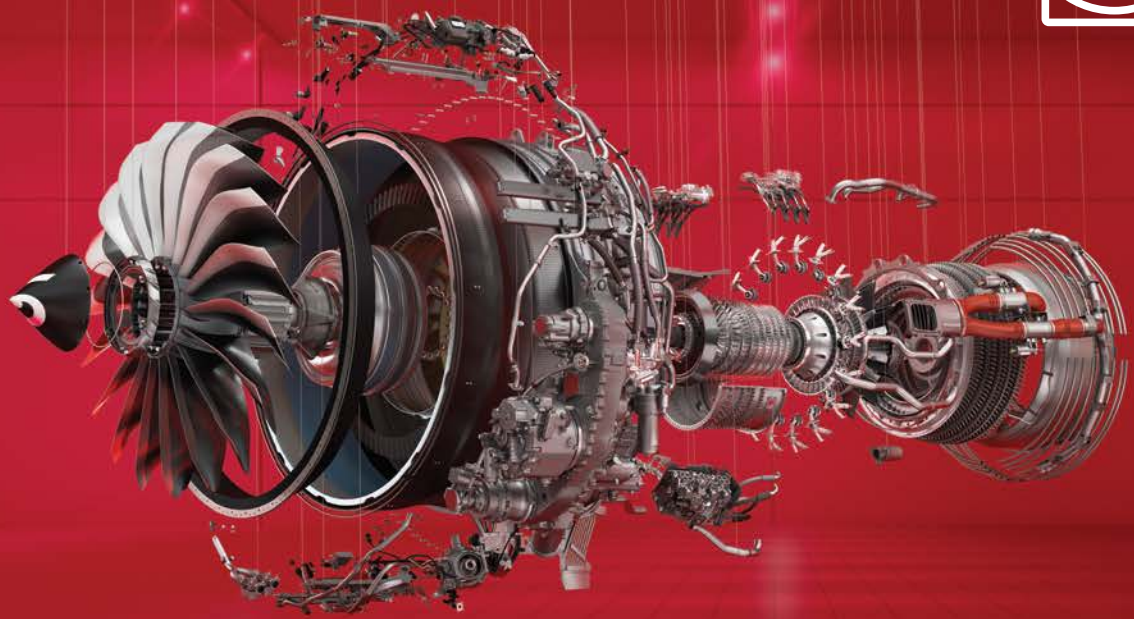

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Feedback

Aviation Week & Space Technology *welcomes the opinions of its readers on issues raised in the magazine. 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 should be shorter than 200 words, and you must give a genuine identification, address and daytime telephone number. We will not print anonymous letters, but names will be withheld. We reserve the right to edit letters.

CAUSE/EFFECT DISCONNECT

I read with some amusement Air New Zealand Chief Pilot David Morgan's statement in "Change Management" that "aircraft last too long (20-25 years) . . . because of the huge investment" (*AW&ST* Oct. 12-25, p. 31).

But it is precisely because of this "huge investment" that it takes a long time to realize a reasonable return on investment. Manufacturing an aircraft, its engines and all its equipment requires a lot of energy and inevitably contributes to pollution.

Barring radical changes to planform and engines, we have advanced aerodynamics and high-bypass powerplants to their limit. The low-hanging fruit is gone, and we should expect smaller future airframe/engine improvements in efficiency and emissions.

It would make more sense to design new airframes with the expectation that their engines, avionics and systems will all be replaced with better components at least once during an airframe's useful life.

Designing for shorter airframe life means wasting the best characteristics of composites and modern alloys.
Fred Bearden
LAGUNA NIGUEL, CALIFORNIA

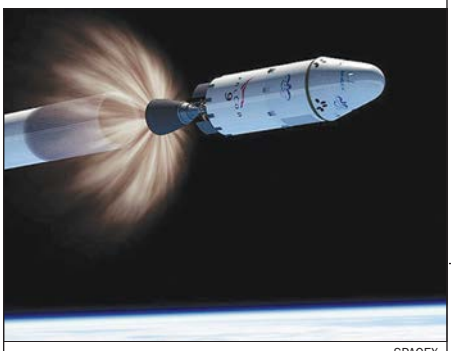
PRICELESS FREEDOMS

In "TMI?" reader Brad Stanton complains about the privilege we have in the U.S. of an open and unfettered press (*AW&ST* Oct. 12-25, p. 13) that countless historians and smart politicians tout as the last and best resort against totalitarianism.

Is North Korea more to his liking?
Bob Kambic
BALTIMORE, MARYLAND

MODAL SURVEY URGED

As stated in "Hard Lesson" (*AW&ST* Aug. 3-16, p. 34) according to the first report, a failed strut in the second



SPACEX

oxygen tank is the likely cause of the failure of the Falcon 9 launch last June.

The strut would have failed at 2,000-lb. force when it was certified to hold 10,000 lb. Although this is a possible explanation, I find it hard to believe that certified suppliers would deliver aerospace material that failed at a load five times lower than expected. It seems more likely that dynamic loads are the main cause of the failure.

I do not know if SpaceX performed modal survey and dynamic tests of launcher stages; if they did, how representative were the tests of the real flight hardware? The main objectives of such tests are to be able to correlate the mathematical models. Modal survey tests are costly, but they can lead to a better understanding of the mechanical dynamic behavior of launcher stages and related major equipment.

If such tests were skipped during development of the Falcon launchers, I strongly recommend performing them; it is never too late.
Bernard Guillaume
OEGSTGEEST, THE NETHERLANDS

CHECK, CHECK AND CHECK AGAIN

On Oct. 20, 1935, a prototype of the B-17 Flying Fortress, the X-13372, crashed during takeoff at Wright Field Ohio, during a test flight. The aircraft pitched up and stalled after becoming airborne; all onboard died. The cause was the failure of the pilot and/or copilot to release the spring-locking device, which locked the rudder and elevators. Because of the large tail, Boeing installed the device to prevent the rudder and elevators from being damaged by high winds while parked on the ground, a Boeing first.

As a result of this tragic accident, the written checklist was born. Used properly, it saves lives.

And now we read in "Reality Check" (*AW&ST* Sept. 28-Oct. 11, p. 62) that failure to carry out these specific items on a pilot's checklist were at least in part responsible for the crash of a Gulfstream IV in May 2014.
David Delisio
WALKERSVILLE, MARYLAND

BOOK IT

I was pleased to see that Frank Morring, Jr., reviewed two recently published books about the Space Race (*AW&ST* Aug. 17-30, p. 18).

Valuable histories of our industry tend to be ignored by the mainstream media, so I hope you will feature book reviews on a regular basis.
Aaron Robinson
CHICAGO, ILLINOIS

WONDERING ABOUT WINGTIPS

I would like to know why the U.S. Air Force and Navy chose not to have their Boeing KC-46As and P-8s equipped with wingtip devices.
Val S. Mazzucca
WOOD-RIDGE, NEW JERSEY

Who's Where

Gloria Flach

Philippe Gassin

Bonnie Cook

Adeline Terrier

Mark Kirasich

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.*

Northrop Grumman Corp. is reducing its business sectors from four to three as of Jan. 1, 2016: **Gloria Flach** (see photo) has been appointed chief operations officer; she has been corporate vice president/president-electronic systems. **Kathy Warden** becomes vice president/president-Mission Systems, which will incorporate electronic attack; she has been vice president/president-information systems. **Chris Jones** will lead the Technology Services sector; he has been vice president/president-technical services. **Tom Vice** continues to lead the Aerospace Systems sector, which will include the company's Azusa, California, military and civil space hardware business. **Dan Cloyd** has been named corporate director for naval aviation and intelligence, surveillance and reconnaissance (ISR) programs. He reports to **Timothy C. Jones,** vice president-aviation and ISR.

Mitch Snyder has been named president and CEO of *Bell Helicopter,* succeeding **John Garrison**, who is joining *Terex Corp.* as its new president and CEO. Snyder was executive vice president of Bell's military business.

Ontic, a subsidiary of London-based *BBA Aviation* and a provider of aftermarket support, has appointed **Bob Hopkins** head of global sales.

Raytheon Co. has named **Mark Nicol** president of *Raytheon International Inc.,* responsible for customer engagement and business development. Nicol had served as a program director for Standard Missiles I and II.

Nexcelle, integrated-propulsion manufacturing joint venture of *GE Aviation* and the *Safran* group, has named **Philippe Gassin** (see photos) director of operations; **Bonnie Cook** chief financial officer; and **Adeline Terrier** contracts director.

NASA has appointed **John Honeycutt** manager for the Space Launch System (SLS) Program, and **Mark Kirasich** (see photo) manager of the Orion Program, to send astronauts to deep-space destinations including Mars. Honeycutt has been deputy manager of SLS since November 2013. He succeeds **Todd May**, who in August was named deputy director of Marshall Space Flight Center in Huntsville, Alabama.

Duncan Aviation, Lincoln, Nebraska, has appointed **Doug Alleman** vice president-customer service, and **Mike Minchow** vice president-sales, for the company's Lincoln; Battle Creek, Michigan; and Provo, Utah, facilities.

Andy Parrish has been named manager of *FlightSafety International*'s Learning Center in San Antonio. Also, **Edward Koharik** has joined the company as executive director, Visual Systems.

U.K. air traffic control provider *NATS* has appointed **Martin Rolfe** as its new chief executive officer.

Hoyle, Tanner & Associates Inc. of Manchester, New Hampshire, has named **Charlotte A.C. Bouvier** as senior structural engineer and project manager in the company's Structural Building Group.

Gilles Gateau will join *Air France* as executive vice president-human resources and labor relations. He has been deputy chief of staff and social adviser to France's prime minister. He succeeds **Xavier Broseta**.

Erickson Inc., based in Portland, Oregon, has hired **Trey Williams** as senior director of sales for government services, U.S. and international; **Will Fulton** as senior director of sales, commercial aviation services; **Tony Lustig** as senior director of sales, Asia-Pacific; and **Scott Ellis** as senior director of sales, MRO and manufacturing.

Inmarsat has appointed **Mario Franci** vice president-inflight services. He has been Inmarsat's vice president-European aviation communications.

HONORS & ELECTIONS

The National Space Biomedical Research Institute has awarded fellowships to nine young scientists who will conduct one-year research projects into protection of astronaut health during long-duration spaceflight. The 2015 fellows are: **Austin B. Bigley,** University of Houston; **David Chesny**, Florida Institute of Technology; **Walter E. Cromer**, Texas A&M University; **Birendra Mishra**, University of California-Irvine; **Marissa J. Rosenberg,** *NASA Johnson Space Center*; **Saurabh S. Thosar**, Oregon Health & Science University; **Gunes Uzer**, University of North Carolina-Chapel Hill; **Linnea R. Vose**, New York Medical College; **Lei Wu**, University of Houston.

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First Take

LOCKHEED MARTIN/RANDY CRITES

DEFENSE

Lockheed Martin flew the upgraded F-16V, equipped with Northrop Grumman's APG-63 active, electronically scanned array radar, for the first time Oct. 21. The -V configuration is being developed to upgrade Taiwan's -A/-Bs and F-16s operated by other nations.

After a surprise victory over the ruling Conservatives in Canada's Oct. 19 federal election, the Liberal Party is expected to act on its campaign promise to end the country's partnership in the Lockheed Martin F-35 program and launch a competition to replace its 65 Boeing F/A-18A/Bs (page 21).

Lockheed Martin has won a $784 million U.S. Missile Defense Agency contract to develop and operate the S-band active-array Long-Range Discrimination Radar—to be operational at Clear AFB, Alaska, by 2020—to increase interceptor capacity and address potential countermeasures.

Finland's defense ministry been given the green light to launch the HX program to replace its Boeing F/A-18C/D fighters. A request for information is expected in early 2016, tenders in early 2019 and a contract in early 2021. Initial operating capability could be declared in 2025-26 and full capability in 2029-31.

In an almost $25-million deal, India has ordered 194 Virus SW80 ultralight aircraft from Slovenia's Pipistrel Aircraft to train cadets for the air force and navy. The aircraft will be delivered over the span of 30 months to more than 100 locations in India; another 100 may be ordered after three years.

COMMERCIAL AVIATION

Irish regional carrier CityJet says it has mitigated the risk of an export ban on Russia's Sukhoi Superjet 100 by concluding a leasing deal instead of an outright purchase. The airline has signed a letter of intent for 15 firm orders and 10 options for SSJ100s, which would make it the European launch customer for the aircraft.

Airbus has launched the ultra-long-range A350-900ULR, and Singapore Airlines is changing part of its order for 63 A350-900s to take seven of the ULR versions for delivery in 2018, enabling it resume nonstop flights to the U.S. The airline is also converting four of 20 purchase rights into firm orders for the regular -900 (page 43).

United Airlines' parent company named Brett Hart, its executive vice president and general counsel, as acting CEO after Oscar Munoz had a heart attack on Oct. 15. Long-time board member Munoz stepped in as CEO on Sept. 8 when United forced Jeff Smisek to step down.

Concluding Malaysian Airlines Flight 17 was shot down by a Russian-produced Buk surface-to-air missile system in 2014, killing all 298 passengers and crew on the Boeing 777, Dutch-led investigators say it will require further forensic work to confirm it was fired from rebel-held territory. Buk manufacturer Almaz-Antey claims the missile was fired from Ukrainian-held territory (page 62).

Turkey's TRJet is working with original Dornier 328 suppliers to reactivate the supply chain for TRJ328 production. Pratt & Whitney Canada has signed a memorandum of understanding for upgraded PW306B engines. Parent company Sierra Nevada Corp. plans to restart the 328 program in Turkey based on a preliminary commitment from the Ankara government for 50 aircraft.

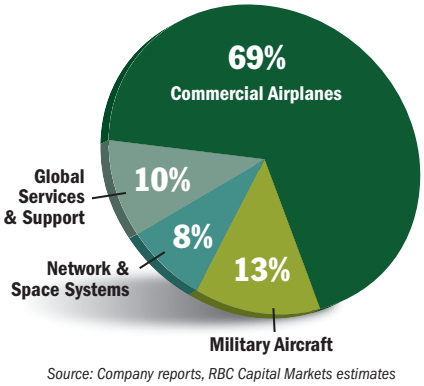
China's Avic has built a 10-stage high-pressure compressor test article in support of developing the CJ-1000 indigenous engine for the Comac C919 158-seat airliner. Creation of an independent Chinese aero-engine manufacturer from Avic's three engine businesses looks close, meanwhile.

UNMANNED AIRCRAFT

The U.S. Transportation Department hopes to finalize by mid-December an expected emergency rule requiring existing and future owners to register their recreational unmanned aircraft with the FAA. A government-industry task force will provide recommendations for procedures and policies for a national registration database by Nov. 20 (page 27).

A Thales Watchkeeper became the first unmanned aircraft to operate in U.K. non-segregated airspace, spending 1 hr. over Wales on Sept. 30 in controlled airspace monitored by NATS Swanwick London area control center. The UAV mixed with other traffic at Flight Level 150 under Project Claire, funded by the Single Euro-

Boeing's Revenue Mix in 2015



Source: Company reports, RBC Capital Markets estimates

Commercial airplanes are expected to account for nearly 70% of Boeing's sales this year, up from just 42% in 2004.

pean Sky Joint Undertaking.

Lockheed Martin and Kaman have flown the unmanned K-Max helicopter in wildland firefighting scenarios, conducting cargo drops, single-target water drops and progressive line building with a bucket at a demonstration in Idaho for the U.S. Interior Department and Forest Service.

LOCKHEED MARTIN

SPACE

SpaceX says the return-to-flight mission of its Falcon 9 launch vehicle, after the failure in June, will lift 11 second-generation machine-to-machine communications satellites to low Earth orbit for Orbcomm, rather than the previously planned SES-9 satellite to geostationary orbit (page 31).

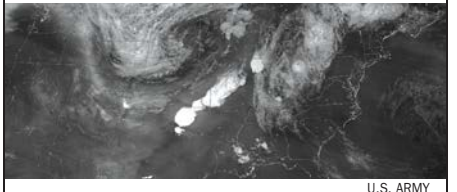
Israel Aerospace Industries is in advanced development of a small communications satellite platform, AMOS-E, using electric propulsion to reach geostationary orbit. At 1,500-2,000 kg (4,400 lb.), and with up to 5 kW of power, AMOS-E will be about half the weight of conventional communications satellites.

ISRAEL AEROSPACE INDUSTRIES

NASA planners are weighing a robotic Mars-landing mission as early as 2026 to test critical technologies in preparation for a human landing at least a decade later. The "robotic pathfinder" mission would fly on a heavy-lift Space Launch System in the planetary windows in 2026 or 2028.

Following a second launch of the Tiangong human-tended laboratory in 2016, China's human-spaceflight organization plans to launch the first element of its three-module space station in 2018, with completion of assembly set for 2020 and full operational capability with rotating three-person crews two years later (page 32).

At the request of Aviation Week, the U.S. Air Force declassified two degraded images from its Space-Based Infrared System (Sbirs), the satellites that warn of missile launches and increasingly are being used for other applications (page 64). One image is on the cover (details on page 4). Here, an infrared image from Sbirs' GEO-2 satellite shows thunderstorms over the central U.S. in May 2013.



U.S. ARMY

QUOTED

STARBURST

"Every industry has been penetrated by disruptive technology —except the aerospace industry."

—VANDAD ESPAHBODI,
co-founder of **Starburst**, *a startup "accelerator" that is focusing on innovators in Europe, the U.S. and Asia-Pacific*

43 YEARS AGO IN *AW&ST*

Airbus was a mere two-year-old fledgling in 1972, but it posed enough of a threat to Boeing that the Seattle company took out a two-page advertisement in *Aviation Week & Space Technology* to challenge the upstart European airframer and tout its Boeing 727-200, which had entered service five years earlier. Titled "Two for one sale," the ad noted that "two 727-200s cost less than one airbus"—leaving the initial letter in Airbus's name in lower case. It goes on to note the appeal of the "Advanced 727-200 'superjet' interior with its overhead storage and crisp, modern look." Production of the 727 would continue for another 12 years and reach 1,832 before finally ending in 1984.

As Aviation Week approaches its 100th birthday in 2016, read about momentous events in its history at: **AviationWeek.com/100**

BOMBARDIER

COMMENTARY

Survival Strategies

How Bombardier could remain solvent

By Kevin Michaels

Kevin Michaels is a vice president with ICF International's Aerospace & MRO consulting practice in Ann Arbor, Michigan.

In early October, Bombardier rocked the industry with the news that Airbus had walked away from the opportunity to take a controlling interest in the C Series. Offering control of its most important aircraft to a fierce rival smacked of desperation.

In my February column (*AW&ST* Feb. 16-March 1, p. 14), I proposed a three-part strategy to save Bombardier's aerospace business: 1) sell the commercial aircraft business or create a joint venture of it, 2) sell the aerostructures business and 3) double-down on business aircraft. The stunning Airbus news may be a sign that, at least for now, Bombardier has run out of options for the first part of this strategy. The Canadian manufacturer's key issue now is liquidity. Some $2-3 billion (U.S.) might be needed to certify and cover the expected C Series losses over the next several years, and an additional $1 billion or more could be required to develop and certify the Global 7000/8000 programs. With a dire financial outlook, rapidly depleting working capital and a weak balance sheet, Bombardier's ability to raise this kind of cash from capital markets is dubious.

This leaves three major alternatives for the world's third-largest civil aircraft manufacturer to survive: sell assets, shut down the C Series or accept government intervention.

The first option is to sell assets. The most obvious one is its $10 billion transportation business. Bombardier previously tried and failed to sell a minority stake of this division. Instead, it could sell the entire business and become a pure aerospace company. This might raise more than $5 billion that could see the manufacturer through the difficult period ahead and help it pay down debt. This would also address the market's perception that Bombardier's very survival is at risk.

What about another asset—the aerostructures business? This makes sense strategically, but the value of this unit is tied to the C Series, and it won't bring in enough capital to fund the company's war chest. Better to sell it after the C Series program is stabilized. Finally, there might still be a buyer for the commercial aircraft business—perhaps Comac or another deep-pocketed Asian aerospace OEM such as Mitsubishi or Avic. This could bring not only capital but also much-needed customers.

Bombardier's second option is to stop the bleeding and shut down the C Series. This will not be cheap, as Bombardier would need to pay back suppliers for development costs, adding up to $1 billion or more. It would face customer ire, penalties and severely damaged credibility. And the move would deal an emotional blow to Canada in the wake of other high-technology failures.

Finally, there is a third option: government intervention. The interesting twist here is that that support may be tied to the outcome of the Oct. 19 Canadian federal election, in which Justin Trudeau's Liberal Party won a smashing victory and a majority government. Will he feel compelled to pay back his supporters in Ontario (where the Global 7000 will be built) and Quebec, home of the C Series? At the provincial level, Quebec has indicated its willingness to support Bombardier. This would likely come via the Caisse de Depot et Placement du Quebec, a huge institutional fund manager with more than $240 billion in assets. An equity injection might qualify as an illegal subsidy with the World Trade Organization. But that is an issue for the future.

Finding a buyer for the commercial aircraft division remains the best option for Bombardier because it could bring capital, critical mass and customers. Alternatively, the sale of Bombardier Transportation or government intervention would remove the risk of company failure, enabling it to pursue new orders aggressively, such as the potential order for 100 jets that United Airlines recently dangled to Bombardier and Embraer.

These alternatives also might drive a restructuring of Bombardier's convoluted shareholder composition, which gives two families effective control of the company. Recent analysis by Credit Suisse indicates that Bombardier could reach breakeven in five years through a $2 billion injection into the C Series, even with modest unit sales of 60 aircraft per year. If Bombardier can execute against these projections, it will be in a much stronger position to sell or create a joint venture of the commercial aircraft business down the line.

Eventually, Bombardier must restructure to address the reality that it competes in too many markets. Right now, survival is the order of the day.

By Michael Bruno

Senior Business Editor
Michael Bruno blogs at:
AviationWeek.com/ares
michael.bruno@aviationweek.com

COMMENTARY

Dominant Subs

Pentagon subcontractors are beating the primes on profit margins

Major aerospace and defense subcontractors take note: More pressure from the Pentagon and prime contractors could be coming, starting with profit margins.

A new report from the data-oriented acquisition office at the U.S. Defense Department shows top-tier subcontractor profits continue to significantly outpace those of primes on both developmental and production contracts. While none of the companies is identified, the data reveal a clear trend across the top primes and their major suppliers.

The latest results come from the third-annual Performance of the Defense Acquisition System report released Oct. 6. For the U.S. government's largest spender, it also suggests a renewed target for supply chain cost-cutting. To that end, defense acquisition czar Frank Kendall says he is talking with several primes to make them more aware of their gap with subcontractors' margins. "Ultimately, it is the primes' responsibility to work with the subcontractors and to make sure they get good business deals," he adds.

Pentagon officials have decried claims by industry boosters that there is a "war on profit," saying companies are free to make whatever profit they can as long as taxpayers keep getting ever better deals. But they readily acknowledge using the Defense Department's massive buying power to gain a bigger "bang for the buck" as well as improved industry performance.

Based on their public reading of the report's findings, officials see room for improvement in the supply chain. The report finds that since 2001, first-tier subs have earned higher margins than their associated primes on the same program across the board. At the medians, the difference is about 2% higher in development programs and about 7% in production. Individual, albeit unidentified, examples also are illustrated (see chart).

Defense officials are trying to figure out why. Whether most prime contractors just do not sufficiently control subcontractor costs or simply lack enough information to negotiate better prices is not yet known. Also, it could be that there is less investment or work required as a prime in certain instances, and so contractors are willing to accept lower final margins. Or there may be a categorical incentive for contractors to prefer subcontracting rather than being a prime that systemically crimps competition at that level.

"Further analysis is needed to understand what the causes may be for these differences, but these illustrate why the Defense Department has been working over the past few years to motivate prime contractors to control subcontractor prices and ensure that profitability is aligned with performance—especially in production, where the difference in margins is large," the report states.

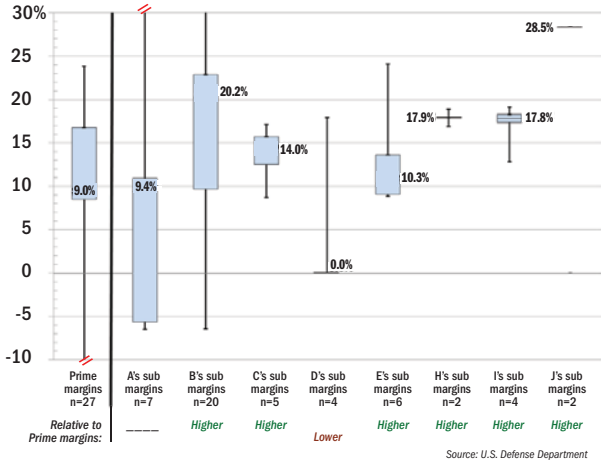
Still, industry consultant Jim McAleese also suggests the Pentagon is sending in its "surprise focus" on subcontractor margins. He sees a "clear inference that some primes are selectively allowing suppliers to propose artificially large subcontract prices during sole-source negotiated contracts after 'winner-take-all'" Milestone B acquisition decisions regarding engineering, manufacturing and development plans.

But if the Pentagon is really concerned about that, it might be behind the curve. "Primes became much more aggressive in targeting supplier costs immediately after the first-quarter 2013 sequester disaster, driving prime margins up from about 9-10% average to the current range of about 12-13%," McAleese says. "Presumably, most aggressive primes are now becoming more adversarial in both subcontract pricing and risk."

Top Pentagon primes traditionally are identified as Boeing, General Dynamics, Lockheed Martin, Northrop Grumman, Raytheon and even BAE Systems or L-3 Communications, depending on context. At least one of them, Boeing, is well into a high-profile effort called Partnering for Success to squeeze cost out of its supply chain.

Apparently, the Pentagon would like more of its primes to pursue that kind of "partnering."

Prime Versus Subcontractor Final Profit Margins, Production Programs
(weighted by spending: 2001-15)



Source: U.S. Defense Department

Percentages above indicate the differences between the profit margins of Pentagon prime contractors and their major subcontractors. For instance, margins for the 20 subcontractors under prime contractor "B" are 20.2% greater than B's. The blue boxes reflect subcontractors' own varying margins. The average for these primes and their subcontractors is in the far left column. No companies could be publicly identified by officials.

By William Garvey
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COMMENTARY

Tropical Attraction

Bienvenido business jets? Si!

True capitalists are always looking for new ways to expand business, and with the tropical chill in Cuba now warming, U.S. business leaders—and the aircraft that carry them—are pointing south to that communist, white-beach bastion and market, seemingly frozen in time.

While outreach by the Obama administration to improve political and economic relations with the island nation has its share of critics, the chance to expand tourism and satisfy the hunger for goods and services of Cuba's 11 million residents has caught the attention of American travelers and businesses.

JOSE MARTI INTERNATIONAL AIRPORT

"There's pent-up demand and interest among Americans about Cuba," says David Rimmer, president of JFI Jets, a charter operator with bases in Farmingdale, New York; Long Beach, California; and West Palm Beach, Florida. He believes the recent, well-publicized visit by Pope Francis further heightened interest in the island nation.

"There are few occasions in this business to pioneer a new market," he says. "I see Cuba as a huge opportunity."

As a result, early this year JFI sought and received the necessary approvals from various federal agencies to enable its aircraft to traverse the Florida Straits and alight at Havana's Jose Marti International Airport (see photo). To date, JFI has operated three flights into Cuba, has another three booked and more in the pipeline.

While the flights are quick—just a 250-nm hop from Palm Beach International to Jose Marti International—initiating them has been complicated, although it is less so now.

So far, licenses to travel there are restricted to a dozen mission categories such as media, cultural exchanges and such—notably tourism is not among them, but Rimmer and others believe that will change. Operators must depart from and return to one of 19 "gateway" airports, Palm Beach among them. JFI relies on its passengers to book trips via tour operators, in part to ensure they qualify. And passengers file affidavits attesting that they meet the mandates; operators must retain these for five or more years.

In early October, the National Business Aviation Association (NBAA) alerted members that the federal treasury and commerce departments now allow U.S.-based aircraft operators authorized by the FAA to fly into Cuba to keep their aircraft there on "temporary sojourn" up to seven consecutive days. Previously, aircraft were limited to a single overnight.

The latest federal revisions also allow, on a case-by-case basis, for export/re-export to Cuba of items "to help ensure the safety of civil aviation and the safe operation of commercial passenger aircraft," including aircraft parts and components, software and technology related to flight safety, air traffic control, aviation communications and weather equipment, airport safety equipment and devices used for security screening of passengers and baggage.

Air ambulance and related emergency medical services for travelers to the island are now also authorized by general license.

Although Cuba has 10 international airports, Rimmer says his charter customers have all opted for Havana. However, with opportunities expanding to telecommunications and Internet services, and the ability to open bank accounts and offices in Cuba, capitalist flights and destinations are likely to expand as well.

BILLION-DOLLAR BABY

One of the modest news announcements at last year's NBAA Convention was that of the creation of Global Jet Capital, a business jet leasing and lending organization. Backed by three global investment firms—Franklin Square Capital Partners with Blackstone advising, AE Industrial Partners and the Carlyle Group—and overseen by business aviation veterans Shawn Vick and Bill Boisture, the future looked promising.

When looking back from the 2015 NBAA Convention, set for Nov. 17-19 in Las Vegas, that promise will have been fully realized. And then some.

In early October, Global Jet signed on to buy GE Capital's Corporate Aircraft portfolio—a collection of 335 business jets, all based in North America—for $2.5 billion. With that agreement, which includes assimilation of 15 GE aircraft finance veterans, the less-than-one-year-old company became the largest such lessor/lender in the business.

Vick, Global Jet's executive director and chairman of its executive committee, says he and his team reached out to GE right after the conclusion of last year's convention and drew interest. Those discussions ended with the acquisition agreement.

"It's been a lot of fun getting here," he says, adding that the company still has another $1 billion to put to work financing midsize to large business jets around the world. "And we intend to do that."

He notes that despite the continuing slowdown, manufacturers will still deliver approximately $10 billion worth of business jets annually and most of the buyers will need funding, presenting his upstart company with lots of financing opportunities.

By Cathy Buyck

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COMMENTARY

What Is 'Fair'?

The EU wants a new fair-competition law for airlines, but it is complicated

Next month, European Transport Commissioner Violeta Bulc and the new head of European Commission's (EC) Directorate General for Transport and Mobility (DG Move), Henrik Hololei, are travelling to the United Arab Emirates (UAE) and Qatar. Two topics will dominate the agenda: fair competition and a comprehensive air services agreement—the European idiom for an open-skies-like accord—between the European Union and the two Gulf states.

Well-defined, stricter rules on fair competition and a liberal approach on market access go hand in hand. At least, this was the deal agreed to by the EU's transport ministers in March. The Transport Council followed the reasoning of France and Germany, which saw open skies between the EU and the Gulf states as a means to persuade these countries to adopt "fair competition" principles and regulatory convergence with EU standards. The French and German position was well thought-through: freeze traffic rights at current levels through complexity and as long as negotiations last (years) and also get a unilaterally applicable instrument that perhaps can sweep away rights previously granted within bilateral air services agreements.

JOEPRIESAVIATION.NET

The rhetoric is well known. Air France-KLM and Lufthansa deplore the aggressive growth of the three big Middle Eastern hub carriers—UAE-based Emirates and Etihad Airways and Doha-based Qatar Airways, accusing them of distorting the level playing field. Not all airlines in Europe support this view; International Airlines Group, Finnair and Ryanair, for instance, take no issue with the Gulf carriers and support liberalization, but their national transport ministers were part of the silent majority in March.

DG Move has been working hard to incorporate this principle—inserting a binding and "open and fair" competition clause in EU external aviation agreements—in its upcoming EU Aviation Package, which will outline the EU's future aviation policy and lay the foundations for a strategy to increase the competitiveness of the sector. DG Move had drafted a review of the EU regulation 868/2004, "on protection against subsidization and unfair pricing practices causing injury to community air carriers in the supply of air services from countries not members of the European Community." As a reminder, 868 was adopted amid concerns about unfair pricing practices by U.S. carriers on the transatlantic market following 9/11.

But the revised text was rejected by other EC departments. DG Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), and DG Trade, as well as the office of services of EC High Representative and Vice-President Federica Mogherini all rebuffed the DG Move draft, insisting they have a say in its review. They argue that the reach of fair competition principles for carriers goes beyond airlines and point out that a repeat of a scenario like the controversial EU Emissions Trading Scheme for aviation—which almost led to a trade war with all major economic partners of the EU—should be avoided.

The manufacturing sector (Airbus, Rolls-Royce, Safran, Thales), airports and air navigation services providers all call for a holistic approach on the matter. They are big employers, and job creation is a priority of the EC now. Alain Alexis, head of unit, Defense, Aeronautic and Maritime Industries at DG GROW, is adamant that the EU should find a balance between the manufacturers' and airlines' interests. That implies granting traffic rights to the Gulf countries, "if the EU wants to keep selling Airbus planes," he says.

Other concerns also come into play. The UAE and Qatar and a number of EU countries have close defense relations and are aligned on the fight against the self-proclaimed Islamic State.

"It is a highly sensitive issue," Bulc tells Aviation Week. "The Aviation Package will be on time," she says. However, only a vague engagement, a "concept" of a revised regulation 868 will be in the Aviation Package, and the regulation itself—if it ever finds consensus—will be rolled out at a later date, such as 2016 or 2017, an EC official confirms.

Still, DG Move is eager to broaden its authority—it believes there is a clear case for "more Europe" in the EU's external aviation policy—and will be seeking endorsement by the commission for a mandate to discuss open skies with Association of Southeast Asian Nations, Mexico, Armenia, Turkey, China and the six Gulf Cooperation Council member states as part of the Aviation Package.

Discussions on the mandates could start as soon as early January.

But will this animated debate around mandates and open and fair competition clauses detract from what the Aviation Package really should be about: increasing the competiveness of European aviation? This means implementing the forever-delayed Single European Sky project, urgent overhaul of passengers' rights regulation, lowering tax burdens and finalizing the essential slots regulation review.

By Graham Warwick

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COMMENTARY

Drone Defeat

Will counter-UAS systems become as prevalent as unmanned aircraft themselves?

At an unmanned-systems industry conference in the mid-2000s, *Wired* editor-in-chief Chris Anderson talked of how his project to create an autopilot from Lego Mindstorm components could turn any model airplane into an unmanned aircraft, and he highlighted privacy and security issues that such accessibility could create.

AIR FORCE RESEARCH LABORATORY

Anderson is now co-founder and CEO of 3D Robotics, a leading manufacturer of consumer "drones"—small, inexpensive and easy-to-operate unmanned aircraft systems (UAS)—soaring sales of which are stoking fears over airspace safety, personal privacy and national security.

The result, barely a decade after Anderson foresaw the issues the coming drone revolution could create, is a rapidly evolving market for counter-UAS capabilities. And, as the development of radar spawned the discipline of electronic warfare (EW) and the cycle of countermeasure versus counter-countermeasure, developers of counter-UAS systems suspect they are at the beginning of a long battle.

It could be argued the first generation of anti-drone countermeasures is like an irate individual protecting his privacy with a 12-gauge shotgun. But that point-defense option will not help government agencies and commercial entities protect the airspace around airports, major events, military bases and critical infrastructure such as nuclear power plants.

What is needed is a suite of capabilities to detect, track, characterize, identify, target and defeat unmanned aircraft, where defeat ranges from interfering with navigation or communications, through taking control of the air vehicle, to destroying it or targeting its operator. And that's where it gets interesting.

Backyard spying is still the public's main concern about UAS, but for government agencies and public utilities the threat is more lethal than embarrassing videos. After 15 years of combating improvised explosive devices (IED) on waysides in Iraq and Afghanistan, the U.S. and others believe they face an imminent threat back home from "airborne IEDs."

A visible sign of this concern is the emergence of counter-UAS solutions, some with ties back to counter-IED systems deployed operationally. There have also been large-scale trials, in the U.K. and elsewhere, to assess the effectiveness of these systems against likely threats—including consumer drones such as the popular DJI Phantom that can be used for illicit surveillance, or worse.

The list of available systems grows longer and includes the Anti-UAS Defense System from a trio of small U.K. companies, Lockheed Martin's Icarus, Selex ES's Falcon Shield, Battelle's rifle-like DroneDefender and the CACI International system to be evaluated by the FAA at U.S. airports (*AW&ST-DTI* edition, Oct. 12-25, p. DT17).

Typically a full system comprises a passive or active radio-frequency (RF) sensor to detect and track UAS, an imaging sensor to identify and target the air vehicle, and some form of RF inhibitor or jammer to disrupt or disable the UAS's camera, navigation or communications, take control and pinpoint its operator.

That is not as easy as it sounds, for two main reasons. One is unintended consequences. Disabling a UAS could make it crash, causing injury or damage and potentially dispersing dangerous substances. Jamming GPS would interfere with the navigation systems of nearby aircraft and can only be used briefly or must be targeted precisely.

"We cannot deny GPS near airports," says Doug Booth, Lockheed Martin's director of business development for cybersolutions. "There are other safe countermeasures we can use that are more specific and precisely focused on the vehicle." Tellingly developed within Lockheed's cyber business, Icarus has multispectral sensors, a signatures database and a non-kinetic payload that can deliver a "surgical strike . . . in seconds."

Similarly, conventional EW "is a sledgehammer solution that disrupts the entire environment," he says. "EW will knock a drone down, but turn it off and it is back in the air. Our technology allows us to seize control and land the vehicle. It is more cyber."

The second reason is the question of who should own such systems. The sensing and jamming technologies come from the military and may not be transferable to the commercial sector to protect critical infrastructure or exportable to other nations with similar concerns about flying IEDs.

For that reason, Booth says, the Icarus sensors are all passive—RF, acoustic and imaging—using technologies already exported. Active sensors are more problematic, but the countermeasures side is most sensitive and will depend on the customer. There is another reason companies are being coy about countermeasures—as with EW, they know illicit UAS users will develop counter-countermeasures, and the cycle will begin.

By Bill Sweetman

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COMMENTARY

Lightning Struck

Canada's election upset heralds a big fighter contest

Lockheed Martin lost 65 aircraft from the F-35 Joint Strike Fighter (JSF) orderbook in a matter of weeks, as Canada's Liberal Party first pledged in writing to dump the JSF and hold a competition and then won an overall majority that no pollsters predicted.

OFFICE OF CANADIAN PM

It's not a lethal blow to the JSF project, still bigger on paper than all its Western rivals combined. It was less about the merits of the airplane than the inept, arrogant and dishonest way in which Prime Minister Stephen Harper's (photo) Conservative administration tried to avoid a competition.

Ineptitude? Harper's team asserted in 2010 that only the F-35 would meet Canada's operational needs, which it summarized in a wish list seeded with cherry-picked JSF features, labeled as "mandatory requirements." In 2012, Canada's auditor-general told Harper to throw his statement of requirements in the bin.

Arrogance? Ministers complained that a competition was a waste of time, and then squandered five years trying to make sole-source happen. Even last year, someone in Ottawa was working on a sketchy plan to create a preelection fait accompli by diverting F-35s from U.S. Air Force orders in 2015.

Dishonesty? One of Harper's ministers told Parliament in 2010 that Canada could not buy the JSF through a competition, because it was already a partner. Two years later, JSF partner Denmark decided to compete its fighter buy, and Team JSF cooperated fully.

Justin Trudeau's Liberals must quickly launch a competition to replace the air force's F/A-18, if they want to have contracts signed before campaigning begins for the next election, no later than 2020. They have said that the JSF is ruled out because Canada's needs have swung back toward air defense.

That decision may well stick because the JSF is as popular as week-old poutine: Former Hornet pilot and rookie politician Stephen Fuhr, who launched his campaign on the JSF issue, just dislodged a nine-year incumbent from a district in British Columbia that had voted Conservative for 45 years.

It is a good time to be in the market (*AW&ST* Sept. 28-Oct. 11, p. 22). And if yours is the biggest fighter order in play, the competitors are checking the price tags on their grandmothers.

Dassault does a lot of business with Canada, including engines for Falcon business jets. Canada has a massive area to defend, and the Rafale has two engines and excellent range. It also has an impressive range of weapons and sensors already in service.

Eurofighter has kept a low profile because of British and Italian involvement in the JSF, but that no longer applies. If you want air defense, Eurofighter will argue, the Typhoon, with supersonic cruise, MBDA's Meteor air-to-air missile, a new radar and infra-red search-and-track (IRST), stands comparison with any aircraft, including the F-22.

Saab is likely to join the fray now that Canada's commitment to the JSF is severed. One argument against the JSF was that its cost would eviscerate Canada's land and maritime forces, and from that viewpoint, the Gripen's economics are disruptive. It can supercruise, shoot the Meteor (as well as a full range of U.S. weapons) and has the same IRST as the Typhoon.

Opening the door to the Europeans accesses new and generous financial and offset options, allowing Canada to move faster and avoid another Hornet life extension. Canada can and should demand forged-titanium guarantees on life-cycle costs as well as acquisition, along with national control of threat libraries and other crucial software. (If Team F-35 self-eliminates on those grounds, so be it.)

The Canadian record on defense acquisitions has not been good, the painful quest for a maritime anti-submarine warfare helicopter being the undoubted low point. But many pitfalls can be avoided as long as Canada neither overcustomizes the system nor demands local work in areas where there is little local experience.

Washington remains Canada's closest ally, and that will go double for Trudeau if it is a liberal, Democratic-led Washington after November 2016. The strength of a Boeing offer will depend on the support of the U.S. Navy for the company's long-term Hornet fleet plan (see page 38), including options for new weapons and upgraded engines. If the Pentagon picks Northrop Grumman to build its new bomber, Washington might look favorably on Super Hornets for Canada as part of a plan to keep Boeing in the game.

And there will be an impact on the JSF, because the program still needs a lot of early partner and export sales—43% of orders over the next seven lots—to get the production rates up and costs down. Canada was among the six biggest export customers for the F-35 and—depending on British and Italian actions—could have been in the top three. The Shangri-La of 150-plus jets per year and $85 million unit costs just moved higher up the mountain.

By Frank Morring, Jr.

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COMMENTARY

Peace, and War

Space congress underscores humanity's progress—and how far we have to go

Jerusalem is "a tough neighborhood," in the words of Nir Barkat, its mayor. He underscored that statement a few hours after welcoming participants in the 66th International Astronautical Congress (IAC) to his city, when he repeated calls for Israelis to go armed in public as a precaution against the wave of violent attacks sweeping the country.

The escalating conflict between Israelis and Palestinians reduced attendance at the annual gathering of space-exploration scientists, engineers, businesspeople and policymakers. Some in attendance left the conference early as the knifings and gunfire continued, sometimes just outside the locked gates of the Jerusalem International Conference Center.

That is a shame, because those who remained for the annual event were treated to a view of what humans can achieve when working together to improve life on Earth by understanding the cosmic context in which it exists. Presentations on the technology that enabled this year's spectacular New Horizons Pluto flyby, updates on the Rosetta comet landing and news that the 10-year-old Mars Reconnaissance Orbiter (MRO) has confirmed that some of the ongoing changes detected in the Martian surface are caused by flowing water highlighted what group efforts can bring to bear.

In a warren of rooms away from the main conference halls, top managers of space agencies met in formal and informal groups to find ways to share the expense and technical challenges of new spaceflight missions—human exploration beyond low Earth orbit and ambitious scientific robots. As always, they discussed Earth-observation missions to monitor the planet's overall changing atmosphere to help mitigate the human effects of rapid surface changes caused by earthquakes, floods, oil spills and other disasters.

NASA Administrator Charles Bolden made news by terming the U.S. ban on civil-space cooperation with China "temporary" and suggesting Congress will allow his successors to fold that nation's growing human-spaceflight enterprise into the journey to Mars.

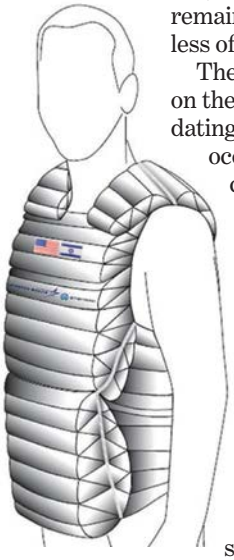
Downplaying a potential conflict over destinations, European Space Agency Director General Johann Woerner elaborated his "lunar village" concept—a site where diverse partners can advance their unique spacefaring skills to the benefit of other "villagers" bound for more distant targets.

Lockheed Martin, which built the MRO, was a major corporate sponsor of the IAC. CEO Marillyn Hewson issued a carefully crafted call for more international cooperation.

"Space is no longer above us, or between us," she said. "It surrounds us and connects us. Space is a place in which we can realize the fullest potential of Earth. There are no borders in space, and international cooperation will drive this exciting new space age."

Sadly, a few hours after Hewson's keynote address, a fusillade of gunfire erupted nearby, underscoring just how lofty her sentiments were. At the central bus station a block away, a policeman killed a Palestinian who had attacked an unarmed woman with a knife, continuing the deadly cycle that played out all week in the ancient city.

Israel controls all of Jerusalem, but it is a border city. The military moved in early in the week of the IAC to block off neighborhoods where Palestinians live, demonstrating that the old border remains in mind if not in fact, regardless of what can be seen from space.



LOCKHEED MARTIN

The conference center was built on the site of a Roman encampment dating back 2,000 years, used by the occupying 10th Legion for two centuries. The architects preserved some of the ruins, which offer historical perspective on the predictions Hewson made upstairs: "The future will see international partners working together more closely than ever to unlock the power of space, to bring connectivity to every corner of the globe, to strengthen global security and to push the boundaries of exploration."

Hewson's company has forged space partnerships of its own in Israel, which has a small but highly skilled space industry. Joseph Weiss, president and CEO of Israel Aerospace Industries, says there are only about 1,200 Israelis working in space-related fields, but they make a contribution to the nation's export-driven economy out of proportion to their number.

Lockheed Martin's booth in the exhibition hall included a protective vest it is developing with a small Israeli company, StemRad, designed to shield astronauts in deep space from the deadly radiation they will encounter beyond Earth's magnetic field (see illustration). The U.S. company is also leveraging the high quality and low prices of Israeli space components to collaborate on secret military and intelligence spacecraft, according to executives from both sides of the growing partnership.

Spaceflight always has involved swords as well as plowshares, dual-use hardware that can secure borders as well as erase them. It was poignant and heartening to hear Hewson, the top executive of one of the largest corporations involved in both sides of the dual-use equation, quote Israel's only space traveler so far, tragically killed in the Columbia accident.

"In the words of Col. Ilan Ramon," she said, "'[T]here is no better place to emphasize the unity of people in the world than flying in space.'"

Edited by Jen DiMascio

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COMMENTARY

Sticky Situation

The cost of a Canadian exit from the F-35 program

Campaign pledges can be hard to live by. And Canada's next prime minister, Justin Trudeau, elected on Oct. 19, is about to experience that firsthand. Trudeau's Liberal Party recently vowed to scrap the F-35 Joint Strike Fighter in its military's hunt for a new fighter aircraft. But if Canada, one of the program's nine original partners, does not follow through on its intent to buy 65 F-35A aircraft, it is likely to feel some heat from its allies.

Air Force Lt. Gen. Christopher Bogdan, the program executive officer for the F-35's Joint Program Office, outlined some of the consequences. If Canada pulls out, the remaining partners will have to pay 0.7-1%, or about $1 million more per aircraft, Bogdan told lawmakers on Oct. 21. While there would be no change to the current development program price, it would affect a follow-on research and development modernization program to add upgrades in software and weapon systems as well as future sustainment—sustainment estimated at $1 trillion in the U.S. alone. Canada's share of R&D efforts was 2.1%, which for future modernization would have to be spread among the other partners and U.S. services. And the three-star general warned about potential effects on Canada's industrial base. "Today there are many Canadian companies building pieces and parts for the F-35 program. We do not have a set rule as to what happens to that industrial participation if a partner reduces airplanes, adds airplanes or even leaves the program," he said. "But it is my opinion that the remaining partners and our industry partners are going to have a discussion about what to do with all of the industry in Canada."

U.S. DEFENSE DEPARTMENT

'We do not have a set rule as to what happens to that industrial participation if a partner reduces airplanes.'

—LT. GEN. CHRISTOPHER BOGDAN

BROADER BANDWIDTH

Some in the satellite industry are cheering a new rule proposed by the Federal Communications Commission (FCC) for high-frequency wireless spectrum bands. The rules would allow for the regulation of next-generation communication technology, 5G mobile service. "The satellite industry will play an essential role in the 5G ecosystem by off-loading traffic from congested terrestrial wireless networks, providing reliable and resilient backhaul services, and providing mobile broadband to vehicles and airplanes," says Satellite Industry Association President Tom Stroup.

The trade association—whose members include Boeing, Lockheed Martin, Northrop Grumman, Airbus Defense and Space, Eutelsat America, O3b, Inmarsat, OneWeb, Orbital ATK and others—adds that it will continue to work with the FCC, "as it considers how to provide spectrum access to all technologies in a manner that does not constrain the deployment of the satellite services that are currently operating or planned in the future."

OPTING IN

Foreign direct investment (FDI) in the U.S. aerospace sector reached a 6.3% compound annual growth rate in 2014, according to the Commerce Department. At the end of 2014, foreign investment in U.S. aerospace products and parts manufacturing industries totaled $22.5 billion, growing annually since 2008. The rate "outpaced the compound annual growth rate of FDI positions in transportation equipment manufacturing and even growth in FDI of all industries during the same period," officials said. The statistics were provided by the department and Aerospace States Association.

NEXT STEPS

Even though President Barack Obama vetoed a defense authorization bill on Oct. 22, many hope a larger budget deal can be reached in Congress to keep it alive. Other than overarching budget issues, the bill largely appeals to both political parties. And the defense policy bill has a long history of success, passing every year in the last 53 years. The consensus includes a host of acquisition reforms, among them, one that allows the military service chiefs to approve purchasing decisions. But such defense policy changes in the fiscal 2016 bill are just the beginning, say Sen. John McCain (R-Ariz.) and Rep. Mac Thornberry (R-Texas), who this year took over as chairmen of the Senate and House armed services committees, respectively. They have begun a series of hearings to inform legislation for fiscal 2017. Continuing in the vein of giving the service chiefs a larger say in weapons buys, one item on the to-do list is updating the policies put in place in 1986 by the Goldwater-Nichols Act to improve cooperation among the branches of the military.

"We have swung in a direction where there are more layers of bureaucracy and no accountability," Thornberry says. Plus, the world has changed significantly in the last 30 years, McCain says, and the rules need to be revised accordingly. The Pentagon needs more flexibility to speed acquisition and get after new kinds of threats including cyberattacks, he says.

Reality Bites

Only South Korea is surprised to find out U.S. systems are not freely available for KF-X

Bradley Perrett Seoul

If South Korea cannot acquire key U.S. avionics for the KF-X indigenous fighter, as is likely the case, then Europe and Israel are obvious places to turn to. And if such major systems as radar and electronic warfare equipment must exclude U.S. content, an attractive option opens up: The rest of the aircraft, including propulsion, could also be made free of Washington's veto over exports of the fighter.

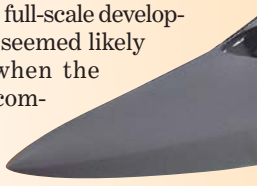
The South Korean government and likely prime contractor Korea Aerospace Industries (KAI) are indeed faced with that possibility. It is not, however, one that would be welcomed by the main customer, the Korean air force, which strongly prefers to use U.S. equipment. The service will not be concerned that the radar may come from Elta, Selex or Saab, for example, or that the Eurojet EJ200 engine instead of the General Electric F414 would propel the twin-engine KF-X. Rather, industry officials say, the air force would worry that Washington could withhold permission to integrate U.S. weapons with the KF-X's non-U.S. systems.

For now, the U.S. refuses permission to integrate radar, electronic warfare systems, infrared search and tracking, and targeting pods—but not weapons; 21 other technology items Seoul requested for the KF-X are pending.

The U.S. government is not just forbidding U.S. companies such as Raytheon and Northrop Grumman from actively transferring technology to South Korean industry in return for system sales. Nor is Washington simply saying that KAI and South Korean suppliers may not integrate the systems, learning much of how they work along the way.

In fact, the U.S. government will not allow the systems to even be supplied, though the integration work could be done by Lockheed Martin, which is obligated to help with KF-X development in return for Seoul ordering the F-35. Washington's concern must be that, even with a U.S. company doing the work, too much know-how would leak to South Korea—and to KF-X partner Indonesia, a country with which the U.S. ordinarily shares minimal defense technology.

European and Israeli system suppliers were prominent at Seoul ADEX, the biennial South Korean defense and aerospace exhibition held Oct. 22-25. Saab, notably, exhibited a model of a fighter-radar antenna with gallium-nitride technology, that offers higher output power and detection range than traditional active, electronically scanned arrays.



KF-X will not enter full-scale development next year—as seemed likely until September, when the finance ministry recommended a budget of only 67 billion won ($59 million) for 2016. While a 2017 launch is possible, the tremendous technical challenges for the mature industry, complicated by difficult choices for critical systems, could easily lead to further deferrals.

The U.S. refusal to allow access to the four key technologies resulted in a political furor in South Korea, with the defense ministry's purchasing agency, the Defense Acquisition Program Administration, criticized for failing to bring home the goods. All this is bemusing to the international industry, since Washington's policy was quite predictable. Indeed, foreign industry and defense officials wonder how and why their South Korean counterparts maintained the pretense that U.S. policy would present no obstacle.

Rather than keeping the KF-X purely South Korean, European and Israeli, KAI suggests acceptance of such U.S. systems as are available and suitable, and later replacing them to create a version that can be exported without a Washington veto. Later integration of South Korean electronics

Access Denied

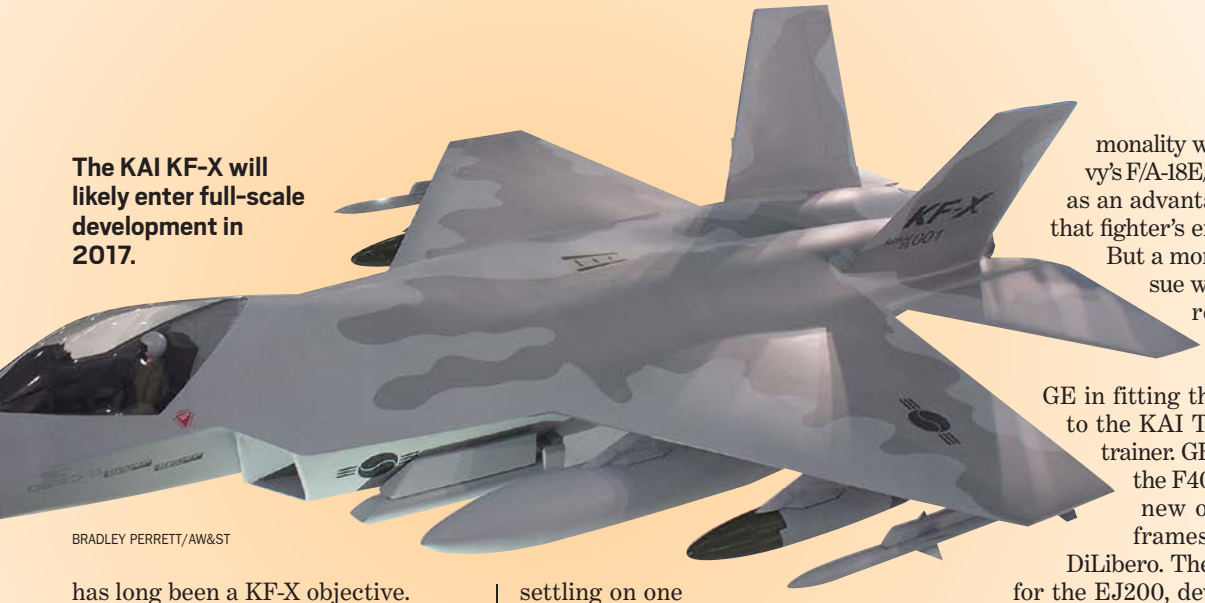
F-35 export buyers must pay for U.S.-controlled software labs

Bill Sweetman Washington

Foreign air forces using the Lockheed Martin F-35 Joint Strike Fighter are being compelled to fund $150 million software laboratories, based in the U.S. and almost 50% staffed by U.S. personnel, that generate data crucial to the fighter's ability to identify new radio-frequency threats.

This regime is more stringent and far-reaching than earlier U.S. fighter export deals. Those usually withheld the software's source code from the customer, but in most cases allowed local users to manage their own "threat libraries," data that allowed the electronic warfare (EW) system to identify radio-frequency threats, with in-country, locally staffed facilities.

For the U.K. in particular, the reliance on U.S.-located laboratories looks like a pullback from its earlier position. In 2006, concern over access to JSF technology reached the national leadership level, and prompted a declaration, by U.S. President George W. Bush and U.K. Prime Minister Tony Blair, that "both governments agree that the U.K. will have the ability to successfully operate, upgrade, employ and maintain the JSF such that the U.K. retains operational sovereignty over the aircraft."



The KAI KF-X will likely enter full-scale development in 2017.

BRADLEY PERRETT/AW&ST

has long been a KF-X objective.

The U.S. technology transfer policy is bringing part of that objective forward. If U.S. policy does not change, then the electronic warfare system will be South Korean, and the radar will be indigenously developed with European or Israeli help, says a senior KF-X official. "We have a Plan B," that manager says.

The two most important equipment decisions, the choice of an engine and a radar, are expected next year, with propulsion probably sorted out in the first half. The EJ200 or General Electric F414 are the only engine candidates. GE's advantages include a record of successful cooperation with South Korea, while Eurojet, a consortium of European companies, can offer an engine free of U.S. content.

The delay brings the benefit of allowing time for an engine to be selected before full-scale development, so the preliminary airframe design can be adjusted before other issues are addressed in detail. For example, the competing engine types vary in weight, so settling on one or the other will allow developers to tweak the airframe to achieve balance with little or no ballast.

To meet South Korean industrial objectives, the engine manufacturers will have to support the manufacture of much of their products by Hanwha Techwin, South Korea's leading aircraft propulsion company. Eurojet CEO Clemens Linden, speaking at ADEX, said more than half of the EJ200 could be built in the country. Various options are available for the F414, and even 70% local production would be possible, according to the GE vice president responsible for the F414, Alan DiLibero. But as more of an engine is built locally, the higher the cost to the customer.

In the case of both offers, parts withheld from South Korean production will surely include the high-pressure turbine module; even if governments allowed the relevant manufacturing technology to be shared, no major engine company would be willing to reveal such secrets.

South Korea may see engine commonality with the U.S. Navy's F/A-18E/F Super Hornet as an advantage in choosing that fighter's engine, the F414. But a more important issue will be South Korea's successful experience of working with GE in fitting the earlier F404 to the KAI T-50 supersonic trainer. GE has integrated the F404 and F414 into new or updated airframes 14 times, says DiLibero. The key advantage for the EJ200, developed for the Eurofighter Typhoon, may turn out to be an ultimate South Korean decision to eschew U.S. content in the KF-X.

Eurojet and GE are both offering their engines in current production standard, citing the advantages of removing propulsion from the list of sources of risk. In each case engine upgrades based on technology already available or in development would be ready for a proposed Mk. II KF-X of improved performance. In GE's case, the engine upgrade would offer an 18% increase in thrust from the F414's current 22,000 lb. in the static, sea-level condition. Eurojet, in turn, has a list of prospective technologies for later KF-Xs, including 3-D thrust vectoring.

The EJ200's static, sea-level thrust is 20,000 lb., but Eurojet points out that the deliberately limited compression in the engine allows it to run at full throttle in fast and low conditions that restrict output from other fighter powerplants, for fear of exceeding internal temperature limits.

LOCKHEED MARTIN

Australian F-35As will share a reprogramming lab at Eglin AFB, Florida, with U.K. F-35Bs.

That promise seemingly contrasts with the severe limits now being imposed on non-U.S. access to the system.

Concerns about the lack of sovereignty and access to the core system are being voiced, since customer laboratory personnel will not be co-located with operating units. A retired senior Royal Air Force officer comments that "the non-U.S. operators are going to have to take a very great deal on trust. Further, 'rubbish in, rubbish out' is still going to hold sway, and I doubt that the non-U.S. customers will be able to check what is going in." Security arrangements "seem to go a lot further and deeper" than on earlier platforms, he says.

Another source close to the U.K. user community notes that Lockheed Martin has advertised the capability of the "fusion engine"—the software that combines inputs from different sensors and data links—to identify targets and implement rules of engagement automatically. But if the logic of the fusion engine itself is not understood at the U.K.'s operational level, he says, "you can imagine that this slaughters our legal stance on a clear, unambiguous and sovereign kill chain."

The restrictions are also likely to be cumbersome. By contrast, "Swedish air force Gripens are often updated between sorties," a Saab spokesman says. Signals intercepted and recorded by the fighter's EW system on one sortie can be analyzed and the system updated in hours.

It is not clear who, ultimately, would control the use of the foreign-funded laboratories, which will depend on host U.S.

bases for power, communications and access. Lockheed Martin referred all questions on this topic to the JSF program office (JSFPO), which did not respond to repeated requests for comment.

But even the current security regime is the result of a compromise by the U.S. In September 2014, JSFPO director Lt. Gen. Christopher Bogdan indicated that the foreign-owned laboratories would allow the operators more access to the system than they would otherwise have enjoyed. This suggests that the initial U.S. position was that foreign nationals would not be involved with reprogramming at all.

The JSFPO will not be the final U.S. authority on security measures. That is the Low Observables/Counter Low Observables Executive Committee, the third and highest level of a special process of reviewing stealth technology transfers, managed by the Defense Technology Security Administration. Of about 700 requests for the export of stealth-related technology each year, only around 30 require the attention of the executive committee.

The mission data files (MDF) generated in the U.S. labs are sensitive because they are essential to the aircraft's stealth characteristics. They include information that allows onboard software to build a so-called "blue line" flightpath that avoids exposing its less-stealthy viewing angles to hostile radar. This process is based on a highly detailed model of the aircraft's radar cross-section against all known threats and at all aspect angles, so any compromise of that data could be catastrophic.

The MDFs also include target models that the sensor system uses to fuse radar, passive electronic and electro-optical signals into a single set of target tracks. "Reprogramming

U.S. ARMY

New Clarity

Strides made in rendering U.S. Army helicopters capable of missions in all visual conditions

Graham Warwick Washington

Momentum is gathering behind a U.S. Army program to equip its helicopters initially to take off and land in degraded visual environments (DVE) and eventually to operate in all visibility conditions.

Following an analysis of alternatives (AoA), the Army is moving forward to develop a request for proposals (RFP) for the Brownout Rotorcraft Enhancement System (Bores) as a first step. The Sikorsky UH-60 Black Hawk will be equipped first, followed by the Boeing CH-47 Chinook, says Col. Matt Hannah, program manager for Aviation Systems.

In April, Army aviation branch chief Maj. Gen. Mike Lundy said he was prioritizing efforts that will enable the force "to fly and fight in any environment," including accelerating the fielding of systems to enable crews to operate in reduced visibility. He described Bores as an initial step, not the solution.

"The first step is a frontal sensor package, the Bores pilotage system. The final outcome will be a DVE pilotage system with 360-deg. coverage, enabling Army aviation to own the night and the environment, and support ground forces 24/7," Hannah says.

Bores will make it possible for helicopter pilots to take off, land and hover in brownout and other conditions that reduce visibility, but not to maneuver or operate in formations of aircraft. "It's like looking out of your car's front window, and as a starting point for 360-deg. DVE," says Hanna.

Following completion of the Bores AoA, the Army has authorized the Aviation Systems office to update its assessment of the technology readiness levels of DVE solutions, begin development of the RFP and conduct a limited user assessment, says Hanna. The Army will also issue a request for information from industry on obscuration-penetration systems that fuse multiple sensors into a single synthetic image.

The limited user assessment set for late spring 2016 at Yuma Proving Ground in Arizona will be conducted with an existing DVE sensor on a UH-60 and will involve pilots with various levels of experience. The goal is to assess the technology readiness and amass pilot feedback that will help with development of the Bores RFP. "It's about the user, not the vendor of the hardware," he says.

The U.S. Army will tackle the single-aircraft DVE problem first, then move to multiship operations.

The RFP is planned for release in fiscal 2017. The capabilities development document for Bores has been drafted and is being staffed, but the Army is still developing its acquisition strategy and schedule. Hanna says he cannot yet give a budget or time frame for the program.

Government and industry have been experimenting with DVE solutions for some time, and Hanna says the Army plans to leverage the Aviation and Missile Research, Development and Engineering Center's (Amrdec) DVE Mitigation (DVE-M) research effort, Special Operations Command's (Socom) DVE Pilotage System (Dveps) program and industry efforts.

The $110 million DVE-M program is looking at multispectral sensor suites, cueing symbology and flight controls with the goal of demonstrating multiship operations in DVE and integration with the aircraft's self-defense systems by 2020. Eight vendors of sensor and fusion technologies participated in ground tests this year at the Yuma Proving Ground. Flight tests are planned for 2016. Hanna says Amrdec is evaluating "lidar, ladar, long-wave infrared and millimeter-wave radar sensors."

Dveps is a program to field a system on Army special-operations Boeing MH-47G and Sikorsky MH-60M helicopters by 2018. Boeing and Sierra

used to be about survivability," says RAF Air Commo. Linc Taylor, assistant chief of staff capability delivery combat air and air intelligence, surveillance, target acquisition and reconnaissance. "Now it's about survivability and effectiveness."

The MDFs are twice as large as the equivalent data load in the F-22, the Air Force has said. There are 12 packages covering different regions.

The Pentagon's director of operational test and evaluation, Michael Gilmore, has stressed the importance of the MDF process to the F-35's capability and warned of delays. "Mission data load development and testing is a critical path to combat capability for Block 2B and Block 3F," Gilmore said in his fiscal 2014 report. "Accuracy of threat identification and location depend on how well the mission data loads are optimized to perform in ambiguous operational environments." Software and hardware used to create the MDFs was held by Lockheed Martin at Fort Worth, Texas, for three years after its planned delivery to the first government reprogramming laboratory, delaying its delivery, says the Pentagon's office of the Director, Operational Test and Evaluation.

The JSF program is establishing two centers to produce and update MDFs, at Eglin AFB, Florida, and NAS Point Mugu, California. The western center will host a lab to support Japanese and Israeli F-35s. An Australia/U.K. facility and a laboratory to support Norway and Italy will be established at Eglin. Lockheed Martin was awarded a contract to build the Australia/U.K. facility in April. According to an Australian government document, the lab will have a staff of about 110 people, of whom 50 will be U.S. nationals, and the international partners will cover all its operating costs.

Nevada Corp. conducted flight tests of integrated systems this year under Phase 2 of the program. Hanna says Socom has just awarded a contract for Phase 3, which covers low-rate initial production and qualification testing.

A source close to the program says the Dveps contract has gone to Sierra Nevada, which has developed a system based on a 94-GHz millimeter-wave radar. An earlier version was tested operationally on Army UH-60s in Afghanistan. "We will look at what [Amrdec and Socom] are doing and take credit where we can so that it requires fewer resources to reach a solution," says Hanna.

After developing the Bores forward-looking pilotage system, which will be designed for takeoff, landing, limited hovering and ground taxi, the Army plans to carry the same technology forward to the full-capability system. Designed to operate in all modes of flight, including formation flying, this will provide a forward-looking pilotage system, 360-deg. hazard warning and DVE capability in all conditions.

Hanna says the DVE effort has gained momentum within the Army over the past few months. The service calculates DVE caused a large part of the almost 400 Class A and B accidents and 152 fatalities over the past 13 years involving Army helicopters. The material cost of aircraft losses attributed to DVE approaches $1 billion, he says.

While the utility Black Hawk and cargo Chinook are to be equipped with Bores, the Apache's existing pilotage sensor provides some DVE capability, Hannah says, so the attack helicopter is scheduled to be equipped later, with the full-capability 360-deg. system. The planned Future Vertical Lift (FVL) replacements for the Black Hawk and Apache are also expected to receive the full-capability system.

Under the Army's Joint Multi Role technology demonstration, a precursor to FVL, Bell Helicopter plans to fly Lockheed Martin's 360-deg. distributed aperture system on its V-280 Valor tiltrotor demonstration to showcase the system's capabilities, including in DVE. The V-280 is scheduled to fly in September 2017.

UNMANNED SYSTEMS

Hammer Time

FAA: laissez fare no longer for drone hobbyists

John Croft Washington

A hastily assembled group of government and industry representatives will decide over the next month how the FAA should proceed with mandatory registration of hobbyist unmanned aircraft, increasingly coming into conflict with the public and other aircraft.

Anthony Foxx, Transportation Department secretary, announced the new rules Oct. 19, giving the newly formed task force one month to come up with recommendations, including thresholds for the size of UAS to be included and how much information will be required during the registration process. The FAA will then have until mid-December to issue a final rule. Toys and other "certain other small" drones will likely be exempt, due to a low safety risk, says the department. The task force includes 25-30 representatives from the unmanned and manned aviation industries, among them the Academy of Model Aeronautics, the Air Line Pilots Association International and Helicopter Association International.

"This isn't riding your ATV on your own property, this is going into the space where other users are occupying that space," says Foxx. "It is a matter of responsibility that we will take seriously. There are penalties associated with failure to do so." FAA Administrator Michael Huerta, who announced the new rule with Foxx, did not quantify the penalties, other than to say operating without a registration gives the agency "a basis for us to go after you with our [local] law enforcement partners." For certified aircraft, owners who do not properly register their aircraft can be fined as much as $250,000 and face up to three years in prison for the felony, according to U.S. regulations.

The increasing number of reports of hobbyist drone sightings by pilots is a concern at the FAA, the agency responsible for providing separation between aircraft. FAA Deputy Administrator Michael Whitaker, at a House Aviation subcommittee hearing early in October, said the agency is receiving more than 100 sightings per month, a fivefold increase from a year ago. An analysis by the Academy of Model Aeronautics, which represents hobbyists, concluded that only a small

U.S. TRANSPORTATION DEPARTMENT

fraction of sightings to date can be considered near accidents. Whitaker, responding to lawmakers' suggestions that a registration system would help track down errant operators, said the FAA was not set up to take in "the level of data" needed to register all drones, and that the agency's preferred approach was education and voluntary compliance with safe operating guidelines.

The agency did an about-face less than two weeks later at the press conference with Foxx, who said a registration rule would help purchasers "learn airspace rules before they fly," and complement outreach initiatives launched by the FAA and others to educate the public. These include the agency's "Know Before You Fly" and "No Drone Zone" campaigns, along with an FAA smartphone application, now in Beta testing, that shows operators where it is safe to fly. Voluntary guidelines for hobbyists flying model aircraft, including drones, call for avoiding airports by 5 nm, unless the operator gets approval from the airport, and staying below 400 ft. altitude.

The registration action is separate from the FAA's ongoing efforts to set operational and certification requirements for using small unmanned aircraft weighing less than 55 lb. for commercial purposes; the agency plans to finalize the rules in June, 16 months after they were proposed. In the interim, the public weighed in on the proposed regulations, submitting more than 4,500 comments. The preliminary rule does not require certification of the aircraft or operator, but does call for the operator to register the vehicle, pass a one-time aeronautical knowledge test at an FAA-approved testing center and be "vetted" by the Transportation Security Administration. The FAA also built enforcement hooks for the hobbyist community into the rule, giving itself "enforcement authority" when model aircraft operators "endanger the safety of the National Airspace System."

The FAA will require owners of recreational drones above a certain size limit to register the vehicles or face penalties.

Given the quick turnaround for the task force, the Transportation Department may have to bypass the public input process, possibly a nod to the holiday season, during which the FAA estimates a million new drones could be sold. Foxx says he expects the task force to recommend retroactive registration for hobbyists who have previously purchased a UAV, but he notes there may be a grace period before the rules are enforced.

The push for registration also represents a position shift for Congress, which in the FAA's 2012 reauthorization bill specifically forbade the agency from creating new rules or regulations affecting hobbyists, albeit with two key caveats—aircraft had to be flown in accordance with community-based safety guidelines, and "in a manner that does not interfere with and gives way to any manned aircraft."

"We are looking very closely at the regulatory process, but we do feel the level of urgency here is sufficient to move as quickly as we possibly can," says Foxx.

Transpacific Tactics

U.S. airlines see growth opportunities in Australia, New Zealand markets

Adrian Schofield Auckland

The Australasian market is increasingly becoming a target for U.S. major airlines, as they launch new routes and solidify their position in the region by forming tighter links with local partners.

United Airlines will complement its existing Australian services by reintroducing a New Zealand route next year. Meanwhile, American Airlines is stepping into the Australian market for the first time in 20 years, and may follow United with a New Zealand route of its own.

To reduce the risks attached to the new services, the two U.S. carriers are seeking regulatory permission to enter revenue-sharing joint ventures with Australasian carriers. Oneworld Alliance members Qantas and American want to collaborate more closely, as do Star Alliance members United and Air New Zealand.

If approved, these deals will draw the battle lines more sharply in this market. The big three U.S. carriers will have transpacific partnerships with the three largest carriers in the region, as Delta already has such an arrangement with Virgin Australia.

Not everyone is comfortable with the alliance carve-up of the U.S.-Australasian market. In a submission related to the American-Qantas proposal, Hawaiian Airlines argues these types of partnerships limit competition by squeezing out independent operators such as Hawaiian.

However, it would be a major surprise if the joint-venture applications were not approved. In the case of Qantas and American, the Australian Competition and Consumer Commission (ACCC) has given them interim authority to market their partnership while it deliberates. A draft decision is due soon.

The two airlines already operate a joint venture on U.S.-Australia routes—even though American does not fly them yet—and they are seeking permission to upgrade this to a full metal-neutral revenue-sharing arrangement.

The partners want such a deal in place for American to launch daily Los Angeles-Sydney flights in December, using Boeing 777-300ERs. This will allow Qantas to use some of its aircraft deployed on the Sydney-Los Angeles route to restart service from Sydney to San Francisco, a route it suspended in 2011.

Qantas currently has daily Airbus A380 flights from Sydney to Los Angeles, as well as three weekly Boeing 747-400 flights. It will cut the three 747 flights when it starts its service to San Francisco using 747s. Qantas also flies to Los Angeles from Melbourne and Brisbane, and its other U.S. mainland gateways are New York (via Los Angeles) and Dallas.

After this reshuffle, Qantas and American will account for almost 60% of capacity on nonstop routes between Australia and the U.S. mainland, according to estimates by rival Virgin Australia. Virgin and its partner Delta would have about 22% and United 18%.

The Australian government department responsible for transportation has told the ACCC that it supports the Qantas-American application. While the department acknowledges the pair would have the largest market share, it notes there is still considerable competition from the other players.

Qantas and American say an expanded alliance would allow them to enter the U.S.-New Zealand nonstop market, and American is believed to be considering launching such a route. However, these plans may be complicated by United's impending entry into the New Zealand market.

United intends to start a San Francisco-Auckland service July 1 using Boeing 787-8s. This will initially operate three times a week, expanding to daily flights with larger 787-9s by November 2016. The carrier previously operated a Los Angeles-Auckland route but canceled it in 2003. Hawaiian is the only U.S. airline now flying to New Zealand.

The United flights will complement codeshare partner Air New Zealand's daily service to San Francisco, with total capacity on this route set to rise by 40% after United enters.

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United Airlines will use Boeing 787-8s on its Auckland route, before switching to 787-9s.

The two airlines want to expand their relationship to a revenue-sharing joint venture for the U.S.-New Zealand market. They have preexisting antitrust immunity to cooperate more closely, but this includes certain conditions that would need to be lifted to allow the degree of collaboration they seek. The airlines are applying to regulators in both countries to remove some of these restrictions.

In addition to San Francisco, Air New Zealand has U.S. gateways in Honolulu and Los Angeles, and it is due to launch service to United's Houston hub in December.

While United has more services to Australia than the other two U.S. carriers, it does not have a partner based in that market. There has not been an Australian Star Alliance member since Ansett Australia folded in 2002.

However, Star Alliance CEO Mark Schwab notes that the alliance still has a strong presence in Australia. Aside from Air New Zealand's array of routes over the Tasman Sea, several Star carriers serve Australia, including Singapore Airlines, which is a major player on the "kangaroo routes" between Australia and the U.K.

Schwab says Australia is an important sales point for Star. For example, more of the alliance's round-the-world fares are sold in Australia than in any other country.

Under Review

EC investigates 'alleged anti-competitive behavior' in commercial aircraft maintenance

Kristin Majcher London

At industry trade shows, airlines perennially gripe about original equipment manufacturers (OEM) holding too much sway over the commercial aftermarket—and pricing their products accordingly. But as 7,000 registered attendees gathered in London in October for Aviation Week's annual MRO Europe show, some potentially seismic reverberations were coming from across the English Channel.

The European Commission (EC) in Brussels confirms that it is taking a close look at the competitive landscape for MRO services in the European Union. In a statement, the regulator says it "is closely monitoring competitive conditions as regards maintenance of engines and components of large commercial aircraft."

AIR FRANCE

The EC's scrutiny was first reported by the *Financial Times*.

As part of the process, the EC is sending questionnaires to relevant companies to learn more about how they develop maintenance contracts. Documents seen by Aviation Week say the commission is investigating "alleged anti-competitive behavior" related to MRO services on large commercial aircraft. The documents also reveal that there are at least two versions of the questionnaire, one focusing on engines and the other on components.

Topics the questionnaires touch on include:

- Specific provisions to which companies agree in purchase contracts.
- Reasons why operators would sign maintenance contracts when purchasing aircraft.
- Perceptions about the safety of parts manufacturer approval (PMA) parts and designated engineering representative (DER) repairs, and whether manufacturers have failed to honor use warranties.
- The percentage of airlines' MRO costs for certain equipment taken up by spare parts.
- Documentation needed for MRO, and the extent to which it is shared with non-OEM shops

Two platforms were specifically mentioned: The CFM International CFM56 engine and Honeywell auxiliary power units (APU) and APU starters. Both Honeywell and General Electric—which manufacturers the CFM engines under a joint venture with the Snecma division of France's Safran—confirm they have received questionnaires and are cooperating. Rolls-Royce, which bundles long-term maintenance agreements with nearly 90% of the Trent engines it sells, confirms it too has received a questionnaire. Germany's MTU Aero Engines, which offers MRO services for the CFM56 as an independent provider, says it has not received one. Pratt & Whitney declined to comment.

The International Air Transport Association (IATA) and other trade groups have also received questionnaires. IATA says aircraft MRO represents 10-13% of airline costs, and those costs are rising beyond inflation despite efforts to rein them in. The trade group estimates that a 1% reduction in maintenance costs could mean $800 million in savings for the industry.

"There has been limited entry in the market for MRO services," says IATA spokesman Perry Flint in a statement. "We are encouraged that the EC will give some attention to driving competition and efficiency in this area."

One of the questionnaires the EC is sending to aerospace companies mentions the CFM56 engine. Here a technician works on a CFM56-7 at an Air France Industries' shop.

Ramifications of the EC's scrutiny—if any—remain unclear. The questionnaires are apparently voluntary, and the EC is gathering facts to determine whether to launch a formal investigation. One aftermarket source estimates questionnaires have been received by as many as 100 companies.

Several airlines have been vocal about keeping maintenance costs down. At the World Financial Symposium in Barcelona in September, IATA Director General and CEO Tony Tyler said 20-25% of airline expenses are related to aircraft ownership costs. He even mentioned that IATA was examining options—including legal steps—to help airlines manage aftermarket costs.

"Unfortunately, certain OEM business practices drive up costs by blocking new entry into the market for [MRO] services," Tyler said. "As a result, airlines often have little alternative but to sign on to long-term OEM maintenance and parts agreements containing pricing escalations that are

often above the inflation rate."

This point causes disagreement because airlines do have a choice—and each year more airlines willingly sign onto long-term contracts—especially for engine MRO—which transfers risk to the OEM and provides fixed costs for the operator. OEM parts price escalation varies, but aftermarket sources say 4-8% annually is typical.

While Tyler does not spell out what the anticompetitive OEM practices are, OEMs and their risk-sharing partners are protecting proprietary data more closely than in the past, which means independent aftermarket service providers must pay more to develop repairs, buy test equipment and obtain technical data for maintenance purposes. And in some cases, independents just do not have access to the data.

Some airlines have at times opted for alternatives to using repairs or material from the major OEMs, including DER repairs at independent MRO facilities and PMA parts from other suppliers. But even then, there have been reports that OEMs limit the information included in maintenance manuals—using remove-and-replace instructions instead of providing repair details, for instance—to retain a proprietary edge.

OEMs defend themselves by saying they need to recoup their R&D development, as well as control costs across supply chains to drive efficiencies and manage expenses across high-tech aircraft, engine and component platforms.

Nonetheless, IATA wants action. In fact, Tyler says, "IATA is examining commercial, legal and economic options where we may be able to contribute to efforts to rein in runaway aftermarket-related costs."

At the association's annual general meeting in June, International Airlines Group CEO Willie Walsh said airlines need to start pushing back on costs in areas where their choices are restricted by a limited number of suppliers controlling the market.

"I think as an industry, we need to start taking action, or our maintenance costs will definitely rise," he said. "If we don't challenge the restrictive practices that exist, we will be held captive, and costs, as we have seen before, will rise, and will rise well in excess of anything that is justified."

—With Lee Ann Shay in London

SPACE

Moving Forward

SpaceX designates testing of Falcon 9's new upper stage a priority

Amy Svitak Jerusalem

Space Exploration Technologies (SpaceX) has been known for its extravagant forecasts of the number of missions it can lift in a given year on the Falcon 9 v1.1 rocket.

But in June, when its launch vehicle exploded en route to the International Space Station (ISS), company founder and chief designer Elon Musk said the mishap delivered a blow to the company, which he conceded might have grown too complacent after a string of Falcon 9 successes.

SpaceX is nearing completion of an investigation into the cause of the June launch failure and has said it will debut an upgraded version of the rocket for the return-to-flight mission. But the company's new and healthier respect for the difficulty of the business might explain why it has decided to reverse the order of payloads scheduled for the Falcon 9's return to flight, affording a chance to test the rocket's new and improved upper stage.

In an Oct. 16 announcement, SpaceX says the return-to-flight mission will lift 11 second-generation machine-to-machine satellites to low Earth orbit (LEO) for New Jersey-based Orbcomm, instead of the previously planned SES-9 satellite destined for geostationary orbit (GEO).

SpaceX founder Elon Musk has said the June failure of a Falcon 9 rocket may be a sign the company has grown complacent.

CARLETON BAILIE/AW&ST

"As we prepare for return to flight, SpaceX, together with its customers SES and Orbcomm, have evaluated opportunities to optimize the readiness of the upcoming Falcon 9 return-to-flight mission," the company said in the Oct. 16 statement. "All parties have mutually agreed that SpaceX will now fly the Orbcomm-2 mission on the return-to-flight Falcon 9 vehicle."

The decision is good news for Orbcomm, which will be on the next Falcon 9 launch, tentatively scheduled for early December. The company's OG2 constellation operates in LEO, where a reignition of the Falcon 9 upper stage is not necessary.

"We are excited to launch our 11 OG2 satellites aboard SpaceX's newly upgraded Falcon 9 rocket and have full confidence in SpaceX and their dedication to this launch," Orbcomm CEO Marc Eisenberg says in a statement.

Commercial fleet operator SES of Luxembourg is slated to be on the following flight, where second-stage reignition is needed to deliver its SES-9 satellite to a drop-off point that will allow it to maneuver to GEO.

According to SpaceX's current schedule, a successful early December flight of Orbcomm and demonstration of the upper stage should allow SES-9 to launch in late December.

"The Orbcomm-2 mission does not require a relight of the second-stage engine following orbital insertion," SpaceX says. "Flying the Orbcomm-2 mission first will therefore allow SpaceX to conduct an on-orbit test of the second-stage relight system after the Orbcomm-2 satellites have been safely deployed. This on-orbit test, combined with the current qualification program to be completed prior to launch, will further validate the second-stage relight system and allow for optimization of the upcoming SES-9 mission and following missions to geosynchronous transfer orbit."

The change has no impact on the timing of the Falcon 9's return to flight, "which is still targeted to take place in the next 6-8 weeks," SpaceX says.

In the meantime, SpaceX has still to orbit the U.S.-European Jason-3 ocean altimetry satellite for NASA. Jason-3 is expected to launch to LEO nearly a year late on a remaining v1.1 version of the rocket from Vandenberg AFB in California. However, NASA says Jason-3 will fly only after SpaceX completes to NASA's satisfaction the investigation into the cause of the June mishap.

The Falcon 9 v1.1 vehicle is being phased out in favor of the new, upgraded Falcon 9, which will debut multiple modifications, giving it an overall 30% boost in power. The increase will allow SpaceX to fly its Falcon 9 first stages—including those used to launch missions to GEO—to a landing platform in the Atlantic Ocean for reuse on subsequent missions. This has not been possible with the v1.1.

SpaceX has been cautious about detailing its exact return-to-flight schedule giving dates from no earlier than mid-September to sometime in October and now in early December.

Meanwhile, a revised schedule for 2016 has not been disclosed, although Jason-3 is expected to be one of the first missions. SpaceX has a long list of customers awaiting launch next year, and since the June failure, it now has an extra mission to perform for NASA in 2016, in addition to the commercial resupply service runs it conducts to the ISS.

Opening the Door

China's human-spaceflight plans gain global backing, despite congressional restrictions

Frank Morring, Jr. Jerusalem

China's space program is forging ahead with plans to put its astronauts in space full-time within the next seven years, and the world's other spacefaring nations—except the U.S.—are ready to join in.

The European Space Agency (ESA) and the Russian space agency Roscosmos already have agreements for scientific research on the Chinese space station (see illustration), scheduled to be operational in 2022, and the chief designer for China's human-spaceflight organization says his nation hopes to bring in more international partners for the new station.

On the 16-year-old International Space Station (ISS), China is a participant in the Alpha Magnetic Spectrometer particle physics experiment and has a small commercial payload on board that was brokered by the U.S. company NanoRacks LLC. The head of Roscosmos said during the International Astronautical Congress (IAC) in Jerusalem that he would like to open the station up to participation beyond the original five partners—NASA, Roscosmos, ESA, the Japan Aerospace Exploration Agency (JAXA) and the Canadian Space Agency.

China is developing the Long March 7 rocket, which it plans to use to launch a cargo vehicle for a Tiangong mini space station eventually.

"That is my hope," said Igor Komarov, when asked about a larger role for China on the ISS. "I think that we discuss [this] with our partners, and principally we discuss that it should be open structure, so if there are some requirements we should develop them. And if countries should follow these rules and requirements, then they should have a chance to join us. That is our principal position."

In the view of NASA Administrator Charles Bolden, the congressionally mandated U.S. ban that prevents his agency from cooperating with China is "temporary" and will not necessarily block future cooperation between the two human-spacefaring nations.

"It's important for everyone to understand here today that we have what I consider [to be] a temporary interruption in our relationship with all the potential partners in the work," Bolden told the opening IAC plenary session. "It's not permanent; it's temporary."

Bolden included Xu Dazhe, admin-

istrator of the China National Space Administration (CNSA), in an invitation to an informal meeting of space-agency chiefs on Oct. 11, but the Chinese official did not attend. The meeting was called for ISS partners to hear from "nontraditional partners" on how they might be able to contribute to human space exploration in the post-ISS era.

The NASA administrator says one focus of that meeting was NASA's plan to assemble a modular habitat in cislunar space, outlined in the U.S. agency's new "journey to Mars" report. The report, requested by Congress, describes the 2020s as a time to iron out the systems and skills that would be needed to go on to the red planet. He made clear that there will be a place for China—one of only three nations that has sent humans into space on indigenous hardware—in those long-range plans.

CHINA MANNED SPACE AGENCY

"Someone who follows me will pick up where we left off and where we are now," Bolden says, noting that NASA continues to work with Congress on expanding its Chinese ties. "I don't want anybody to think we're not collaborating with China."

Bolden reiterated the work NASA is doing in cooperation with the Chinese Academy of Science, with the approval of Congress. That includes space-based characterization of glaciers in the Himalayas, and helping with disaster mitigation after the recent earthquake in Nepal. The agency also is in discussions about possible communications and other support for China's planned Chang'e 4 lander/rover mission to Mars.

China is open to partners on its planned space station and enjoys widespread support outside the U.S. for a wider role in international human exploration.

Members of Congress who have used the civilian space agency as a way to protest China's record on human rights have blocked NASA from working with China in most cases, but Bolden has visited the nation twice in his official role.

He says he told his Chinese counterparts any future collaboration must be based on "transparency, reciprocity and mutual benefit."

"We have to be honest with each other," he said at the IAC plenary. "We have to be open; we have to share data. If we don't want to share data, that's not reciprocal, so we took what I consider to be a very tough stand. Our Chinese partners said: 'Sounds good; we can do that.'"

NASA is in discussions about possible communications and other support for China's planned Chang'e 4 Mars lander/rover

ESA Director General Johann-Dietrich Woerner suggested an early practical step to bring China and other nontraditional partners into the human-exploration fold would be advancing work on international standards for docking mechanisms, so spacecraft from different nations can link together in space. The work is moving forward on the ISS, as NASA prepares to send commercial crew vehicles to the orbiting outpost, but so far China has not taken part.

Zhou Jianping, chief designer for the China Manned Space Agency, told an IAC audience that the idea has merit. "I think we should do more," he said of his own agency.

Next year the China Manned Space Agency plans to launch a second Tiangong mini space station for testing with the cargo vehicle—based on its manned Shenzhou spacecraft—that it will use to resupply the station. The cargo vehicle, with pressurized, "semi-pressurized" and unpressurized compartments, will be launched on the Long March 7 vehicle, currently in development. That vehicle is set for its first flight test next year from the new facility on Hainan Island.

The station's "testing core module" is set for launch on a Long March 5—which also may get its first flight next year, also from Hainan Island. "Several" manned Shenzhous and unmanned cargo vehicles will be sent to the core module to iron out the operating procedures before the first two "experiment modules" are launched.

The station will be fully operational in 2022, Zhou says, with multiple experiment racks and a free-flying space telescope that can be serviced from the station. An initial crew of three could be doubled with the addition of more modules, up to a six-module complement.

Both Zhou and Xu say China is "open" to any other international partner on this station. Asked if that might include NASA, Xu said it would be up to Bolden.

"We're open and we hope to bring more people into that scenario," Xu says. "The next part you have to ask him [about]."

Engine Trouble

V-22 mishap leads to tight flight restrictions

Bill Sweetman Washington

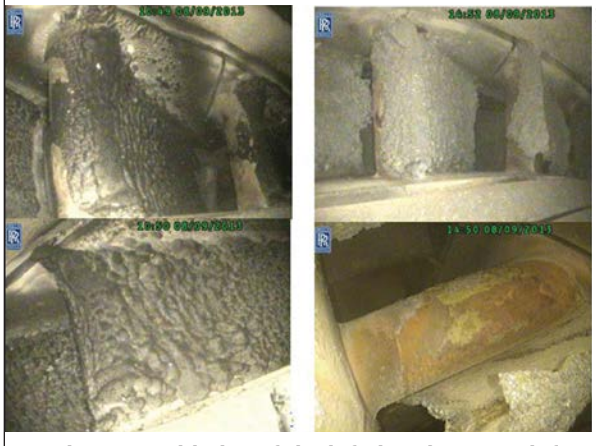
Investigation of a fatal accident in May involving a Bell-Boeing MV-22B Osprey tiltrotor transport points to an undiagnosed failure mode in the Osprey's trouble-prone propulsion system and has resulted in tight restrictions on restricted visibility landing (RVL) operations. The preliminary report findings—disclosed in documents obtained by Aviation Week—also reopen questions about an April 2010 fatal accident involving a U.S. Air Force CV-22B in Afghanistan. In that case, a senior Air Force officer dismissed investigators' focus on engine problems and put blame on the pilots.

A major modification to fix the Osprey's perennial problem—damage to engines caused by the dense and high-energy dust cloud the aircraft creates when landing on any loose surface—is under development, but testing will not be completed until late 2017 and the cost and time required to retrofit the fleet is unknown. The fleetwide engine life remains a fraction of the goal for other helicopter engines. If the problem could be fixed, Bell suggests, it would increase engine life by a factor of eight.

Two U.S. Marines died, and two pilots and 20 other occupants were injured May 17 when an MV-22B crashed while attempting an RVL at Bellows AFS on Oahu, Hawaii. The aircraft was attached to the 15th Marine Expeditionary Unit and had deployed to Hawaii for training May 10.

The MV-22B experienced a compressor surge and abrupt power loss in the left-hand engine at an altitude of less than 150 ft. during the second incursion into RVL for the mission, says a Naval Air Systems Command (Navair) Sept. 9 status report. The V-22's cross-shafting system and pilot inputs kept the aircraft in level flight, but the pilots were unable to control the rate of descent. The second Osprey in the formation also lost power and was a "near-miss" for an accident, the report says. Navair declined to comment on the report or recommendations because the formal mishap report has not been published.

The likely cause of the power loss, according to the document, was that the engine ingested sand containing reactive minerals—classified as calcium, magnesium, aluminum and silicon (CMAS) compounds—which melted in the combustor and solidified on the fixed first-stage turbine vane. This restricted airflow and reduced surge margin, but indications of these conditions to the aircrew "are not sufficient," the report says. Throttle movement can trigger a surge with no other warning.



U.S. NAVY

Turbine vane blades of the left-hand engine (left) of the MV-22B that was written off after an August 2013 hard landing and fire at Creech AFB, Nevada, show the glasslike accretion of melted particles that reduced airflow and caused the engine to surge. The right-hand engine (right) was not as badly affected.

Like many rotorcraft, the V-22 cannot maintain altitude on one engine, or with significantly reduced power, without forward airspeed. In most circumstances the V-22 cannot maintain height unless the rotors are tilted forward, but this requires substantial altitude—this defines a "one-engine-inoperative avoid region" where power loss will result in a forced landing. Also, unlike a helicopter, the V-22 cannot autorotate to kill its descent rate close to the ground.

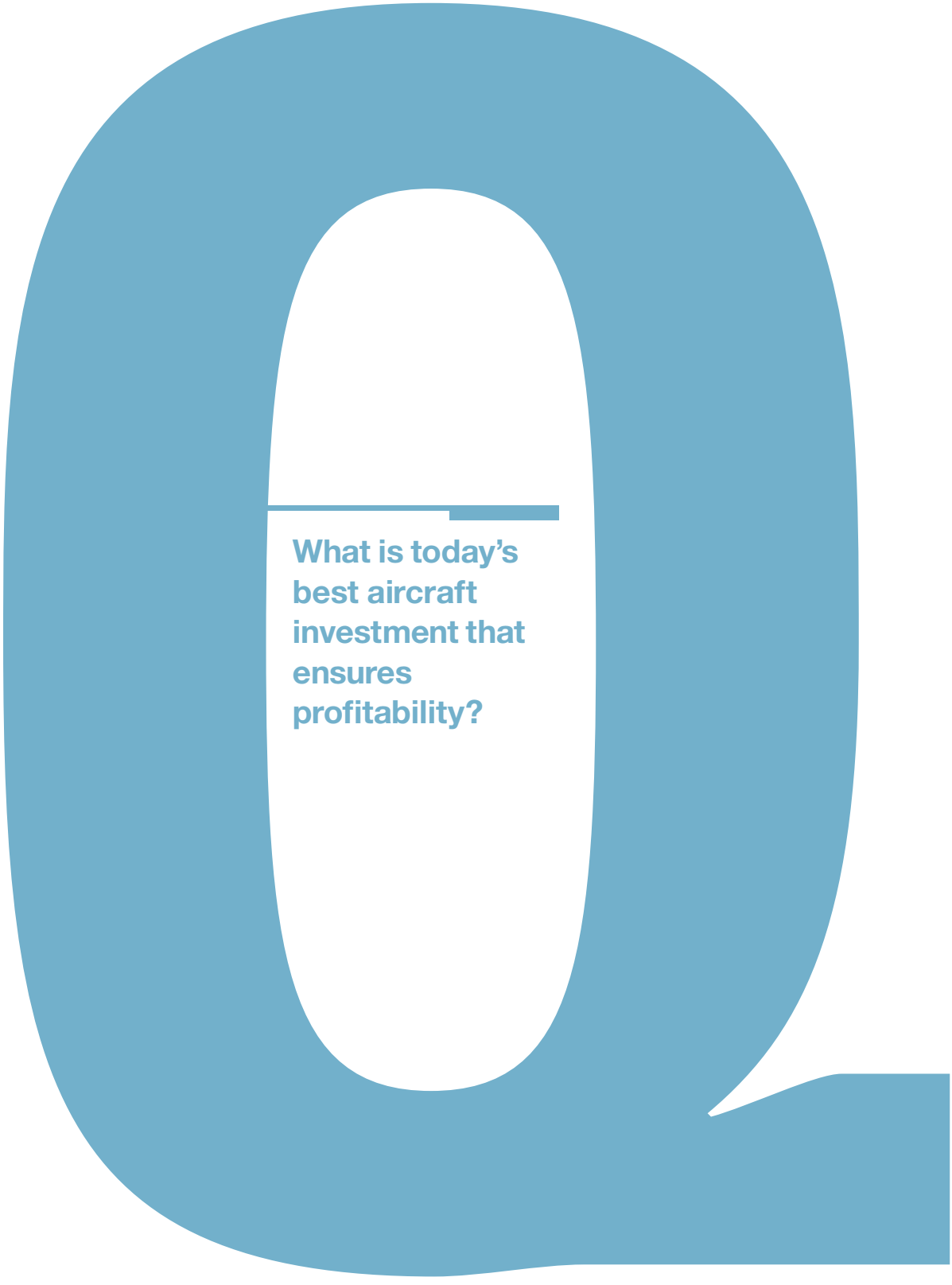
The Navair report identifies three earlier surge events related to reactive sand, one of which—Aug. 26, 2013, at Creech AFB, Nevada—resulted in a Class A mishap and loss of the aircraft in a postimpact fire. In addition, surveys of flight operations have found six more "rapid power loss events" in areas where there is known to be reactive sand.

The problem is compounded by lack of essential data. The Rolls-Royce AE1107C has not been tested for its resistance to CMAS ingestion. The problem is different from the engine's long-running issue: compressor-blade erosion caused by ingested particles, which gradually saps performance until the engine is overhauled. The CMAS content of ground surface material varies from region to region, and the engine surge margin is hard to quantify.

The result, according to another document provided to Aviation Week, is a recommended change to Naval Air Training and Operating Procedures Standardization (Natops) procedures that sets a 60-sec. limit on exposure to RVL conditions per mission. (The Hawaii mishap aircraft was exposed to RVL for an estimated 110 sec.) The limit is to be monitored below 150 ft. and at less than 20 kt. of airspeed, including landing, departure and time on the ground with dust ingestion. (Ingestion on the ground can be avoided by tilting the nacelles to a 75-deg. angle and reducing power.) After the mission, Navair recommends a hot-section engine wash to remove accreted material and restore surge margin.

The newly discovered risk factors in the Hawaii accident parallel known information about the first Osprey combat loss, an Air Force CV-22B that crashed in Afghanistan in April 2010. The investigation was complicated because the pilot and flight engineer were among the four fatalities, the injured copilot had no recollection of the event, the wreckage was destroyed because of its location, and the team that rescued survivors failed to retrieve the flight data recorder.

An investigation board headed by Brig. Gen. Donald Harvel concluded—from video of the accident, rotor strike marks on the ground and other evidence—that the aircraft had experienced sudden power loss, forcing the crew to attempt a rolling landing that ended in a crash after the nosewheel collapsed and the aircraft struck an irrigation ditch. Significantly, in view of the recent findings, investigators noted the left-hand engine air particle separa-



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The original inlet particle separator installed on the V-22 has proved inadequate to handle the dense dust clouds kicked up by the tiltrotor's high-velocity downwash, and a replacement is under development.

tor (EAPS) had failed in dusty conditions shortly before the accident and subsequent to the last aircraft's performance check.

But Lt. Gen. Kurt Cichowski, vice commander of Air Force Special Operations Command, convening authority for the investigation board, ruled engine power loss could not be considered a major factor in the accident, and issued a statement contrary to the mishap report. "The probability of an engine failure, less than 2 sec. prior to impact, was assessed as being highly remote," Cichowski wrote—although this appears to have happened in Hawaii. In a later interview, Harvel alleged he had been pressured to change his findings.

Today, Harvel tells Aviation Week that the new findings are "definitely a possible explanation" for the Afghanistan accident. "They suddenly went into a 2,000-ft./min. rate of descent while less than 200 ft. above the ground," he says.

In the course of the investigation, Harvel says the team studied how the V-22 would respond to a sudden power loss. Even though the pilot commands maximum power, the good engine can only give so much [it is full authority digital engine control-limited], and that power demand does not equate to changing blade pitch," he says. "Instead, the flight control system prioritizes rotor rpm over blade pitch—it will reduce the pitch to keep the rpm up. The next bad thing to happen in that sequence is for the good engine to be tasked so much that it also compressor-stalls."

Problems with the V-22's engine life have been reported since the Marines first took the aircraft into combat operations in 2007. Marine Col. Matt Mulhern, then V-22 program manager, said at a media briefing in March 2008 that the service was dissatisfied with the engine life and "could go as far as reengining the airframe."

The proposal did not go forward, but at a Boeing media event in 2011, Col. Greg Masiello, Mulhern's successor, said that engine time-on-wing in theater was averaging "100-200 hr." The fleetwide average was better, at 560 hr.—but to take one comparative example, the time-between-overhaul goal for the CH-47F Chinook's Honeywell T55-L-714A engine is 3,000 hr.

Today's average time-on-wing is 861 hr., Navair says. However, as Maseillo's comments show, lifetime is heavily influenced by environment and the percentage of landings performed from ships or concrete, which will have varied with fleet size and operational demand.

The U.S. Navy has experimented with MDS Coating Technology Corp.'s BlackGold titanium-nitride coating to extend engine life, but finally issued a request for information (RFI) calling for a replacement engine in August 2014. It is still in work, and General Electric (which produces the only U.S. turboshaft engine with sufficient power, the T408 for the CH-53K helicopter) says that it has responded to the RFI.

Other studies have focused on the EAPS itself, with various modifications being proposed to the hydraulically powered centrifugal system. Because of the V-22's high cruising speed, it cannot use the same type of barrier filters or multitube inertial particle separators used on helicopters. However, its dual rotors and high disk loading create an intense dust-flow pattern that exposes the EAPS to heavy dust flows and overloads it.

The latest attempted fix is to replace the EAPS with an Improved Inlet Solution. Following a demonstration program in 2013, including 55 hr. of flight test, the Bell-Boeing team was awarded a $70 million contract in July 2014 to develop and flight test a new inlet system using oil-wetted, cotton-media barrier filters, but with a bypass door that opens in the cruise. The program is due to be completed in the fall of 2017, after which "a decision will be made as to when and how the retrofit will occur," according to Navair.

Check 6 *Bill Sweetman and Aviation Week editors discuss the V-22's complex history and future prospects.* **AviationWeek.com/podcast**

Rhino Charge

Boeing offers new F/A-18s to fill Navy fighter gap

Bill Sweetman **Washington**

Boeing is offering the U.S. Navy a plan that includes continued long-term production of the F/A-18E/F Super Hornet to alleviate a major projected shortfall in the service's strike-fighter numbers and keep the force capable until a replacement is fielded, in the mid-2030s or later.

The Navy's oldest Super Hornet fleet will reach its 6,000-hr. design lifetime in 2017. The rest of the fleet will follow at approximately the rate they were acquired—around 40 per year—but the Navy can afford 20 Lockheed Martin F-35C Joint Strike Fighters each year, at most, and may buy fewer than that.

To fill this gap, Boeing is inspecting high-time Super Hornets in support of a service-life extension program (SLEP) that would extend the fighter's life to 9,000 hr. But Navy commander for aviation Vice Adm. Mike Shoemaker said in August that maintaining the force through a SLEP alone is "not an inconsequential challenge." If no new F/A-18s are built, rebuilt Super Hornets could account for 60% of the strike-fighter

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The next issue of the MRO Edition will be dated December 7-20.

Waste Not, Want Not

Proving life remaining for an on-condition part can provoke disagreement given its predictive nature.

Airlines could collectively be spending an extra $2 billion on lease return costs by failing to scrutinize redelivery conditions and processes, according to a new International Bureau of Aviation (IBA) whitepaper on redelivery expenditures.

IBA analyzed manufacturer's maintenance planning document (MPD) requirements and found that lessors' requirements often go beyond the airworthiness tasks called for in the MPD, said CEO Phil Seymour, on the sidelines of MRO Europe Oct. 14.

Some of the additional heavy maintenance and engine costs could be paid for via maintenance reserves, depending on what the airline negotiated. (Many large airlines typically do not pay maintenance reserves, in which case they would pay redelivery charges outright.)

A typical narrowbody aircraft such as a Boeing 737 or Airbus A320 on a six-year lease averages $1.65 million in additional costs per airplane, says Seymour. Given that 522 single-aisle aircraft were returned to lessors last year, this equates to $861.3 million last year.

For widebody airliners, the IBA study pegs the additional cost at $3 million for aircraft such as an Airbus A380 or Boeing 777.

Turboprops and regional jets incur an average overpayment of $500,000 per redelivery, according to the IBA survey.

The consulting company's most recent survey broke out redelivery expenses into major categories covering engines, components, interiors, landing gear, corrosion and more.

Engine maintenance accounts for the largest portion of extra cost—at 35.3%—or an average of $350,000 per narrowbody aircraft on a six-year lease, because, IBA says, it is the hardest to manage. "Proving life remaining for an on-condition part can provoke disagreement given its predictive nature. Many leases are written on the basis of no more time since refurbishment than x-amount of hours, or cycles, since that cannot be argued," the consulting firm states.

Components represent 15.3% of the extra costs for narrowbody aircraft redeliveries. Life-limited parts often have to be pulled off prematurely because leasing agreements require ones with more minimal cycles of hours, says Seymour.

Landing gear, wheels and brakes alone can cost an average of $50,000 per narrowbody jet because airlines need to remove these elements early to satisfy lessor's mandates that they have at least half of their useful life left.

Seymour says structural repairs are also problematic—typically because airlines must review old repairs, often without benefit of the original paperwork. "A review of redelivery work packs averages this cost at $150,000 per aircraft" to cover the additional repair, says Seymour.

"Airlines need to manage the redelivery process better," and they should ideally start focusing on redelivery when they are negotiating the initial lease, he says. Planning for an end-of-lease check too late can cause airlines to miss their return delivery and incur months of extra costs.

Given that airlines don't generate high-profit margins, this really is wasted money.

—Lee Ann Shay

Keep up with Shay at **AviationWeek.com/mro** *and on Twitter* **@AvWeekLeeAnn**

Great Expectations

Manufacturers balance stepped-up engines and maintenance needs

Guy Norris Los Angeles

Not since the dawn of the jet age has so much anticipation surrounded the introduction of a new generation of commercial turbofans. Designed to break the paradigm for efficiency, the debutants promise double-digit reductions in fuel burn, as well as an unparalleled single-leap improvement in emissions and lower noise.

CFM

To achieve these significant jumps in thermodynamic and propulsive efficiency, the emerging generation of single- and twin-aisle-aircraft engines employ an unprecedented array of new materials and design technologies. They are also engineered to operate at pressure and temperature levels never before seen in commercial service and yet offer the same, if not better, standards of reliability and time on wing than current-generation turbofans. So how will the engine manufacturers meet the challenge of these seemingly mutually exclusive goals?

Leading the charge in the single-aisle market are CFM International's Leap-1 family and Pratt & Whitney's PW1000G geared turbofan; between them they are in line to power upward of an astonishing 10,000 new aircraft already on order or option. The new-engine field in the growing widebody market is dominated by General Electric's GEnx-1B/-2B and the soon-to-follow GE9X, and by Rolls-Royce with the expanding Trent 1000, 7000 and XWB families.

CFM's Leap family includes the -1A, currently in flight test on the Airbus A320neo, the -1B in test for the Boeing 737 MAX and the -1C in development for the Comac C919. Aimed at the demanding, high-cycle world of the narrowbody aircraft networks, the Leap engine designers worked with a "maintainability team" for the final four years of development, says Gareth Richards, Leap program manager. "As the design went through, they assessed it from a maintenance perspective. It was a very structured process and culminated in development of a three-dimensional view of the engine, which can be used to check access to every part in a virtual reality environment."

The final placement of line-replaceable units (LRU) and features to enable easy access, removal and replacement, was determined in this virtual environment. "You see things [virtually that] are not always obvious when you look at a drawing," says Richards. CFM targeted a "remove/replace" time of 30 min. for most of the LRUs, sensors and other replaceable parts. "The majority met that objective," he adds.

Reliability targets for Leap are based on an enhanced level beyond that of the CFM56. "We have worked hard to improve the design, and we [acknowledge] that the CFM56 has had a lot of time for refinement. We don't get that luxury with Leap. The CFM56 is the industry leader, and we need to match it. One way was to demand a very high reliability specification on our LRUs," says Richards.

Most of the line-replaceable CFM Leap systems are located on the fan case and designed for change-out in under 30 min.

The combined assembly of Leap engine accessories, LRUs, full authority digital engine control (Fadec) and actuators has been put together as a full shipset for a series of systems tests in an aerospace equivalent of a torture chamber in Evendale, Ohio. The testing puts the entire system through a punishing cycle of extreme vibrations, temperatures and humidity levels to simulate continuous operations in harsh conditions. Testing will continue "well into 2016," says Richards, who adds that although individual LRUs and components are subjected to such testing on a routine basis, "this is the first time we've done tests like this as a system."

As part of testing for overall reliability prior to service entry, a complete Leap engine will also be run through

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40,000 cycles before the first enters commercial service in 2016. "We are at around 11,000 cycles, so we are on our way," he adds.

Other design innovations for improved maintenance include an advanced Fadec with enhanced sensing and diagnostic capabilities. "A typical Fadec has the ability to self-test, and we've extended that to all the subsystems attached to the Fadec. We've also replaced switches that measure 'on-off' signals with transducers that can measure more, provide feedback and have no moving parts," says Richards. "These transducers can self-test the system itself so we can tell if a situation is real, rather than being a faulty signal; [we can now] diagnose the engine with a new degree of sophistication."

CFM plans to use the vast amounts of data from these systems to interrogate the operation of the engine in "myriad ways that couldn't be done before," says Richards. CFM is leveraging GE's computer analytics know-how to exploit the data, which will stream off the Leap fleet in ever-expanding volume. "The goal is to have an initial shop visit 20,000 cycles after first run. That's a big number, so the more intelligence we can bring to keep the engine operating successfully, the more we can eliminate maintenance needs."

A related initiative is to use the data to segment the fleet. "One size does not fit all," says Richards, who explains that inspections required for engines operated in one region may not necessarily be required for identical engines operated in more benign environments. "We are connecting the dots on the real way the product is used—not based on the assumption of some engineer. We are putting infrastructure in place to support it with gigabytes of storage on the aircraft and Wi-Fi access at the gate to download the data. We are building an engine with so much data capability that we can't yet even foresee all the situations where it will pay off."

A major design decision driven by maintenance considerations was to locate the accessory gearbox and major LRUs—electronic engine control, hydraulic and fuel-pump systems—on the fan case. "It's not the preferred choice if you are an aerodynamicist, because you'd prefer them to be on the core," says Richards, referring to the design challenge of minimizing the relatively high drag of the newer higher-bypass engines on single-aisle aircraft. However, from an engine-designer perspective, fan case mounting is better because of lower ambient operating temperatures and easier access for maintenance. "We effectively took a penalty for the sake of the customer," he adds.

PRATT & WHITNEY

CFM's debris rejection system also is designed for lower maintenance and improved performance. This system is common to the Leap as well as GE's GE90 and GEnx families, and incorporates a series of variable bleed valves (VBV), which extend into the flow entering the compressor to divert debris into the bypass duct. The fan spinner pushes heavier particles to the outside of the flow entering the core. At lower power during taxiing or reverse thrust, when debris is highest, VBVs open to reject particles to the fan stream, reducing erosion of the compressor blades over time. The VBVs are closed at high power and in cruise to avoid a performance penalty. "Because of that, we've been able to eliminate periodic borescope inspections of the compressor module entirely," says Richards.

The first versions of Pratt's PW1000G GTF are nearing entry into service on the Bombardier C Series and Airbus A320neo, with other derivatives following close behind on the Mitsubishi Regional Jet, Embraer's E-Jet E2 series and Irkut's MC-21. From an MRO perspective, Pratt says the fundamental geared design of the engine holds key advantages. By connecting the fan to the low-pressure spool via a gearbox, the design eliminates several life-limited part (LLP) low-pressure stages and removes 2,000 airfoils as well as offloading the engine core temperature by hundreds of degrees.

Pratt, effectively reintroducing itself to the single-aisle commercial aircraft market with the PW1000G, has taken additional steps to ensure the engine design captures maintenance-driven lessons from as broad a spectrum as possible. "From a line maintenance perspective, we've gathered worldwide operator input to design the GTF's internals and externals to simplify maintenance. Using customer feedback, we incorporated several major features," says Jill Albertelli, vice president of next-generation product family 30K (30,000-lb.-thrust) programs.

Location of flanges, borescope ports, engine externals and layout of bearing compartments were optimized for maintenance prior to launch of Pratt & Whitney's PW1000G geared turbofan.

"Prior to the GTF engine launch, Pratt & Whitney did extensive MRO reviews of best practices [among] our engineering, tooling and support equipment experts," says Albertelli. "We engaged our Columbus [Ohio] Engine Center and Pratt Canada's West Virginia MRO facilities with focused mechanic input. We reviewed the GTF engine design concepts and architecture with each MRO facility. We also focused on engines that they overhaul and looked at what went well and what they would like to see changed in the GTF engines."

Discussions centered on flange locations, bearing compartment layouts, modularity, part repairability, bore-

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scope port layout and overall external configurations, Albertelli says. "While mechanics were performing the work, we were allotted time to witness and assess ease of maintenance, human factor issues, and [talk to the workers]. The team visited multiple repair sites, diving into . . . issues that drive unnecessary repairability costs." The team came away with more than 300 recommendations for the basic engine design architecture, she adds.

Key design features include borescope ports for every stage of the engine, the ability to blend all stages of the compression system on-wing to address damage from foreign objects and a special design for the high-pressure compressor top case, which provides accessibility and allows the removal of fan-exit guide vanes on wing. The company has also validated removal and installation of LRUs with operator line mechanics, and selected a core-mounted accessory gearbox to reduce external part count by 30%.

"From a shop visit perspective, the smaller part count and LLP disk reduction lessen the overall work scope," says Albertelli. Pratt says airlines have long ago stopped questioning the expected reliability of the fan-drive gear system at the heart of the GTF. Exhaustive endurance tests on the gear mechanism and its lubrication system were run on several elaborate rigs; hours and flight loads were replicated, as well as unusual angles and attitudes. "The fan drive gear system [FDGS] is designed to run for infinite life with no life-limited parts," she says. "Our overall objective for the GTFs is to deliver dramatic fuel and environmental savings, up to $1.5 million per year, while maintaining overall maintenance requirements consistent with today's narrowbody engines.

"The FDGS . . . shares an oil system with the main bearing systems. Adding oil to the main oil tank addresses the entire oil servicing requirement," Albertelli says. "Also, we've designed the FDGS for on-wing, simple, borescope inspection, as well as being removable on-wing."

For GTF engines, Albertelli says, there will be a network comprising Pratt & Whitney shops along with multiple partner company setups. Some independents will offer GTF overhaul solutions—for "choice and competition within the MRO landscape."

Pratt says it will include advanced diagnostics and analytics as part of its Big Data initiative to establish a predictive model to monitor engine-event performance. Designed to produce a proactive approach to maintenance planning and requirements, this intelligence is meant to help operators optimize fleet operations and reduce maintenance costs. The Big Data project initially focused on field operational data and system health information data from PW4000; a similar predictive analytics model is being built to support the V2500 engine fleet.

GE

General Electric's new large engines, the GEnx-1B/-2B and GE9X, derive many of their maintenance-oriented design features from the experience gained from the GE90. "The GEnx engine leveraged the GE90 architectural advantage of the [modular] fan and propulsor that allow for the fan to be separated and the propulsor easily shipped for maintenance for lower costs, more flexibility and lower spare engine costs," says Brian Pfeiffer, GEnx customer technical programs and flight operations director. This architectural approach, which was also used for the Engine Alliance GP7200, will also be used for the GE9X, he adds.

After two decades of operations with the only composite fan blades in commercial service, Pfeiffer says fan-set maintenance on GE90/GEnx families remains easier than for engines with titanium fan sets, which require periodic re-lubing of the area around the blade roots, and dovetail fitting in the hub.

Also highlighted is the debris rejection system for maintenance and performance enhancements. The VBV-based system is said to be particularly appealing to operators in more challenging environments.

Special considerations for maintenance were key in designing the GE9X—the physically largest aero engine. Developed exclusively for the Boeing 777X, the 105,000-lb.-thrust turbofan generates less power than the GE90-115B but has a 134-in.-dia. fan, 6 in. wider than the current GE 777 engine. Given customer emphasis on maintainability, "GE has placed a significant focus from the very beginning of the GE9X product design process," says program leader Chuck Jackson.

"This early focus on 'design for maintainability' has let us drive maintainability features into the design, as opposed to working them after most of the product design is finished," says Jackson. "We instituted 'keep-out' zones around critical hardware [like LRUs] in the computer modeling to preserve easy removal. This greatly reduces the work required [from a part-removal aspect] when you need to remove a line component." Regular tasks—fan blade lubrication and engine control system rigging, for instance—also were streamlined or eliminated by accounting for known-wear mechanism or system variations early in the design process.

General Electric's GEnx, like this -1B, benefits from a debris rejection system that spills particles into the bypass duct via a set of variable bleed valves.

The GE9X will be the first high-thrust, large commercial turbofan to make extensive use of ceramic matrix composites (CMC). Lighter than the high-temperature metallic alloys normally used in the hot section, CMCs are expected to help improve fuel consumption. "They also change the game relative to addressing key wear modes, such as oxidation and corrosion, found over time on hot section parts," says Jackson. "As parts made from CMCs do not have the same chemical makeup


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as metallic components, the oxidation/corrosion processes are greatly reduced or eliminated," thereby leading to greater reliability and durability, and ideally, fewer required inspections.

Like other new-generation engines, the GE9X will be a lot "smarter" than its forebears, thanks to additional sensors and built-in self-monitoring systems. "The key feature for the GE9X centers around the ability to predict maintenance activities—what we call analytics-based maintenance," says Jackson. "If we know a particular part will need to be serviced, and we can identify that need well in advance, the airline can then plan for that activity during a more convenient time [e.g., during A checks] or, even better, plan an on-wing mitigation action.

"To facilitate this ability, we are including additional processing capability and sensors on the engine to collect key information on how it is performing. We will then marry this data with our Predix cloud-based computing platform built on sophisticated physics-based algorithms and predictive modeling to produce advance notice," he adds. "These notices are generated on an engine-by-engine basis for each key service requirement."

ROLLS-ROYCE

Rolls-Royce's Trent 1000 TEN and Trent 7000 derivatives will be the first to cluster ducting and pipes on composite rafts mounted for quick removal or inspection on the fan case.

Rolls-Royce also sees inherent maintenance advantages in the baseline three-shaft configuration of its Trent engine family, the latest versions of which are about to be tested for the A330neo, Boeing 787 and A350-1000. Key changes in the Trent 1000 TEN, which will power all versions of the 787 including the double-stretch 787-10, include features derived from the Trent XWB engine, which began development after initial versions of the Trent 1000.

The changes include adoption of a Trent XWB-style "rising line" intermediate pressure compressor in which the aft stages rotate at higher speeds, as well as the introduction of three stages made from bladed disks, or blisks. The TEN also incorporates a modulated turbine clearance control system for better performance retention, and an adaptive high-pressure cooling system, which uses a fluidic control switch to actively match the amount of bleed air to the specific phase of flight.

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based on the TEN, but adapted to work with the new Airbus electrical bleed air system (EBAS) to power the more conventional air-driven cabin systems of the reengined twin. The Trent 7000 already incorporates intermediate- and high-pressure compressor bleed ports to assist with surge margin control; it will be configured with two additional bleed outlets to supply the EBAS.

The low hub-to-tip ratio and static inlet configuration of the three-shaft architecture "helps the upkeep and performance of the core," says Trent XWB marketing head, Tim Boddy. "The arrangement centrifuges out FOD [foreign object damage] and presents less of a target area. Also, because it is a static inlet, we can recirculate core air into vanes and provide a bit of heating into the front of the engine," he adds. The anti-icing function prevents ice formation by ducting bleed air from the intermediate compressor to the core engine section stators. "They help prevent ice breaking off and causing nicks and dings, and provide more protection for the core. This maintains higher performance for longer and reduces the maintenance requirement," says Boddy.

The ongoing trend for larger fans and smaller cores has opened up new "real estate" on the fan case for mounting LRUs. "It moves them to a cooler area, and it is a place where mechanics can troubleshoot issues quickly. We can almost take a Formula 1 [automotive racing]-type approach to enable fast intervention and the replacement of LRUs in 25 min. If you have to change a pump, actuator or solenoid bank, you can do it without having to remove major parts," he adds.

The TEN/7000 will be the first Trent to incorporate composite electrical harness rafts, which are designed to simplify installation and maintenance of the engine's pipes and cables—attached to the turbofan casing. "[A product of our R&D, rafts] hold all the pipes, wiring runs and bracketry together. Using the single raft unit, people can interrogate them quickly via the engine health-monitoring (EHM) system or physically. Just take the raft off and put it back on," says Boddy.

The XWB and latest Trent 1000 derivatives are also the most sophisticated in terms of embedded sensors and monitoring systems. "It's all about prognostics and EHM capability and using it to the best advantage; as we get to the Trent 1000/XWB, we have tried to push the boundaries of what we can monitor," says Boddy. The information will feed our push to utilize Big Data in the maintenance program. "We have [this ability] because we have big fleets with lots of information. [We're looking at] measuring an engine to map normality. Through this process we will gather EHM data for FOD events like birdstrikes and volcanic ash and grit, which are simply a fact of life. They produce nicks and dings on blades that could produce a vibration, so you know something has shifted." Operations-room personnel will then recognize when an event has happened and be able to have tools and spare parts ready when the aircraft reaches its destination, he adds.

The company is also introducing advanced technologies such as on-wing bore blending and automated laser ablation to help speed up and improve maintenance and repairs.

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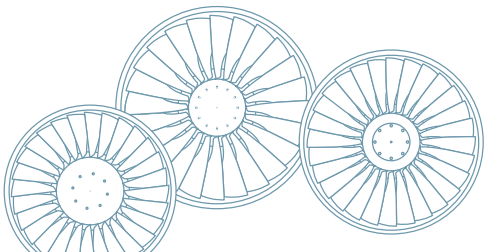

Engineering Overhaul

Qantas reaps benefits from heavy maintenance consolidation

Adrian Schofield Auckland

While an extensive restructuring by Qantas Airways has meant major changes for its engineering operation, the resulting savings have constituted one of the main factors in the carrier's rapid financial turnaround.

The transformation over a relatively short period has been dramatic. Accelerated aircraft retirements have allowed consolidation of heavy maintenance facilities, the engineering workforce has been cut back significantly and efficiency gains have been realized in line maintenance and other areas.

QANTAS

Staff and cost cuts were also made in other parts of the business, helping Qantas reverse spiraling losses. The carrier posted a pretax underlying profit of AU$975 million ($720 million) for the fiscal year ending June 30, an improvement of AU$1.6 billion over the previous year.

Chris Nassenstein, executive manager of Qantas Engineering, says his division has "been right at the heart of the success" of the Qantas transformation program. The carrier "has had to modernize our [MRO] processes and get our footprint right to make sure that we're globally competitive," he says. However, along with the cuts, Qantas has also invested in expansion in some areas, particularly its Brisbane heavy maintenance facility.

As an example of the productivity gains achieved, Nassenstein cites reduced aircraft turn times. "We now have a third of our domestic flights turning around in 40 min. and [next] we're introducing 35-min. turns, which is a significant increase in productivity and has led to record punctuality."

The airline is targeting AU$2 billion in savings from its three-year transformation plan, unveiled in February 2014. Qantas has not detailed how much of the total will come from the engineering division, but it reported that this division accounted for AU$120 million in savings from January 2014-June 2015.

During this 18-month period, Qantas reduced its engineering workforce by 900 full-time positions. Going back further and taking 2012 as the baseline, the division has cut its workforce from 5,500 to 3,400.

The biggest change for the MRO operation has been the consolidation of mainline heavy maintenance. Qantas previously had three bases for this work, at Tullamarine in Melbourne, Avalon to the south of Melbourne, and Brisbane. Now heavy maintenance is performed only at the Brisbane facility.

The first to be phased out was Tullamarine, in 2012. The Avalon facility was closed by March 2014, after Qantas decided to outsource heavy checks for its shrinking fleet of Boeing 747-400s. The Avalon closure was included in the savings estimate from the transformation plan launched earlier that year.

Heavy maintenance for the carrier's Boeing 737, 767 and Airbus A330 fleets was concentrated at Brisbane—although all the 767s have since been retired. Qantas spent AU$30 million upgrading the Brisbane facility to be its primary maintenance base.

The airline is currently conducting two major fleet refurbishments at Brisbane, on its A330s and 737-800s. A total of 28 A330s are to be refitted with new cabins, with 12 completed so far. Each of the aircraft takes three weeks to finish. Some of the work will also be done at the Sydney line maintenance base.

The 737 program is still in its early stages. Out of 67 737s, two have been refurbished, and a third is being worked on now. The cabin refit will include in-flight entertainment content that can be streamed to passengers' devices, except on aircraft that already have seatback screens. An extra row of seats is also being installed.

Recent retirements have left Qantas with 11 747s in its fleet, and Hong Kong-based Haeco has been selected to perform their heavy maintenance checks. The carrier has also contracted to send its Airbus A380 heavy work to Lufthansa Technik at its facilities in the Philippines or in Germany.

Outsourcing Boeing 747 heavy maintenance helped Qantas consolidate its MRO facilities.

In each case, the carrier determined these fleets were too small to justify keeping an in-house heavy maintenance capability for them. However, Qantas stresses it still does most of its aircraft heavy maintenance in Australia, and is the only local carrier that can make such a claim. The airline argues the trend has actually been to in-source, because it made the decision to do the 737 and A330 refurbishment work itself when it easily could have sent it offshore.

"Like any MRO, we need to keep transforming and evolving with changes in the industry, but we do think having the only airline heavy maintenance operation in Australia is a major strategic asset and competitive advantage for us and will be for many years to come," says Nassenstein.

No decision has been made on heavy maintenance arrangements for the Boeing 787-9s recently ordered. Qantas low-cost carrier subsidiary Jetstar has also not decided how it will handle heavy maintenance for the 787-8s it operates. Jetstar has a heavy maintenance facility for its Airbus A320-family aircraft in Newcastle, Australia.

Regional subsidiary QantasLink, meanwhile, is creating a heavy maintenance base in Canberra for its 18 Boeing 717s, due to open in October. The carrier has also expanded its facilities at Tamworth, where it does heavy work on its Bombardier turboprops.

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Chinese MRO looks much more sustainable with slower wage hikes

Bradley Perrett Beijing

A few years ago, anyone with a sharp pencil had to wonder how long China could remain a big player in heavy airframe maintenance. For years, wages had been rising 10% annually. As that rate continued, labor costs doubled every seven years. Even the greatest MRO managers in the world could not deliver equivalent efficiency gains year after year. Inevitably, competitiveness would decline.

The day of reckoning now looks a lot farther off. The economy is slower, competition from other industries is lower, the training system—finally—is more or less meeting the demand for airframe technicians, and wage increases are now probably much less than 10% a year.

Some managers say finding and keeping people with the right skills is now easier. That is consistent with the airlines' view of the situation. For as long as anyone could remember, airlines had been hard pressed to find technicians, but availability seems notably easier, if not exactly abundant.

On the other hand, China's increasingly liberal attitude to licensing airlines is creating a new problem for MRO operators. Every new carrier needs a team of people with key skills—and will pay as much as necessary to get those employees, including in maintenance.

Exact figures for the current pace of wage hikes are unavailable, but Norbert Marx, general manager of Guangzhou-based MRO shop Gameco, estimates it is now only 5% and that it has dropped from 10% about three years ago. Other senior managers in the industry think 5% is plausible, while others place the rate a little higher.

That 5% is an interesting number for a special reason. It corresponds to a common estimate of the rate at which efficiency can be raised—not for decades, but for at least a few years. Output per worker hour in China has never ceased to rise, but there is still considerable room for improvement. Plenty can be learned from high-wage Western Europe, where best practices are essential for survival. If Chinese efficiency gains match wage increases for the rest of this decade, industry profitability will be quite stable.

Two factors may be most responsible for the unaccustomed restraint in Chinese wages. One is that GDP growth—and therefore, roughly parallel, the rate of income rising across the economy—has dropped to, at best, 7%. Historically, it was about 10% a year (in real, inflation-adjusted terms; the amount of yuan deposited in the bank each month for the average Chinese was actually increasing a little faster than that, and thus faster than what the MRO sector was struggling with).

AMECO BEIJING

Skilled technicians are now a little easier to find in China than a few years ago.

The silver lining from slower GDP growth is less disruption for businesses reliant on moderate labor rates. Chinese MRO employees' expectations are no longer advancing as fast. Moreover, other industries, such as manufacturing, are not well placed to throw around cash to lure airframe repairers into, for example, automotive assembly.

A second factor is that the MRO industry is training more people. Demand begets supply, which for skilled labor means schools, especially company training systems. The larger MRO shops in China are each turning out hundreds of graduates a year, fed by universities and technical schools that supply young people who already know a thing or two about, for instance, working with sheet metal.

Aviation remains an appealing industry in China, says Marx. And, although living in Singapore as a mechanic is hard, it can be done in China. "In Guangzhou we can find enough people [who] are interested in the job," he says. Gameco's staff turnover is 4%; a few years ago it was 6-7%.

Location affects staff turnover, however. A senior manager with an MRO operation in well-developed eastern China complains that the appearance of each new airline results in demand for skilled maintenance people. MRO operators can hardly lift workforce-wide wages in response, so every so often a group of important people quits. The problem is not critical, says the manager, but it is more than a mere annoyance.

After several years of restraint, the Civil Aviation Administration of China resumed licensing airlines without government connections in 2013. The policy appears aligned with the liberalizing attitude of the administration of President Xi Jinping.

The senior manager estimates industry-wide wage growth at 5-10%, perhaps about the middle of that range. Less positive about the labor market than others, he does not see a trend improvement in the supply of skills.

Labor rates are far less of an issue in the capital-intensive engine maintenance business. In recent years, MTU Maintenance Zhuhai has been able to hire enough employees, says CEO Frank Bodenhage. The company has not needed to hire many people, he adds. "There are, of course, differences from skill to skill and position to position, with highly skilled and experienced people being the most difficult ones to find."

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Open Market

With the largest airline market in Southeast Asia, Indonesia has only one major MRO provider

Leithen Francis Jakarta, Indonesia

Indonesia only has one internationally certified MRO provider, even though the country is the largest airline market in Southeast Asia.

The country had 58.9 million domestic and 13.7 million international passengers last year, representing year-on-year growth of 6% and 5%, respectively, according to Indonesia's central bureau of statistics. The Aviation Week Intelligence Network (AWIN) database shows that the country's top 10 commercial airlines have a total fleet of 455 aircraft (see graph on page MRO 19). There are also a large number of aircraft on order for Indonesian airlines, such as 306 Boeing 737s and 269 Airbus A320-family aircraft, according to AWIN data.

Garuda Indonesia's MRO company, GMF AeroAsia, is the only airframe and engine-overhaul facility in Indonesia with European Aviation Saftey Agency (EASA) and FAA certification. The company established its own Part 147-approved training organization in 2009.

Richard Budihadianto, president director of GMF AeroAsia, says many Indonesian carriers send their aircraft and engines overseas—to places such as Singapore and Malaysia—to be overhauled. But that is more expensive and is a lost opportunity for Indonesia in terms of jobs and work.

There are 60-70 aviation MRO companies in Indonesia, says Budihadianto, who is also chairman of the Indonesia Aircraft Maintenance Services Association (Iamsa), which represents about half of the country's MRO providers. Many of these cater to the business aviation and general aviation sector.

Iamsa has been encouraging MRO companies in Indonesia to apply for EASA and FAA certification, because it can see that in the future more customers will insist on this, says Budihadianto.

WIKIMEDIA COMMONS/DMITRY PICHUGIN

Sriwijaya Air and other Indonesian carriers can turn to only one in-country airframe and engine MRO provider. Sriwijaya operates 46 aircraft, such as this Boeing 737.

But most MRO companies in Indonesia have failed to act because they are very focused on the domestic market and their customers are happy enough with Indonesian Directorate General of Civil Aviation (DGCA) certification, he says.

However, there are many leased aircraft in Indonesia and foreign leasing companies generally want their aircraft maintained at FAA- or EASA-certified MRO companies to retain the highest residual value of their assets.

A stumbling block to EASA and FAA certification is that it costs money. "In Indonesia not many of the MRO companies are big enough to cover the cost of the audit. For big MRO companies, spending $50,000 on an audit is all right. But for some MRO companies that it is a very big amount," says Budihadianto.

There is also the issue—particularly in the case of the FAA—of whether the agencies would actually be willing to come to Indonesia and audit a new MRO provider. In recent years it has been hard for MRO companies outside the U.S. that are not already FAA-certified to receive FAA approval. Some have attributed this to U.S. protectionism and caving in to U.S. unions, while others have said the FAA may be unable to certify more overseas MRO companies because of funding constraints. For a few years, the U.S. Congress also banned the FAA from issuing new foreign repair station certifications due to security rules.

Budihadianto says FAA certification is hard to get. He says if the FAA approves an overseas MRO provider then it is responsible for oversight of that company, which means more work and costs for the FAA.

Another impediment faced by Indonesian MRO providers is inadequate airport security. Regulators require MRO companies to be located at an airport with adequate security and where unauthorized personnel have no access to the runways. But there are airports in Indonesia where, for example, the runways and taxiways need to be improved and new perimeter fencing needs to be built.

"Airport infrastructure development is on the government's agenda. They have decided to build new airports and improve old airports to meet international standards," says Budihadianto. But he adds: "We have around 300 airports in Indonesia already and with a limited budget, the authorities have to prioritize which ones to develop and improve."

He thinks the government should work with the private sector to develop airport infrastructure through public-private partnerships. In some countries, such as India, private companies have paid for new airports with the stipulation that they will operate the airport for 30 years, after which it will be returned to the government. All of Indonesia's major airports, with the exception of Batam's, are controlled by state-owned Angkasa Pura I and II.

GMF AeroAsia is based at Indonesia's main international gateway, Jakarta's Soekarno-Hatta International Airport. Aviation Week spoke to Budihadianto in his office beside GMF's fourth hangar, which has just been built and can accommodate 15 narrowbodies simultaneously.

The hangar was constructed relatively quickly. Indonesia has no shortage of building laborers or materials, but obtaining approvals from the authorities to build the hangar took a long time.

Rather than rely solely on its Jakarta base, GMF AeroAsia is working with Singapore-based Gallant Ven-

ture, which has a concession to build an airport on Indonesia's Bintan Island, a short ferry ride from Singapore.

Budihadianto says the airport on Bintan is due to open in 2017, and GMF AeroAsia plans to build a hangar there. It chose Bintan because it is near Singapore, and the developer offered GMF AeroAsia plenty of suitable land.

Many OEMs, such as GE and Pratt & Whitney, have component repair shops in Singapore. Specialized components often have to be sent to the OEM for repair, so it is easier if the MRO facility is located near the OEM's.

GMF AeroAsia could have chosen to build its hangar on Batam Island, which has an airport and is also a short ferry ride from Singapore. But Budihadianto says the Batam authorities were unable to provide enough land.

One issue GMF AeroAsia will confront with its new MRO facility on Bintan Island is finding enough maintenance engineers and technicians to staff the facility. Boeing has forecast that Southeast Asia will need 60,000 new technicians over the next 20 years.

Budihadianto says GMF AeroAsia already has started recruiting and training people from Bintan for these positions. It takes a long time to complete training, and the plan is for these technicians to start work at GMF AeroAsia in Jakarta. When the facility opens in Bintan, they will be transferred there, he says.

"New training colleges have been established in Indonesia, but not as many as we would have hoped. The growth in capacity of the schools, such as state-owned Sekolah Tinggi Penerbangan Indonesia (STPI) in Curug, is very limited. This has created an opportunity for new schools, but we still can't get enough. So we set up our own training organization, which was approved in 2009," says Budihadianto.

"GMF now has the largest training organization in Indonesia for engineers and technicians. But we discovered that we can't continue to do it on our own," he notes. "We can continue to train technicians, but not licensed maintenance engineers, because that takes a lot of time. In 2012, we decided to try to shift activity to educational institutions that we would then help to turn into DGCA-approved schools."

Budihadianto says they are working with seven polytechnics and two universities. "We're working with them to help them get approval as a Part 147 training organization. Our aim is to get the first school approved in the next two years," he says, adding they are already training the course lecturers so they can be qualified as licensed maintenance engineers.

Budihadianto says one of Indonesia's edges is its large, young population. "This is our advantage and strength right now. Indonesians aspire to work as maintenance technicians. If you look at our population over the next 10 years, you can see that more than 50-60% will be productive young people. These young people will need jobs."

Another challenge Indonesia's MRO sector faces is retaining its skilled personnel. Once Indonesians gain an internationally recognized qualification, some go overseas, where the pay is higher.

Budihadianto notes that Indonesian-licensed engineers who leave tend to go to the Middle East but eventually return. "Indonesian people generally don't like to stay abroad. They go overseas to work because they have to," he says. "For example, maybe they need to earn more money to pay for their children's university education. But once that is completed, they come back."

He also says having many Indonesians working in the airline industry overseas does have its advantages. "We stay in contact with them, and they help us to find out about projects that we can bid on," he says. The markets that GMF AeroAsia is targeting mostly are for third-party MRO work in the Middle East and India, he adds.

Indonesia's Top 10 Airlines by Number of Aircraft

Source: Aviation Week Intelligence Network. Aircraft in service Sept. 30, 2015.

Engineering One's Future

Singapore diversifies with more manufacturing

Leithen Francis Singapore

Singapore's MRO sector is seeking to remain competitive by moving up the value chain and conducting more design engineering work and manufacturing.

The city-state has difficulty recruiting technicians locally because Singaporeans generally gravitate toward higher-paying, higher-skilled MRO jobs such as engineering.

The country has overcome its immediate shortage of technicians by supplementing its workforce with overseas technicians, mostly from China and the Philippines, on temporary contracts.

But this is hardly a long-term solution, and with more MRO companies in lower-cost countries offering airframe heavy maintenance it is becoming harder for Singapore's MROs to compete.

MROs here are responding by moving into market segments that are less price-sensitive and where they can add value.

ST Aerospace, one of the world's largest third-party MROs, is taking that route by expanding its passenger-to-freighter conversion business. The company recently launched the A320-family passenger-to-freighter conversion program with Airbus. ST Aerospace already has an agreement with Airbus for A330 passenger-to-freighter conversions, and it performs conversions for Boeing 757s and 767s.

For the A320 program, "Airbus will provide us with the data and we're the one doing all the engineering work," says ST Aerospace President Lim Serh Ghee.

ST AEROSPACE

ST Aerospace is expanding its MRO capabilities to include VIP completions and A320 cargo conversions.

Airbus, which has dedicated a large portion of its engineering resources to new aircraft programs, was pleased to partner with ST Aerospace to supply the engineering manpower needed.

"We have a very strong engineering capability compared with other MRO companies. The engineering capability puts us above [them]," says Lim.

He also says the passenger-to-freighter conversion business helps the company gain even more airframe heavy maintenance work because heavy checks can be done concurrently with the freighter conversion.

"The initial work on the A320 passenger-to-freighter conversion program will be done in Singapore, but the work can actually be done at any one of our facilities worldwide," namely Singapore, China and the U.S., says Lim. "One of our advantages is our geographic spread. We can do the conversion [near] wherever the aircraft are."

The first A320 converted freighter is scheduled to go into service in early 2018, says Lim, who declines to name the launch customer.

ST Aerospace—through the auspices of Germany's EFW, of which it owns 55%—is responsible for the A330 passenger-to-freighter conversion program. The launch customer for the -200 model is EgyptAir; it holds a firm order for two and options for two more. Entry into service is slated for the end of 2018.

But the -300 model is due to enter service in 2017; ST Aerospace has yet to announce the launch customer. Lim says, "We're in discussions and hoping that by year-end, or the first quarter of next year, we can announce who it is."

Another high-value area in which the company hopes to expand is the business aviation sector, particularly maintenance and VIP configurations.

ST Aerospace owns Aeria Luxury Interiors, a U.S.-based VIP configuration company, as well as DRB Aviation, a U.S. company specializing in design, program management and certification of aircraft interiors, avionics and structural repairs.

Lim says ST Aerospace is in the process of establishing a business aviation aircraft interiors business at Singapore's Seletar Airport, where it will use one of its existing hangars. The company is drawing on its U.S. experience to succeed in this segment in Asia.

The volume of work is less compared with upgrading interior cabins for commercial airlines, but the margins are much higher.

Lim says they have yet to officially launch the business at Seletar because they want to "spruce up the hangar" to have a showroom for business jet customers, but the facility has already performed maintenance and minor modification work on business jets operated by some of Singapore's casinos.

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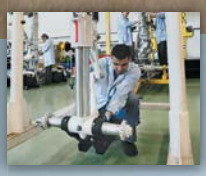

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ST Aerospace decided to make this move because of the many high-net-worth individuals in Asia who were sending their aircraft to Europe and the U.S. for maintenance and modification work.

"But we know they will be attracted to a facility in Asia that is reliable and dependable," Lim avers.

Singapore's reputation for reliability and dependability has attracted many original equipment manufacturers to establish MRO facilities in Singapore.

Pratt & Whitney, for example, has several engine-overhaul as well as component-repair facilities here.

Kevin Kirkpatrick, Pratt & Whitney director of aftermarket operations-Singapore, says his company chose to do business here because "the pool of talent is very strong; English is widely spoken; and there is a good education system and logistics infrastructure to support the MRO industry."

He also says Singapore is business friendly and has an excellent legal system in place.

Many of Pratt's MRO facilities here don't just serve the region but the global market as well, says Kirkpatrick, who cites as an example the Eagle Services Asia (ESA) business, which is the only PW4000 MRO facility in the world. PW4000 engines from around the globe are brought into ESA, disassembled, worked on and then reassembled.

After the engine is disassembled, the different bits are sent to specialized component and parts repair shops that Pratt and its major suppliers have in Singapore. Some PW4000 cases and some life-limited parts may be sent overseas, but most of the components and parts are worked on here.

One of the country's key advantages is that because the MRO industry has developed to such an extent, most of the work can be conducted here, eliminating the need to send so many component and parts overseas.

Singapore is also moving up the value chain by taking on more manufacturing work. Pratt has established a factory here that will manufacture GTF fan blades and turbine disks. It is one of only two sites in the world that will produce GTF fan blades—the other is in Michigan.

Kirkpatrick says the facility in Singapore has yet to make any GTF fan blades for production engines, "because it is still coming up to speed on the machining," but the plan is for the facility to complete its first machined blade for a production engine by year-end; at that point, the facility will need to master blade assembly. The assembly process includes, for example, the application of coatings and production of titanium leading edges. The assembly-process milestone will be achieved early next year, says Kirkpatrick.

Another aspect of the engine business that Pratt is working on here is Big Data. Kirkpatrick says Pratt & Whitney, tech giant IBM and the Singapore Economic Development Board are jointly pursuing how Pratt's MRO companies can make better use of data—to track parts and inventory—when managing the volume and movement of engines through an MRO facility. He says this is a very important initiative because Pratt forecasts that the volume of engines going through its MRO facilities will increase dramatically as the GTF engine type becomes more prevalent.

PRATT & WHITNEY

Kevin Kirkpatrick Pratt & Whitney aftermarket operations director, Singapore

Singapore is also an important MRO center for Rolls-Royce. The engine maker has two MRO facilities here, both of which are joint ventures with SIA Engineering—Singapore Aero Engine Services and International Engine Component Overhaul. The latter serves the global market.

Jonathan Asherson, Rolls-Royce regional director for Southeast Asia and the Pacific, says there are 1,200 employees within the two MRO joint ventures and a further 800 at the engine maker's manufacturing facility at Seletar Aerospace Park.

Singapore is Rolls-Royce's global production center for assembly and testing of Trent 900 and Trent 1000 engines. It also manufactures fan-blades in Singapore for these engine types and others.

Because the Rolls-Royce factory is in Singapore, its suppliers have set up shop here as well. U.K.-based RLC has established a facility next to the Rolls-Royce fan-blade factory, to which it will provide titanium sheets.

Singapore company Wah Son has also established a new factory at Seletar. It makes tooling such as engine stands that it supplies to Rolls-Royce.

The British engine manufacturer also announced in August that Malaysian manufacturing company UMW has won a contract to supply fan cases for the Trent 1000.

Asherson says Rolls opted to open a factory in Singapore for several reasons including: access to a skilled workforce; solid national infrastructure; respect for intellectual property rights and other legal ramifications of conducting business; a minimum of red tape; and "investment support programs, including incentive-based setups, through the Singapore Economic Development Board."

Rolls-Royce also values Singapore as a center for research and development. It has a technology center here and works with the national Agency for Science, Technology and Research as well as the National Technology University (NTU) and National University of Singapore.

"We are developing new repair techniques. For example, we are looking at ways to automate the preparation process that fan blades require before undergoing repair. Also, when we apply coatings on some engine parts, we need to mask certain sections of the part. We are looking at ways to automate that process."

Asherson says some of the research projects Rolls-Royce is working on with NTU include: power electronics and controls, computational engineering, and precision manufacturing.

Rolls-Royce recently established a customer service center here for the Asia-Pacific region, the first of its kind, according to Asherson. He says the company is now looking at establishing other centers in other parts of the world, such as North America and the Middle East. "These centers are able to engage customers on a technical level. The centers encompass engine health monitoring, fleet planning and operations planning," and other areas of interest.

LHT: A View From the Top

Johannes Bussmann became chairman of Lufthansa Technik's (LHT) executive board in April, replacing August Henningsen, who retired. Bussmann joined LHT in 1999 as a development engineer, and most recently oversaw human resources, engine and VIP services, beginning in 2012. He spoke with Lee Ann Shay about his aspirations for the MRO.

MRO: What changes are you planning for Lufthansa Technik's strategic vision?

Bussman: August Henningsen and I worked together on the board for almost three years, so we have already determined a new strategic approach. The main targets will remain but we also want to grow stronger in the Asia-Pacific and Americas regions. One good example is the Puerto Rico facility we will officially open in November.

How is the Puerto Rico operation going so far?

We are very proud that from groundbreaking to the first check only took 11 months. Already we have a couple checks running through to ensure everything is properly working and to see what changes will speed up this process. We are very happy with the performance there, and have lined up a good local workforce who are currently training at our facilities around the globe—so the international training puts us in good shape. Puerto Rico is running fine but to be honest, for a fair assessment we have to wait until the first 20 or 30 checks have gone through there smoothly.

Globally, how full are your hangars and are you anticipating further capacity expansion?

I think that worldwide there is an overcapacity of hangars—I don't think the problem is that we don't have enough. The main difference is how they are run. For instance, look at efficient car manufacturing production plants. MROs that have just one or two lines probably don't make sense. More carriers with big fleets want to buy complete lines. The tenders for single checks are dwindling. We are seeing bigger projects in the market.

LUFTHANSA TECHNIK

Are more carriers committing to longer-term contracts?

That's what we would like to see in the market. But bigger airlines will not put all their eggs in one basket. I wouldn't do that myself. But I'm very sure that providers that can truly offer three or four lines exclusively for bigger projects will succeed in the long run if they give the airlines the flexibility they need for the usage of their aircraft and for rescheduling their flight plans, but that is hard to do if you have less capacity.

What are your expansion plans in Asia and how does Ameco fit in?

Air China wanted to integrate the Air China Technics group with Ameco. We have found a new stable setup for Ameco if the transition is performed. We are in the midst of the process, including technology transfer.

It is a partnership we have run for many years and we want to maintain it. The investment Lufthansa has there did not change on an absolute basis, but via integration of Air China Technics a lot of line maintenance capabilities came to the new Ameco.

So that is why we hold our absolute investment, but it leads to a dilution to 25% from 40% as the line maintenance was added because it is a big portion of the integration. The capabilities are not changing, but we modernized the management structure. Historically the management positions were shared between Chinese and German colleagues—and now Ameco will either be led by a German or a Chinese colleague.

At LHT Philippines, the [Airbus] A380 expansion should open in November. And there are other carriers outside China and the Philippines that could have an interest in working with a partner, which offers further possibilities. Talks are ongoing, and if things go well, we might find another location in Asia.

What other joint ventures would you like to establish, and will there be changes to your engine MRO network?

In the next decade or two, there will be a big swing in the engine MRO market. If you look at the sales numbers of the OEMs—they hold 50-60% of the aftermarket at the point of sale already. So that means for an MRO that the accessible market in a traditional perspective, with airlines as the direct customer, is smaller—at least for the first life of the engine. But that definitely means cooperation among bigger MROs and OEMs becomes more important. That is one of the main reasons we teamed up with GE.

The risk portfolio they take under their wings when they sign aftermarket contracts makes a good fit between partners because their traditional model is changing, too. They have to keep repair costs in line with the contracts they sign—and that is the experience LHT brings to the table. For older engines and those working under the traditional mechanisms, that is stable.

How will repair development work with the new GE joint venture?

We will have joint efforts with engineering teams and the experience we gain from the existing engine models—so it is not that we will be starting anew—we've had engineering teams working together for quite a while. But now they will be doing it for the benefit of

the same company, which should speed up the process and get more things on the table. Because intellectual property is now shared, this makes things a lot easier. That's how we will run the joint venture and why we will have an almost equal share, because that is our understanding of cooperation.

How do you decide when to cooperate and when to compete with OEMs?

It depends. Take the engine side as an example because it illustrates what is happening. The market structure changes and it is very hard for an MRO other than the OEM to make all the investments. Because of the increased reliability of the aircraft and engines—and longer time on-wing—you need more and more business to gain the scale. And IP is completely different. We're not talking about 10-15%, we're talking about times two, times three, times four. And on the components side, times 10.

So for smaller facilities—10-15 years down the road, it can't be economical. If you don't have the scales, you will not be participating in the market.

That's one side, so we make a judgment [as to whether] there is an economical market. If there is, we go for it. For someone deep in the technology already, the investment is less than for someone coming to it new.

The other factor is that if the OEM is a potential customer itself, they hold a lot of signed contracts; from that perspective they have a lot of risk in their portfolio. We have had, for many decades, a different approach to repairs and on-wing services, for example, because we look at it from an airline's perspective. We know from our maintenance staff every day what problems are encountered and what materials are used.

So if the OEM is interested in the experience we bring, it is a win-win situation—as long as there is an openness about cooperation and [melding] these things together. If so, we can cooperate, but if it doesn't coalesce, then we compete.

Most engine OEMs are making bigger strides to provide services for mature engines. Do you agree with that approach?

It means a big change for them with all the surplus parts on the market. We watch this closely too, because it also drives the work we do here in the shops. We use more surplus than we did in the past because the surplus prices can compare to the repair prices—so we balance repairs, parts and on-wing time. Whatever is more reasonable will be performed. And some customers change engines to avoid shop costs [and] save money—or do a dedicated workscope to meet the end-of-lease requirements, or whatever the needs are.

With the increased surplus in the market you can request parts with 1,000 more cycles. A decade ago, it was hard to generate that much surplus to have the freedom to decide that. And I think the thing that will definitely increase are on-wing services, with the increased number of flat-rate contracts out there with the intent to avoid shop visits. Shop visits 95% of the time are more extensive than doing the same thing on-wings.

On-Field Action

Mobile repair options could clear logistics and materials headaches

Paul Seidenman and David J. Spanovich San Francisco

AMERICAN AIRLINES

When a severe hailstorm hit the Dallas area in 2013, American Airlines took a major hit. In less than 1 hr., 103 of its aircraft, including McDonnell Douglas MD-80s and Boeing 737s, 757s and 767s, sustained damage at the carrier's huge Dallas/Fort Worth International Airport hub. The storm not only affected metal fuselages and wings but also composite panels and flight controls.

"We took about 40 mechanics and a team of about 10 composite repair specialists to Dallas to inspect the damage," says Kevin Ferrin, technical supervisor for aircraft maintenance at American's Tulsa, Oklahoma, MRO complex. "We did temporary repairs to the composite panels where we could, and replaced some flight controls where the damage was too extensive. In some cases, we removed the composite flight controls and composite panels, which were then sent to our composite shop in Tulsa for repair and return to the aircraft."

Ferrin says some of the temporary repairs were approved by American's engineering staff, and some by Boeing, for continued use of the airplanes in service until their next C-check. About 75% of the affected aircraft were back in revenue service within 24 hr., although five were grounded for about 10 days due to the extent of the damage or the need to wait for repaired parts.

Composite structure field repairs "present all options including on-site work on the damaged area, change-outs, and in some cases, ferry flights to a maintenance facility," Ferrin emphasizes. In cases of change-outs, American maintains inventories of spare composite structures, primarily at its "Class One" (largest) hub stations at Dallas/Fort Worth, Miami, and Chicago-O'Hare, he says.

"American is very fortunate to have a well-trained composite maintenance group, but with deliveries of our new 787s, there will [at some point] be repairs that even we haven't done," he says. "This will require us to learn new repair concepts."

However, because the carrier's engineering group started preparations for the 787 a year before it went into service at American in 2015, the airline is "well-prepared" to handle in-house much of the potential damage that could occur. "Any extensive damage to the fuselage may still require bringing in Boeing to accomplish the repairs," Ferrin says.

American has 42 787s on order, including 20 787-8s and 22 787-9s.

When it comes to composite repairs in the field, airlines "could be presented with a huge logistical problem," says Jim Epperson, senior manager, global customer support services for Spirit AeroSystems. The Wichita-based company is a supplier of complete composite nacelles, nacelle

A composite component is being positioned within the autoclave at American Airlines' composite repair shop, at the airline's Tulsa, Oklahoma, maintenance complex.

panels and composite thrust reversers used on Boeing airliners and more recently the nacelles for the new Gulfstream G650 business jet.

As Epperson explains, getting the materials and repair equipment to the aircraft is one of the biggest challenges maintenance technicians face. This is complicated further by the fact that the materials have a limited shelf life—up to about one year for prepreg materials that in many cases require cold storage at temperatures ranging from 0F to -20F.

"When the material needs to be used, you have to take it out of the freezer, thaw it, cut the quantity you need, rebag that and transport it to the aircraft—keeping in mind that the material will have a limited life at room temperature," he says. "If the material has to be shipped to an international destination, it could be delayed at customs, which could lead to spoilage prior to customs clearance."

Epperson also points out that there are more mechanics trained to repair metal structures than those qualified to do the hot bonding required for composites. "And when you also add in the need to do nondestructive testing as part of the repair process, that takes another skill set," he says.

Spirit AeroSystems addresses these issues by positioning nacelles and nacelle components at strategic global locations, and by dispatching aircraft-on-ground teams. But as Epperson notes, there are times when an interim repair may still be required in order to ferry the airplane to where more permanent, complex repairs can be done.

"A good example of an interim repair is a bolted-on sheet metal patch. Although we normally don't like to do this, because when you bolt metal onto a composite structure, it does additional damage," he explains. "However, another repair method we could use in preparation for a ferry flight is a wet layup, which uses an epoxy material mix and a dry fiberglass or graphite patch that is layered on. That is allowed to cure for a couple of hours, at room temperature—up to temperatures [as high as] 150F. It's a quick way to do a patch for a ferry flight that doesn't involve hot bonding, which takes about 5 hr. with temperatures of 250F."

Fortunately, the trend is toward repairs in place. Henrik Schmutzler, an innovation engineer at Lufthansa Technik in Germany, reports the company is offering "an increasing

SPIRIT AEROSYSTEMS

A Spirit AeroSystems technician performs composite repairs to a thrust reverser.

number of mobile repair solutions" for composite structures. "Most complex repairs are being developed in a manner [so they can] be conducted onsite in the future," he says. "For example, infusion as substitution for wet layups offers significant advantages for in-field repairs. Furthermore, we are introducing a mobile scarfing system that will enter service in 2016."

Ed Montalvo, an aircraft maintenance supervisor at Southwest Airlines in Dallas, says the carrier has a number of options available for field-level composite repairs, as specified in the Boeing Structural Repair Manual (SRM), for its all-737 fleet.

"We have been able to perform [most of] the repairs without taking the aircraft out of service or delaying it for a significant period of time," he says. "If we find that the problem has not been addressed in the SRM, Southwest's Structures Engineering Group, which is well-versed in composite repair issues, will design a repair that will be sent to Boeing for approval."

However, as Montalvo points out, most composite repairs resulting from damage in the field are "carryovers," which means the damage is so minor repairs can be carried over to the next scheduled maintenance event. But if the damage is more severe and cannot wait for a scheduled check, the repair has to be done in the field. This, he says, mandates a clean working environment.

"In the field, even when a hangar is not available, you have to make the extra effort to create a clean working environment, according to what the OEM's SRM dictates," says Montalvo. "In some cases, it means you have to improvise some kind of shelter, which our technicians have had to do at times. One way this has been done is to create a tarp using plastic sheeting, which can be positioned over the damaged area, once it has been cleaned."

However, even with a tarp in place, ambient temperatures could preclude an outdoor repair. According to Montalvo, if outside temperatures are less than 50F, a heated area is mandated. "Under cold-air conditions, you have to have a hangar because it becomes difficult for a hot bonding machine to generate the temperatures—200-350F—to carry out the repair."

Montalvo cites continuing developments at Boeing in the direction of new composite repair schemes that will enable operators to get aircraft back into service faster. "We would like to see more composite repair that can be accomplished during an overnight check—within 8 hr. or less," he says.

In fact, Epperson predicts composites incorporating even greater damage tolerance will make their way into large airframe structures, such as wings and fuselages. However, he cautions that repair-process requirements will likely become much more stringent, given the more complex material formulations that will be involved.

"There will be increased requirements associated with analyzing the damage location and the criticality of the condition of the support substructure at that location on the aircraft," he says. "The problem is, most airlines today do not have the composite material design allowables data—often proprietary—to be able to proceed with an analysis of their own. That will drive the airlines back to the OEM for approval of the repair size and repair approach methodology."

GIMME SHELTER

Paul Seidenman

Composite repairs demand a clean environment, for which humidity, dust and temperature control are critical. Buildair of Spain and J.B. Roche of Cork, Ireland, see portable, inflatable and reusable shelters as the solution.

"The shelters, once inflated, are totally supported by air at low pressure, making them safe for aircraft and maintenance personnel," says Ian Nagle, managing director at J.B. Roche.

Even a hangar may not provide a sufficiently contamination-free environment, needed for certain types of repairs. "This is why our shelter systems have been designed to completely seal off the part of the area on which work is being done—whether the repairs are taking place inside a hangar, or outdoors on the ramp," he says. The units are available off the shelf, or can be made to order. Nagle points out that shelters built for in-hangar applications perform the same functions as those designed for outdoor use, but can be built using lighter fabrics since they will not be subject to wind and other outside climate conditions. Given their lighter weight, they afford some cost savings along with easier handling.

JB ROCHE

A Boeing 787 fuselage repair shelter set in in Doha, Qatar.

J.B. Roche offers three types of aircraft shelters—for engine changes, fuselage and nacelle maintenance, and nose and windshield repair. Although the engine change shelter is the company's biggest seller, Nagle says the increasing use of composites in airframes could double the company's total sales rate, now at 4-5 shelters per month.

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Big Numbers

787s set to generate more than $8 billion in annual MRO demand by 2026

Production rate ramp-up to 14 aircraft per month by the end of the decade will help the 787 MRO market mushroom.

BOEING

Sean Broderick Washington

Boeing designed the 787 to do many things, but boosting revenues for aftermarket providers is not one of them.

The airframer's stated targets for 787 MRO center on a 30% reduction in airframe and systems maintenance costs once full check-interval escalations are reached. The primary driver is composites, which make up more than 50% of an airframe's weight and, says Boeing, should reduce worker hours 20% on a per-heavy-check basis.

Before the 787 entered service, Boeing's most composite-centric airframe design was the 777, at about 12% of airframe weight; Airbus had the A380's airframe at about 25% composite. (The A350, which followed the 787 into service, is about 53% composite.)

Boeing's thumbnail cost projections, provided in its latest *Aircraft Economics Handbook*, illustrate how far aircraft design has come in improving MRO efficiency. The original equipment manufacturer's (OEM) example of monthly maintenance costs for 787-9 airframe work are about $10,700, or $300 less than projected costs for the 737-900ER.

Aviation Week's latest Commercial Fleet & MRO Forecast data puts the financial ramifications of the 787's advanced design in perspective. Projected total airframe maintenance costs for the entire 787 family for 2016-25 are just under $1.5 billion—a minuscule 3% of the $44.6 billion in total MRO costs in the 10-year period. Component maintenance is projected to be $15.6 billion—the largest share of the 787 aftermarket pie—at 35%. Line maintenance, at $14.0 billion, is a close second, at 31%. Engine work is expected to set operators back $9.9 billion, or 22% of the total, while modifications will account for $3.8 billion, or 2%.

MRO Demand for Boeing 787 (U.S. $ billions)

Year	Total
2016	$1.1
2017	1.6
2018	2.4
2019	2.9
2020	3.9
2021	4.7
2022	5.4
2023	6.3
2024	7.9
2025	8.4
10-Year Total	**44.7**

Source: Aviation Week Commercial Fleet & MRO Forecast

The market is set to mushroom as 787s continue to enter service, bolstered by planned production ramp-ups that will take monthly rates from the current 10 to 14 by the end of the decade. The 787's 2016 MRO market is projected to be $1.1 billion. In 2025, the figure is forecast to swell to $8.3 billion, nearly 20% of the total for the entire decade.

While composites are praised for their lighter weight and imperviousness to costly corrosion compared to metal, they also bring new inspection and repair procedures. Cognizant of the need to keep aircraft flying following ramp rash and other minor dings, Boeing's special "quick repair" kit enables certain types of damage to be fixed outside the hangar. The kit includes 10 types of adhesives, various patches, sanding disks and special protective gear.

As manufacturers design models with an eye toward trimming maintenance costs, the battle for aftermarket dollars is intensifying. Components—growing more sophisticated, reliable and expensive—are a particularly competitive market, in part because of OEM interest.

Boeing's deal with Oman Air, announced in July, is typical of agreements manufacturers are landing. The carrier will tap Boeing's Component Services parts exchange program, loadable software airplane parts, and condition monitoring through airplane health management for its 787 fleet. The carrier has six GE-powered 787s, a mix of -8s, and -9s. The first is slated to enter service in late October.

Boeing has targeted its high-margin services work—everything from pilot training to MRO support—as a growth opportunity. Its estimated annual aftermarket revenue, which it does not break out, is $6.5-7 billion, or 8-10% of its total commercial revenue.

Its GoldCare deals play a role in boosting aftermarket growth—more than 60 customers and 2,100 aircraft use some type of GoldCare suite offering.

The 787's ramp-up should help boost these figures. At the end of September, Boeing had delivered 329 787s. Aviation Week figures project another 1,743 from 2016-25, factoring in anticipated production ramp-ups and continued "catch-up" deliveries that have seen Boeing's delivery numbers exceed monthly production numbers.

After an inauspicious in-service start that included dispatch reliability problems and the infamous four-month grounding in early 2013 while a portion of the aircraft's battery system was redesigned, the aircraft's reliability has steadily improved. By mid-2014, dispatch reliability was at 98.5% on a three-month moving average, and was pushing 99% by mid-2015.

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Beating Big Data

Smart operators are using existing data sets to improve operations

Sean Broderick Washington

As the promise of using reams of data to improve processes and guide maintenance events grows more viable, some operators are breaking new ground by leveraging current data-driven programs in a quest for safer, more efficient operations. But while so-called Big Data's vision depends on proactive measures, today's analytics-enhancement efforts often focus on what is necessary rather than exploring what is possible.

Flight data monitoring programs (FDM) are a prime example. European airlines are required to have them, and though such programs in the U.S. are voluntary, most large commercial operators are adopting them.

Most do the bare minimum needed to make their programs viable, which means manually offloading data a few times a month. But those looking to shift FDM data transfer from the "sneakernet" to an automated process—often using cheap, light quick-access recorders (QAR), then offloading data via cellular or Wi-Fi networks—are seeing more potential.

"No avionics manager wakes up one morning and says, 'I need to put QARs on all of my airplanes,'" says Mike McConnell, director and vice president of business development at Avionica. "Hardware is just hardware, and software is just software. It is the mandate to have data, and do something with it, that is the issue."

Armed with easier ways to collect and manage data, industry is waking up to the idea that current programs, run more efficiently, can shift from meeting requirements to solving problems. Flybe took its FDM program, added Avionica equipment and began offloading data after every flight. In one case, it was able to use postflight data to determine that a rough landing of one of its Bombardier Q400s was not significant enough to remove the aircraft from service. Absent the data, the aircraft would have been parked and technical experts from the OEM called in.

SEAN BRODERICK/AW&ST

Simple changes such as offloading FDM data after each flight can help jump-start deeper analytics efforts.

While examples like this are compelling, QAR upgrades continue to be driven by a desire to automate FDM programs. Still, the Flybe example illustrates what can happen when operators look beyond baseline needs.

McDonnell says Avionica is in talks with several U.S. carriers about fleetwide QAR upgrades, including handfuls of aircraft that are not too many cycles from the desert. And while dumping legacy recorders is the primary driver, McConnell says the opportunities are allowing avionics providers to pose big-picture questions: "How does data make me smarter? How does it make me safer? How does it make me more efficient?" He adds, "Once you can prove that, you have a chance to introduce [broader analytics] to operators that never thought they wanted it or needed it."

In some cases, leveraging data simply means allowing suppliers to do their jobs. Fluids specialist Eastman, which bought Skydrol manufacturer Solutia, conducts about 17,000 free hydraulic fluid sample tests for customers each year. While the main purpose is to help customers know when to change fluid, the aggregated data has proven useful. Data sets have helped operators troubleshoot problems on specific airframes, with Eastman's technical experts analyzing historical samples and offering guidance that supplements the manufacturer's maintenance manuals.

In other cases, efficiencies are created by connecting existing programs. Seabury MRO Solutions—formerly Volartec—has been approached by a Caribbean-based customer that uses its Alkym maintenance software, says Seabury MRO vice president John Barry. The request? Connect Alkym to the airline's Flyht Afirs data-streaming service, so that key operational data such as gate out, wheels off, wheels on and gate in is fed automatically into the maintenance software at the tail-number level.

Small efforts such as these are a precursor to the promise that new-technology aircraft such as the Airbus A350 and Boeing 787 hold for producing terabytes of data that can be mined for trends. PwC, cognizant of the oft-heard refrain that aircraft health monitoring and predictive maintenance are poised to transform MRO, sought to see what could be done fleetwide at an airline today, regardless of the types of aircraft flown.

Using a U.S. major as a test case, PwC mined routine fault data generated by onboard systems as well as text entered into both pilot and mechanic logbooks. It found that such data sets can be used to help predict future issues and, somewhat surprisingly, that the logbook text—rarely, if ever, aggregated and searched for trends—was at least as helpful as what was being captured automatically.

"The good news is that leveraging data is no longer a strategy of the future that requires large investments in IT infrastructure, new technologies, and fleets," writes Rick Wysong, director of PwC transportation and logistics advisory, in a blog post that touches on the work.

PwC's next steps include looking at only logbook data to validate how useful such "unstructured" data sets can be. If all goes well, the next step may be finding a customer willing to put its own data to the test, with an eye on beating Big Data to the punch.

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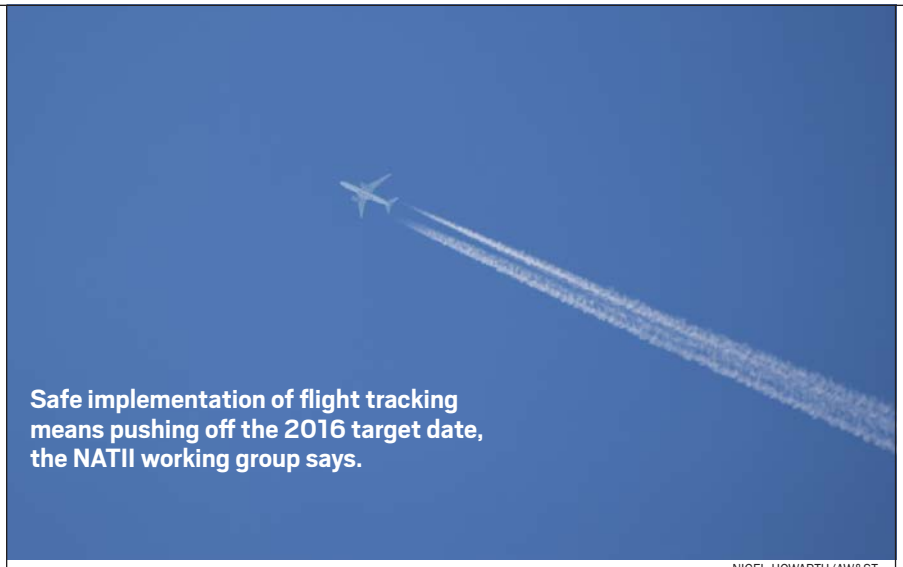
Tracking Trials

An industry working group's recommendation to delay the November 2016 deadline for implementing aircraft tracking using current technology is rooted in concerns that rushing the effort could lead to unsafe scenarios, and an extra two years are needed to mitigate that risk.

Members of the Normal Aircraft Tracking Implementation Initiative (Natii) reached their conclusions with the help of a series of tabletop exercises held over the summer, according to a report delivered to the International Civil Aviation Organization (ICAO) in September. The exercises showed that unexpected circumstances—such as the failure of a primary system used for tracking—could raise risk as flight crews scramble to ensure their aircraft are being tracked. They also made clear that procedures such as how to handle missed reports when aircraft were transitioning between flight information regions (FIR) must be hammered out as part of a prudent approach to implementing flight tracking.

The push to track all flights, elevated after the June 2009 crash of Air France Flight 447 in the Atlantic Ocean, gained unprecedented momentum after the disappearance of Malaysia Airlines Flight 370 in March 2014. Two months after the Boeing 777 was lost, the international civil aviation community, led by ICAO, established the Global Aeronautical Distress and Safety System (GADSS) concept of operations. The effort's focus includes implementing near-term standards that rely on existing technology and establishing more robust, longer-term standards. The plans will be laid out in new ICAO Standards and Recommended Practices (SARP), which, while not mandatory, are de facto requirements for state-level regulators to include in their rules.

Natii was formed in February 2015 to help develop real-world guidance for tracking. "The initiative identified existing practices used by some operators to determine the location of their aircraft when operating in oceanic areas, as well as challenges facing the practical implementation of Normal Aircraft Tracking (NAT)," the report explains.



Safe implementation of flight tracking means pushing off the 2016 target date, the NATII working group says.

NIGEL HOWARTH/AW&ST

Most of the challenges came to light during six "what-if" exercises conducted during a two-day meeting in June. Each exercise picked a route and a scenario in which an aircraft and an air navigation service provider (ANSP), where applicable, was required to follow proposed tracking standards. Chief among them: providing and receiving so-called 4D/15 data—latitude, longitude, altitude, and time. Operators receiving the information from aircraft, regardless of an ANSP's coverage capabilities, are defined as 4D/15 Tracking. An ANSP receiving the information directly from aircraft is 4D/15 Service. Both are seen as necessary for a complete, redundant tracking initiative.

The exercises reinforced that technology exists to accomplish the near-term tracking initiatives. But they also highlighted the ramifications of possible system failures and inadequate guidance.

"Most significantly, the Natii identified scenarios where the prescriptive nature of the proposed SARPs imposed an unrealistic operational burden across industry stakeholders," the report states. "The proposed SARPs have the potential to result in a number of unintended consequences to operations, especially when elements required for Normal Aircraft Tracking become unavailable."

In one scenario, a 777 flying from Sydney to Tokyo's Narita International Airport lost its Automatic Dependent Surveillance-Contract (ADS-C) capabilities. The flight continued, because the ANSPs along the route supported high-frequency (HF) communications. But the group found that relying on manual means, such as the HF capabilities, to meet the 4D/15 reporting standard created significant additional workload "and had a negative impact on the overall safety of the operation," the report notes. Manual reporting also introduces uncertainty. "In other words, the manual report could indicate that the aircraft was in one location when it actually was in a different place."

Natii suggests that fulfilling the Normal Aircraft Tracking requirements and recommendations should be done with automated systems only.

In another scenario, an Airbus A340 with only a data link was flying from Sydney to Santiago, Chile. The limited equipage meant the operator had to provide tracking along the route. The scenario had the aircraft miss a report when it was near an FIR. "By the time the operator had performed its established procedures (i.e., attempting to reestablish a 4D position and/or establishing communications) the aircraft had crossed the FIR boundary," the report says. "Although prevalent in all scenarios, this scenario highlighted the need for operators and ANSPs to have up-to-date operational contact details."

This scenario led to a recommendation for a central database, "preferably hosted by ICAO," of contact details for airline operations control centers and ANSPs.

In another scenario, a Bombardier Q400 was flying between Cairns, Australia, and Port Moresby, Papua New Guinea, a 90-min. flight over the Coral Sea. The route selected has a 30-min.

4D/15 Service gap, meaning the aircraft and operator needed 4D/15 Tracking capability for dispatch.

The aircraft was equipped with a portable tracking device to enable the flight crew to meet the proposed tracking requirements. The scenario tested the device's failure combined with the operator's inability to contact its aircraft. In the scenario, the aircraft lost contact while in the service gap but was back on radar before the operator made contact with the ANSP.

"This scenario highlighted the need for operators to develop procedures to assess the aircraft tracking system's serviceability," the report notes.

It also raises the question of whether such short gaps should trigger the tracking mandate. Participants "also questioned whether 4D/15 Tracking was necessary for this type of operation (i.e., short 4D/15 Service gaps)," the report continues, adding that the exercise "identified the need for complementary ICAO provisions to address the scenario when 4D/15 Tracking capability does not exist for short segments where 4D/15 Tracking would be required."

Another topic covered by the exercise was data retention. The working group "took into consideration [air traffic service] unit recording requirements and concluded that, unless there was an accident, there was no need to retain tracking data after the aircraft had landed safely under normal tracking conditions," the report says. Accordingly, Natii recommends that data retention only be used "for the purpose of assisting [search and rescue] in determining the last known position of the aircraft."

The report makes 13 recommendations, focusing on the proposed SARPs and related guidance. It also calls for developing "complementary risk-based variations to the prescriptive requirements" that would maintain safety while ensuring compliance with the SARPs.

"Aware of the ICAO processes, the Natii determined that an implementation period to the proposed SARPs should be established that would permit the necessary time for all of the aforementioned tasks to be completed. This could be accomplished by extending the proposed applicability date to November 2018."

In addition to the two-day tabletop exercise meeting, Natii's work included regular discussions in April-September 2015. Among the general conclusions reached during the working group meetings: Industry overestimates the costs of available tracking services.

"Several vendors noted that operators in general appear to have a perception that the cost of tracking is high," the report says. "They presented some system solutions that were relatively inexpensive. That disconnect between the perceived cost and the actual cost meant that many operators were not considering all of the available tracking system options."

—Sean Broderick

Repairing Aircraft in Asia

Regina Kenney Chicago

Aviation Week's MRO Asia-Pacific event, held in Singapore, includes conferences led by industry experts and an exhibition hall where airlines, MRO providers, suppliers, OEMs, regulators, lessors and industry experts can peruse products and services in the MRO industry. Below are a variety of services and products based in the region that will be featured at the event.

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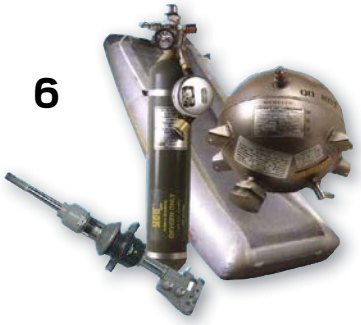

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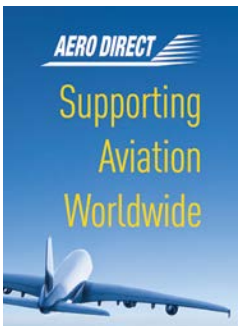

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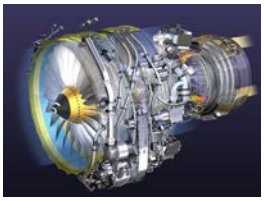

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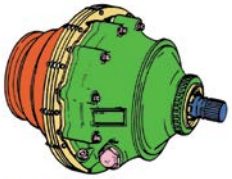

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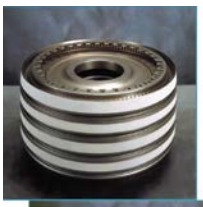

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force by 2030, Navy documents show. Industry officials say that SLEP will not be enough: "It helps," says one, "but it doesn't get you there."

The answer is a "holistic, integrated solution" combining SLEP, new production and upgrades, according to Dan Gillian, Boeing's F/A-18E/F and EA-18G programs vice president.

Boeing's plan—which does not envisage cuts to the F-35C buy—would continue new production well into the 2020s. That and SLEP create opportunities to insert upgrades into the fleet while increasing the payback period for the initial investment. The company is no longer using the Advanced Super Hornet name but instead is briefing the Navy on an "enhanced Hornet flightpath," with a menu of possible upgrades including conformal fuel tanks, improved engine and widescreen cockpit.

The company is in the process of slowing production down to two aircraft per month, the level at which it can maintain current prices. Current orders will keep the line open until 2017, but Congress's final markup adds another 12 Super Hornets in the 2016 budget. Boeing is in "good discussions" with another Super Hornet export customer, Gillian says. Other industry sources say a 24-30-aircraft deal with Kuwait—a split buy with Eurofighter for Typhoons, a deal announced in September—is close to being finalized.

Those orders would sustain production through 2019, Gillian says. Boeing is still in competition in Denmark, planning bids in Belgium and Finland and would be in a strong position if Canada opens its requirement to competition after the Oct. 19 federal election (see page 21).

With the planned Super Hornet SLEP, Boeing and the Navy are hoping to avoid the problems the service has found with the F/A-18A-D "Classic" Hornets. About half the Navy/Marine Classic inventory is in "out of reporting" status today, either because they are in the Navy's depots (at Jacksonville, Florida, or North Island near San Diego) or out of hours, waiting for the SLEP.

The SLEP has overloaded a depot system never designed to cope with it, Boeing says, but another major issue is corrosion, which differs from aircraft to aircraft and is often invisible until they are inducted into SLEP. The depot then needs to order specific parts while the aircraft occupies a line position.

U.S. NAVY/MASS COM. SPC. 3RD CLASS. E.T. MILLER

Rebuilt, life-extended F/A-18E/F Super Hornets will be the backbone of Navy aviation through the 2020s.

The plan Boeing intends to offer the Navy expands capacity by establishing a separate contractor-operated SLEP line, with NAS Cecil Field near Jacksonville—where Boeing already performs high-flight-hour inspections—as a likely location. Northrop Grumman, which builds the center body section where many repairs are concentrated, would be involved.

With the high rate of SLEPs—each taking about a year—life extension alone will not fill the gap. The Navy has a notional strike-fighter force of 40 squadrons—four each for 10 carrier air wings. The service is short of fighters, a Boeing executive says, but the problem is masked because the Navy is short one carrier until the new USS Gerald R. Ford is commissioned, and other carriers are taking longer than usual to complete routine overhauls. As the carrier fleet recovers, the shortage will be more apparent. Add-on Super Hornet buys since the early 2010s have alleviated the shortfall, Boeing says, but not prevented it.

The problem has been exacerbated by the 2010-11 slip in the F-35 Joint Strike Fighter program and by delays in the F-35C ramp-up, the latest in the fiscal 2016 budget proposal. This cut 16-20 aircraft from the fiscal 2016-20 Future Years Defense Program and set a peak buy of 12 aircraft in 2020.

Filling the fighter gap with more F-35s—costing 80% more to buy and operate than the F/A-18, according to Boeing and government numbers—is unlikely to be an option as long as budgets are limited. The Navy may cap F-35C buys at as few as 12 per year in the 2020s, against a planned 20, according to internal documents. Shoemaker confirmed in late August that "budget numbers may force us to a number between 12 and 20."

Navy aviation has been the bill-payer for other Navy department procurement accounts, one executive says. Navy Secretary Ray Mabus has ring-fenced shipbuilding accounts, and the Marines have protected their F-35B and Bell Boeing V-22 buys. In the fiscal 2016 budget the administration sent to Congress, non-Marine aircraft buys were at a record-low 25 units, although Congress has increased that number.

Sea Breezes

F-35C expands carrier operations as Stovl F-35 ramps up ski jump tests for U.K. application

Guy Norris Los Angeles

Tests to assess the suitability of the F-35 Joint Strike Fighter (JSF) to operate from two fundamentally different types of aircraft carrier designs are entering a new phase as the U.S. Navy evaluates lessons from the latest sea trials of the F-35C and test work begins on roles geared primarily for U.K. operations of the Lockheed Martin F-35B short-takeoff-and-vertical-landing (Stovl) version.

Lockheed Martin, BAE Systems and U.S. and U.K. military test units are set to begin an intensive second phase of envelope expansion flights using the ski jump ramp at the U.S. NAS Patuxent River, Maryland, site in the build-up to trials with the ramp-configured U.K. Royal Navy's new HMS Queen Elizabeth carrier in 2018-19. In addition, a new round of work is about to further refine techniques for the ship-borne rolling vertical landing (SRVL) technique in development for the U.K. and potentially other F-35B operators.

Pilots also conducted military- and

LOCKHEED MARTIN

F-35B ski jump tests are set to ramp up following completion of a short initial phase in June.

maximum-level F-35C launches with simulated missiles in early October from CVN 68 USS Dwight D. Eisenhower off the Virginia coast, testing the aircraft at gross weights with international weapons, proving out the JSF's carrier speed needs during the lowest and highest "energy" catapult shots. The aircraft's Joint Precision Approach and Landing System was also tested for approach handling qualities at higher gross weights and gathered data for the system's wind-over-deck survey. Flights also included evaluation of the Gen III Helmet Mounted Display for night operations.

Back on dry land, F-35B ski jump tests are aimed at risk-reduction work "as well as some development to make sure it works as advertised," says BAE Systems lead F-35B Stovl test pilot Peter "Wizzer" Wilson. At the Society of Experimental Test Pilots symposium in Anaheim, California in September, Wilson told Aviation Week more than 100 ramp takeoffs are required "to clear that capability, so we have quite a long way to go."

The ski jump idea was conceived in the 1970s as a means of improving the slow speed takeoff performance of the Harrier from a ship's deck. However, the F-35's automatic lift system control will make operations from the ramp simpler and safer, says Wilson. "It has become remarkably simple, thanks to the cleverness of the airplane," he adds. For a ski jump takeoff the pilot lines up, advances the throttle and maintains alignment with the main nozzle fully aft. When the ramp is reached, rate sensors on the aircraft recognize the change in attitude and deploy the nozzles to the appropriate vectoring angle. Once airborne, weight-on-wheels sensors signal the flight control system to reconfigure the aircraft for up-and-away flight.

Future F-35B testing to support U.S. Marine Corps, U.K. and other Stovl operators also includes completion of external stores testing in Stovl and up-and-away modes. "Nor have we gone to the maximum speeds yet that you can go to with external stores. So nearly every flight we do now is with external stores, either symmetric or asymmetric," says Wilson. External weapons testing will also form part of the focus for a third set of F-35B sea trials provisionally planned for the second half of 2016.

The work will also include more night flight and performance testing, including deliberately slower-than-normal takeoffs from the deck to assess tolerance to errors. "The aircraft does well at slow speed because of the amount of lift you get off the wing. You are getting thousands of pounds of lift at speeds you would drive your car at," he adds.

The U.K. in particular is counting on development of its SRVL technique, which will be used to increase the "bring-back" weight of stores and fuel to land on the ship. In SRVL, the aircraft will be brought in to land in hover mode but with sufficient forward, or "overtake" speed to generate useful lift. Target landing speed will be around 30 kt., which when added to the ship's forward speed and headwind of more than 30 kt., will be the equivalent of a 60 kt.-plus landing speed.

Although the U.K.'s F-35Bs are expected to be capable of bringing back a typical internal weapons load of around 5,000 lb., the SRVL technique is under development to boost that by over 2,000 lb. for high temperature conditions. The added capacity will allow the aircraft to return with large pylon-mounted weapons, such as the U.K.'s Storm Shadow standoff, air-launched missile.

"We have not yet done the equivalent of an SRVL, though we have done a lot in the simulator," says Wilson. New simulator trials are planned at BAE Systems' Warton facility in England in the last quarter of 2015 to "massively derisk the problems." Trials aim to tackle potential concerns with SRVL, including pilot workload and failure cases such as a tire burst. Pilots plan to limit the risks by limiting maximum overtake speed to around 40 kt., says Wilson.

—With Michael Fabey aboard the USS Eisenhower

Galleries *Check out images of the latest F-35C trials on the USS Eisenhower:* **AviationWeek.com/F-35CTrials**

High Fiber

U.S. Army's demo of a 60-kW weapon will be key step in maturing fiber-laser technology

Graham Warwick **Washington**

With inherently higher electrical efficiency and beam quality, fiber lasers are in a race to reach maturity before the military makes decisions on the development and deployment of high-energy electric laser weapons.

A key step is the U.S. Army's planned demonstration in 2017 of a 60-kW fiber-laser system developed by Lockheed Martin. But rival solid-state lasers have already exceeded 100 kW in demonstrations and are at a higher technology readiness level (TRL) as the services eye the potential for early fielding of directed-energy weapons.

Lockheed has begun production of the fiber-laser modules for the 60-kW system. The company was awarded a $25 million contract in April to build and test the modular laser for integration into the Army's Boeing-developed High-Energy Laser Mobile Demonstrator (HEL MD). "We will deliver the la-

ser to the customer at the end of 2016," says Lockheed senior fellow Rob Afzal.

Previously, Lockheed built a 30-kW system using internal funds to demonstrate the feasibility of combining the beams from multiple fiber lasers while maintaining beam quality and electrical efficiency. The modular technology allows the laser to scale up to beyond 100 kW, Afzal says.

Generating the laser beam by diode-pumping a long optical fiber results in higher beam quality and electrical efficiency but less power than solid-state devices using slabs of laser crystal as the gain medium. This requires the beams from multiple fibers to be combined efficiently to form a single high-power beam. Lockheed says its laser can achieve 40% efficiency, reducing power-generation and cooling requirements for the overall weapon.

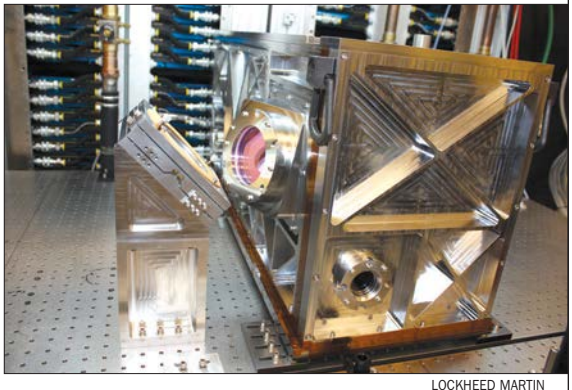
Afzal says the beam-combined fiber laser's higher power and beam quality puts more irradiance on the target at greater range. This can increase engagement range or reduce defeat time, allowing a laser weapon system to "shoot-look-shoot" against multiple targets. Lockheed uses spectral beam combining. The output from each fiber-laser module is at a slightly different wavelength. A diffraction grating combines the beams by laying one on top of the other to form a single high-power beam—like a prism in reverse, he explains.

Compared with coherent beam combining used in other high-power lasers, spectral beam combining provides the highest "power-in-the-bucket" efficiency, a measure of beam quality that is a function of the power delivered to the target area. "The issue with a phased array is the sidelobes. The power in the lobes does not provide effect on the target," says Afzal. "Coherent is efficient, but there is a lot of added complexity we feel isn't necessary for the types of power and tactical applications we are trying to achieve. We went for the simplest, most elegant approach."

The 30-kW Aladin demo system has around 100 fiber-laser modules. The 60-kW prototype for the Army has fewer, higher-power, kilowatt-class fiber lasers. "It's almost 1 for 1 [lasers vs. kilowatts]. You can tack on 5-10%. That's one of the big advantages of spectral beam combining," says Afzal. On the end of each laser module is a delivery fiber that terminates in the beam-combiner box. This outputs a single high-power beam to the weapon system's laser-beam director turret.

One aim of the demo system was to understand how to manufacture the lasers and what life-limited elements would wear out. The production modules are "more rugged, more traceable to a tactical vehicle and to beyond 100 kW," he says. The truck-mounted HEL MD has been tested against mortars and unmanned aircraft with a 10-kW industrial fiber laser, but range and lethality was limited. After demonstration of the 60-kW system in 2017, plans call for tests of the 100-kW version by 2022.

Lockheed makes its own fiber lasers because of the need for high beam quality, but it uses component technologies such as optical fibers and pump diodes from the commercial market. "There have been two revolutions in lasers: telecommunications, and industrial cutting and welding. We bring them together to create a new class of laser," Afzal says.



LOCKHEED MARTIN

Industrial fiber lasers are available with higher power, up to 10 kW per fiber, but not with the quality required for beam combining. Most live-fire tests of laser weapons so far have used industrial lasers but scaled the power by aiming multiple beams at a common point so they overlap. This is done with the U.S. Navy's 30-kW Laser Weapon System prototype, which has been deployed operationally for evaluation in the Persian Gulf on the forward-staging ship USS Ponce.

Advantages of a modular fiber laser include scaling, cooling and packaging. "With a modular design, you can scale to higher power by loading more modules into the rack, like blade servers in a server farm," he says. Each module is independently cooled. "As we add more modules, we increase the size of the cooling system but not its complexity. It's parallel, not serial. Previously, you ran into a scaling problem where, as the laser got more powerful and the slabs got bigger, you couldn't get the heat out."

Flexibility in packaging the modules is another benefit. "You can stack them vertically or horizontally, or in two cabinets. They are all independent, and the fiber delivers the power," Afzal says. The Air Force Research Laboratory (AFRL) is looking at systems for sixth-generation fighters where the laser modules would be distributed throughout the aircraft and the beams routed by fibers through the tight confines of the airframe to a conformal array on the fuselage surface.

As it begins building the Army system, Lockheed is studying how the fiber-laser technology can be applied to other requirements. "We are looking at how we could package the system into a weapons module for the Littoral Combat Ship or into a pod for an aircraft, as well as Army tactical vehicles," he says.

The Aladin 30-kW system demonstrated the ability to scale power by combining multiple fiber lasers.

One potential application is AFRL's planned Self-Protected High-Energy Laser Demonstration (Shield), for which a solicitation is expected shortly. Shield aims to demo an anti-missile self-defense pod for fighters by 2020 and a longer-range, 100-kW system by 2022. The Air Force wants the laser technology for a self-defense pod to be scalable to an offensive weapon that can be carried by larger aircraft, beginning with special-operations gunships.

"The Shield technology level we can do now," says Afzal. "We would look at modifications to make it more relevant to the Air Force, but it is not a next-generation system." But the key issue could be maturity of the fiber-laser technology versus other solid-state electric lasers. Army trials of the 60-kW system will take Lockheed's technology to TRL 6, "arguably TRL 7 depending on how they use the system and if they do tactical engagements," he says. The race is on.

Blame the ARJ21

The C919's certification troubles are revisited upon Avic's new turboprop

Bradley Perrett Beijing

Obtaining Western airworthiness acceptance is looming as a key difficulty for the Avic MA700 turboprop airliner program, which has begun moving down a regulatory path that has led the Comac C919 to what may be a seriously curtailed market. Avic's program is at the detail design phase, and it hopes to complete that stage this year, but there is no clear road map for obtaining FAA or European Aviation Safety Agency (EASA) recognition of the Civil Aviation Administration of China (CAAC) oversight of that work.

Almost two years after program launch, the schedule is unchanged. A first flight is due June 2017 and first delivery in 2019. Avic Aircraft, the Avic subsidiary developing the MA700, is highly aware that the quality of program execution may risk what could be a promising concept.

AVIC VIA INTERNATIONAL AVIATION

To foster the ARJ21, the Chinese government does not want a 90-seat version of the MA700 too soon.

Program executives point out that Avic has an important advantage over Comac: experience gained in developing and supporting similar aircraft—the 60-seat MA60 and MA600 versions of the Y-7 turboprop, itself based on the Antonov An-24. That experience includes an understanding of mistakes made, they say. Comac, by contrast, began developing the C919, its second type, eight years before the February 2016 entry into service now expected for the first, the ARJ21 regional jet.

The MA700 schedule slipped several times before Avic launched full-scale development in December 2013. Delivering the aircraft to a customer in 2019 will not be easy, say industry officials, though the schedule allows a generous 30 months for flight testing after the first flight. Detail design was set to finish this year but could stretch into 2016.

To sell the MA700 in many of the potential markets, including most of the large ones, Avic will need endorsement of the CAAC type certificate by the FAA or EASA. But neither agency has yet completed a program, reliant on the long-overdue ARJ21, intended to result in the FAA recognizing its Chinese counterpart's capabilities in this area. Meanwhile, the CAAC is already working on the MA700, overseeing detail design, raising the question of whether its assessments can be retrospectively accepted by the foreign agencies.

The C919 is in the same hole, but deeper. The CAAC has had to support C919 development over the past 4-5 years without that FAA recognition. As a result, the 158-seat jet, originally meant to challenge the Airbus A320 family and Boeing 737, so far looks like it may have to rely for the most part on the Chinese market.

The first version of the MA700 will seat 78 passengers at 79-cm (31-in.) pitch, compared with 68 for the ATR 72 and 74 for the Bombardier Q400. That is an advantage, because many operators of turboprop airliners are calling for larger aircraft, preferably seating at least 90. Indeed, Avic intends to eventually offer an MA700 version with at least 90 seats, but under current planning a 60-seater, mentioned last year as a 50-seater, will come first.

The government has imposed that sequence on Avic, because a 90-seater would compete with the ARJ21, which has the same capacity. That policy could change if, when the initial MA700 version is certified and Avic is ready to develop the first variant, authorities decide that the ARJ21's production future is dim. They might see no sense in sandbagging a potentially successful turboprop to protect a jet that had clearly flopped.

So, while the ARJ21's poor performance in development is hindering the MA700's certification prospects, sufficiently poor performance of the regional jet in operation would ultimately help the Avic program.

Maybe 20% as many MA700s could be sold in the 60-seat version as in the standard length, says a program official. The shorter version will better suit operations from high altitudes, and especially airports, such as many in Indonesia, with short runways surrounded by big hills. Indonesia should be a particularly interesting market for Avic, since it accepts aircraft with CAAC certification and relies heavily on air transportation to connect its islands.

Program managers are sure they have a strong concept in the MA700, the key features of which are its edge in seating, the manufacturing and maintenance economies of using large structural parts instead of assemblies built up from many pieces, Chinese fabrication costs, and the new Pratt & Whitney Canada PW150C engine. And its price will be lower than its competitors', says chief designer Dong Jianhong.

The big question, as program officials well know, is whether they can execute the program well enough. One issue is the tendency of Avic's military programs to attract the most valuable people.

Avic says it has orders for 185 MA700s from 11 customers, but Chinese state manufacturers tend to loosely refer to options and other nonbinding deals as orders. The announced customers are Okay Airways, Avic subsidiary Joy Air, Cambodia's Bayon Airlines, CDB Leasing, CMB Financial Leasing, Chongqing General Aviation Financial Leasing, Poly Technologies, Air Avenues of Nepal, Bahrain's EGA Group, Hybrid Aviation of Pakistan and South Africa's Segers Aero.

Going the Extra Mile

SIA restarts ultra-long-range flights, based on A350ULR

Jens Flottau Frankfurt

Singapore Airlines (SIA), one of the relatively few proponents of ultra-long-haul flying, tenaciously clung to the model. But in 2013, after a nine-year attempt and with fuel prices spiking, even SIA gave up on the project. Now, with Airbus offering a new version of the A350 and fuel a relative bargain, it is taking another shot. Will others follow?

SIA flew A340-500s on its nonstop New York-Singapore route. But the combination of fuel costs plus a four-engine aircraft rendered the operation uneconomical. The airline now serves New York via Frankfurt, and Los Angeles via Tokyo. But it has continued to lobby Airbus for a longer-range version of the A350 with hopes of again offering nonstop services.

At a distance of up to 8,700 nm, Singapore-New York will again become the world's longest commercial route. The A340-500 flights were planned around a westbound block of time—nearly 19 hr.—but, given the higher cruise speed of the A350, the new flights are likely to be somewhat shorter—although not by much.

The airline has not given many details about cabin configuration except to note that it will be "all-new." However, inside sources say it will feature 170 seats in a three-class layout: economy, premium economy and business.

With SIA's backing, Airbus formally launched the A350-900ULR (ultra-long-range). As part of its launch deal, the airline will alter its existing order for 63 -900s, taking seven in the new ULR version. It is also converting four of its 20 options into firm orders for the regular -900. Seven aircraft will be delivered in 2018 and could lead to additional destinations in the U.S.

The baseline A350-900 has a range of 7,590 nm, according to Airbus, but the ULR variant will fly 1,200 nm farther and match the range Boeing projects for its 777-8X. Airbus cites the main change as increased fuel capacity— to 165,000 liters (37,250 gal.) from 141,000. To achieve this, the air venting system in the tanks has to be adapted and sensors relocated, along with inert gas distribution pipes. Some structural reinforcement is also required, as are a few unspecified aerodynamic improvements. The maximum takeoff weight (MTOW) will grow to 280 tons from 275, much in the way that adjustments were made to move the A330's MTOW up to 242 tons.

Of in-production aircraft, the 777-200LR has the longest range at 8,555 nm (carrying 317 passengers), followed by the A380 (8,200 nm). The availability of smaller widebody aircraft with even longer range creates the option for Middle Eastern airlines in particular to revisit their route networks. Geography dictates they need longer ranges for service to the U.S. West Coast or Latin America. Emirates is considering either the Boeing 787 or the A350, but that had been based on filling the airline's need for an 8-10-hr.-mission aircraft it wants to use on routes to Europe, Africa and Asia.

At 7,500 nm, Qantas's A380 Sydney-Dallas service is now the world's longest route, followed by Delta Air Lines' Atlanta-Johannesburg flight (7,300 nm on Boeing 777-200LRs) and Etihad Airways and Emirates services from Abu Dhabi and Dubai to Los Angeles. Emirates is also launching a 777-200LR Dubai-Panama service, which will be slightly longer than the Qantas service to Dallas. Airlines now operate 15 routes of close to 7,000 nm or longer.

SIA is due to receive its first regular A350-900 in January 2016. The initial aircraft will be used selectively on routes close to home—Jakarta and Kuala Lumpur—for crew-training purposes; the first scheduled route will be Singapore-Amsterdam, beginning next April. By then SIA will have received more A350s, so the type will be able to take over from the 777-300ERs all of the daily frequencies on the Amsterdam route.

The carrier says additional A350 routes will be announced in coming months. SIA is due to receive 11 A350s in 2016; early deliveries for the most part are expected to replace 777s on existing routes.

—With Adrian Schofield in Auckland

Singapore Airlines plans to reintroduce ultra-long-haul flying to New York and Los Angeles in 2018.

AIRBUS

Eating Ash

On-wing ash ingestion test could limit airspace disruption after volcanic eruptions

NASA

Graham Warwick Washington

Statistically, an aircraft flying into a cloud of ash spewing from a volcano was a rarity—until April 2010, when Iceland's Eyjafjallajokull erupted. The ash cloud closed airspace over Europe for days, canceling more than 100,000 flights and incurring airline losses approaching $2 billion. The disruption exposed how little the industry comprehended the effects of volcanic ash on aircraft and engines.

It was known that ingesting volcanic ash could damage engines, but the concentrations at which safety and performance effects could become critical were not well understood. This led to conservative assumptions for closing airspace, which were eased slightly to limit flight disruptions as the crisis persisted. The result was an upsurge in research into the effects of ash ingestion.

The biggest of these efforts is the NASA-led Vehicle Integrated Propulsion Research (VIPR) program, which culminated in July with an ingestion test involving a Pratt & Whitney PW2000 engine on a Boeing C-17 airlifter—on the ground but on-wing, to simulate prolonged flight through a volcanic ash cloud. "The engine surprised us," says Paul Krasa, VIPR program manager at NASA Langley Research Center.

The VIPR program is a multiagency-industry partnership created in 2010. At that time, NASA was looking at developing engine health management systems and sensors for next-generation aircraft engines. Then Eyjafjallajokull erupted and both the FAA and U.S. Air Force "became very interested in the impact of volcanic ash on high-bypass turbofans," says Krasa.

Previous encounters with ash had been inadvertent. In 1982, all four engines on British Airways Flight 9, en route from London to Auckland, flamed out when the Boeing 747-200 flew through ash from Indonesia's Mount Galunggung. In 1989, all four engines failed on a 747-400, KLM's Flight 897 from Amsterdam to Tokyo, when it flew through ash from Alaska's Mount Redoubt. Both aircraft landed safely.

In 2000, en route from Edwards AFB, California, to Kiruna, Sweden, NASA's own McDonnell Douglas DC-8-72 airborne laboratory inadvertently flew at high altitude through a diffuse ash cloud from Iceland's Mount Hekla volcano. All four CFM56 engines had to be replaced. Coming after these events, the 2010 airspace closures increased interest in understanding the effects of ash.

"The Iceland eruption caused three weeks of disruption," says Krasa. In addition to the impact on commercial airline flights over Europe, there were wars underway. "There was a huge impact on Air Force logistics to Iraq and Afghanistan. They had to send flights westward, the long way round."

The result was a project that has involved not only all four of NASA's aeronautics research centers at Armstrong, Langley, Ames and Glenn but also the FAA and Air Force Research Laboratory, while the Big Three engine manufacturers—Pratt & Whitney, General Electric and Rolls-Royce—and Boeing have contributed resources and research.

"When you do a test that has never been done before—introducing volcanic ash directly into an engine on the wing of an aircraft, you really need to understand the full system effects," Krasa says. "We could not do it on a test stand. We needed to do it on an aircraft, as an integrated system, to understand the effects on the engine and how the flight crew perceive them."

A VIPR series of ground tests involved Pratt & Whitney F117 (PW2000) engines on a C-17.

The Air Force loaned NASA two F117 (PW2000) engines, flyable spares taken off a C-17 prototype in the Air Force Museum and overhauled by Pratt to restore their operating limits. The team was careful not to stress the engines too soon, he says, and VIPR testing was conducted in three phases.

In the first test, VIPR 1, "we ran a lot of peripheral sensors attached to the outside of the engine. We ran simulated faults, but they were not detrimental to the engine," he says. VIPR 2 moved into modifying the engine to integrate sensors into the core. "We loaded it up with science, but did not harm the engine." Tests included inducing faults to see how the sensors reacted, and injecting powered chalk to simulate ash and understand how to do the ultimate test.

"VIPR 3 was always the vision, to inject ash into the engine," says Krasa. "And we learned a tremendous amount from the test." VIPR 3 was the first controlled exposure of an engine to ash. Ground tests were performed by Calspan in the 1980s on a Pratt & Whitney F100 fighter engine to assess the performance deterioration from exposure to dust from nuclear explosions, "but we did it in a more controlled way," he says.

Before VIPR 3 what was known about volcanic-ash ingestion is that the rapid impact can include erosion of the compressor and melting of the ash in the hot section, blocking the fuel system, clogging the combustor and coating the turbine, and blocking the cooling holes. Longer-term effects include loss of compressor efficiency, lubrication system contamination and reduced turbine component life.

For the tests, ash was injected at two flow rates—1 mg and 10 mg per cu. meter. Over Europe in 2010, "no-go zones"

were established where ash concentrations exceeded 2 mg/cu. meter, later raised to 4 mg/cu. meter. Today engine manufacturers do not recommend operations in concentrations above 2 mg/cu. meter. The ash encountered by KLM Flight 897 was estimated at about 2,000 mg/cu. meter.

Conducting the ingestion tests was not as simple as shoveling ash into the engine. The material had to be selected carefully. Ash from Mount Mazama in Oregon was chosen with help from the U.S. Geological Survey, in part because the material occurs naturally on the dry lake bed at Edwards, where the test was conducted. "The majority of the ash went into the core, but some went through the fan and out the back, and this made the environmental release much easier," says Krasa.

GE developed the volcanic ash distribution rig. "We did a lot of CFD [computational fluid dynamics] simulations and predicted over 90% of the ash would go into the core. The actual test was about 99%—that's how tightly it was designed," he says. "We never could see the ash going in, but we could see erosion on the fan—a cleaning of the blades over the first couple of inches."

GE developed the ingestion rig, or spider, that injected volcanic ash into the engine.

But GE had to redesign the rig. "They took the sand ingestion standard used in engine certification and put factors on top, because ash is more erosive and corrosive. They thought they were conservative, but the ash rig ate itself," says Krasa. "Ash cut through fittings in a short period. So we recharacterized the ash. It is much nastier than we thought. Ash is fine like talcum, but under a microscope you can see it is so angular that it has cutting ability."

The VIPR 3 ingestion tests totaled 14 hr. of engine runs over multiple days at the low flow rate, then two days at the high rate. For each run, the engine was operated at a nominally constant pressure ratio, and ash was fed into the core only when it was at the correct power.

Preliminary data has surprised the team. "At 1 mg/cu. meter we predicted we would see some [performance] degradation at 1 hr. Then at 10 mg/cu. meter we expected a redline breach [the engine no longer airworthy] after 3 hr.," he says. "We ran at low flow rate for a week, followed by two days at a combined low and high rate and at no time was there a redline breach."

There was degradation, but after a longer time than expected. "We saw the engine performance shift at the 10 hr. point. When we went from low to high flow rates we hit a knee in the degradation curve, but when we stopped the test at 14 hr., the engine was still running and putting out power," Krasa says.

Borescoping the engine after the first day of high-flow tests, the team thought it would never start again because there was so much glassification in the high-pressure turbine section where the ash had melted and coated the rotors and stators. "We had the combined expertise of GE, Pratt & Whitney and Rolls-Royce going over the borescope results to determine if we could go ahead safely," he says. "Rolls has one of the world's definitive experts, Rory Clarkson, and he said not to worry."

NASA

The glass-laden engine started and tests continued beyond the 10-hr. mark. "For the first 10 min. the engine would chug and cough, and a big brown cloud would come out the back. The glass is very brittle. It would accumulate and accumulate then, when thick enough, break off," Krasa says.

"We expected in the first day of high-flow tests to have all the research done in 1.5-3 hr. By the end of that day, we saw degradation as the engine loaded up with glass. The second day we decided it was safe to start the engine, but thought it would not last the day. We started out predicting a redline breach in 3 hr.; at 14 hr. it had not hit the stop point," he says. "Could we have gone on? The major reason we stopped is we had met our success criteria."

Now that the tests are done, the head-scratching over the results has begun, he says. "At low flow, we saw an increase in performance in the beginning, which we think was a cleaning effect. They used to use walnut shells to clean engines early on, and our hypothesis is that at low flow we saw a slight cleaning [of the compressor] at first. As we went on we saw a knee in the curve and erosion in the compressor."

In the high-pressure turbine, the team saw glassification effects that looked like ice shapes—"the shapes you get when supercooled water droplets hit the leading edge of an airfoil," Krasa says. "The same thing may be happening with ash. As it comes through the hot section, it turns into very small volcanic glass droplets and you may get the same supercooling effect as with water droplets. Scientists look at the borescope images, see familiar ice-type shapes and wonder if there is a correlation. Can we take our analytical capability for ice shapes and apply it to ash?"

The results from VIPR are to be published early in 2016. The FAA and International Civil Aviation Organization (ICAO) are waiting for the data to better understand the effect ash has on engines. "ICAO will look at the data and understand more about to how to fly safely and whether the current guidance is too restrictive or not," says Krasa.

Ice Hunters

Researchers fly into tropical storms to evaluate possible warning methods for core icing events

The HIWC campaign focused on regions of highly convective air masses, such as those over the Gulf of Mexico.

GUY NORRIS/AW&ST

Guy Norris Fort Lauderdale, Florida

The warm subtropical waters of the Gulf of Mexico in late summer may seem an unusual place to hunt for a rare form of atmospheric icing, but this is prime research territory for NASA and the agency's highly instrumented DC-8 aircraft.

Searching for super-cold conditions from the sweltering heat of a Florida airfield is as counterintuitive as the ice crystal icing (ICI) phenomenon NASA is trying to find, a condition in which ice particles accumulate inside the hot core of a jet engine. Also known as high ice water content (HIWC), the state occurs without warning, generally at high altitudes above normal icing levels, and can result in temporary power loss, surges, blade damage and, in some severe cases, engine shutdown.

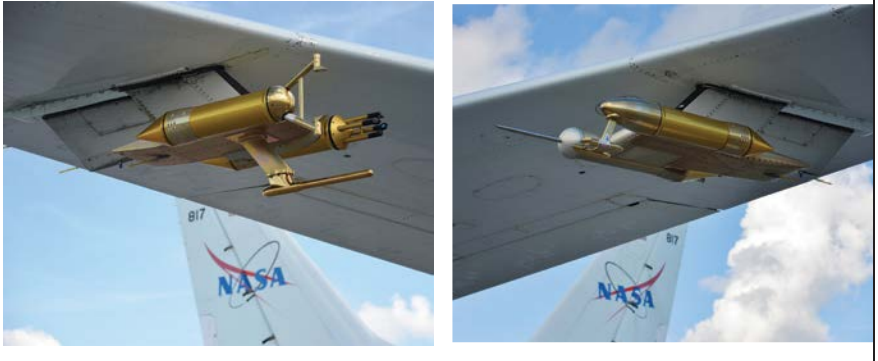
Researchers believe that ice crystals start to melt and evaporate as they meet warm parts inside the engine, cooling core surfaces to temperatures below freezing. The cooling engine causes the melted ice crystal water to refreeze, and ice accumulates inside the engine core. At some point, slabs of ice come loose and are ingested, causing power loss or blade damage.

While the dangers of traditional icing at medium altitudes are well understood and easily countered, the high-altitude HIWC scenario continues to puzzle researchers. The number of ice core icing events appears to have mushroomed from virtually nothing to more than 150 known incidents over the past two decades, and the rate is increasing. The growing incidence of core icing has forced changes in aircraft operating procedures and prompted the creation of a new set of certification standards for engines and avionics.

Solving the HIWC mystery is important. Researchers theorize that ice core incidents are on the rise partly because more airliners are flying with greater frequency through mid-latitude and subtropical regions prone to intense convection. In addition ice crystals can affect aircraft data systems leading to errors in readings of temperatures, air speed and angle of attack. Icing is thought to have contributed to the loss of Air France 447, which crashed into the Atlantic after flying through storms in 2009.

Two international HIWC research groups are focused on tackling the icing problem. The North American HIWC study group involves NASA, the FAA, Transport Canada and Environment Canada, Airbus, Boeing and the Australia Bureau of Meteorology. The European high-altitude ice crystals (HAIC) consortium, which is coordinated by Airbus, brings together 34 industrial and research partners from 11 European countries and five from Australia, Canada and U.S. Both groups are coordinating research on three main

PETER MERLIN/NASA



The key ice particle instruments included (right) the isokinetic evaporator probe on the left side, which measures ice water content, and a cloud droplet probe. On the right wing (left), was a particle-imaging probe (on right side) and a 2DS stereoscopic probe.

objectives; understanding the physics of the HIWC process, developing new regulatory guidelines and developing HIWC detection methods.

Aviation Week was invited to join a NASA HIWC research flight from Fort Lauderdale, Florida. The test campaign forms part of what is "really a three-pronged approach to cracking this nut," says Ron Colantonio, project manager for engine icing research at NASA Glenn Research Center, Ohio. "First we have to characterize the weather that's causing the problem. Are the ice crystals small or big? How much is the water concentration? We don't have a handle on things like that," he says.

"Second, we want to know what's happening in the engine. What are the physics? It's not intuitive you can have icing inside an engine." To reach these answers, and to develop a simulation tool for engine makers to use for testing designs against core icing, Glenn has modified its Propulsion Systems Laboratory (PSL) to replicate HIWC conditions. The facility has been tested with a fully instrumented Honeywell LF502, which was one of the earliest high-bypass turbofans to exhibit vulnerability to "roll back" caused by icing.

"We can 'fly' an engine from the ground up to 40,000 ft. The ice crystals are generated in front by spraying liquid water into a cold airstream. By the time it gets to the engine it is frozen," says Colantonio. "It is the only capability in the world that can do this, and our hope is with this flight campaign we can see we are indeed replicating the right conditions in this facility. We think this is the new method of ground-based engine ice testing, and we are trying to develop new test methodologies and new ways to calibrate the facility. We need new diagnostics for ice crystals and water content. We are on the right path and we should have a solid capability in the next few years," he adds.

With updated engine certification regulations on the way to cover core icing requirements, NASA is working with the FAA and other agencies to use the PSL as a means of compliance. "We have an icing research tunnel that manufacturers could come to from around the world," says Colantonio.

The third target is to develop detection and warning methods, preferably by adapting existing onboard equipment. "The focus of these flights is to see if we can use remote-sensing capabilities, like the weather radar [to detect and avoid HIWC]. It is like the low-hanging fruit," he adds. For the HIWC program the DC-8 was fitted with a Honeywell RDR-4000 X-band weather radar, which is designed to measure liquid water content and turbulence. "A lot of the signal is filtered and we are going into engine icing conditions and saving the raw radar data; we hope to see that we can detect ice crystals with the radar or at least infer if there are ice crystals there," says Colantonio.

One puzzling question researchers hope to answer is why existing radars routinely fail to pick up ICI-like conditions at all, despite the very high water content. Air crews frequently report that weather radar at the time of engine thrust loss shows relatively

benign green (low reflectivity) or even black, indicating no discernible threat. NASA Langley Research Center weather radar principal investigator Steven Harrah says: "The amount of moisture that's deemed to be in these HIWC clouds is 3 grams/cu. mm or more, and if you converted that into precipitated rain, it would be 2 in. per hour, which is heavy rain. On a weather radar, that's deep into the red, so we are scratching our heads and saying, 'why aren't we seeing this already?' The systems work perfectly, so where's the missing part?" The answer likely boils down to droplet size, says Harrah, but even the variations found within a typical convective cell or between different regions of the world cannot account for the discrepancy.

A potential answer is that the drop size distribution is skewed, and that although there is a lot of water held within the cloud, it is made up predominantly of particles too small to be picked up the radar. Weather radars operate on wavelengths optimized for around 1 mm, "which works very well, but for HIWC conditions that are maybe dominated by particles of 100 microns or smaller, that's not so good," he adds.

While dual-band radar could provide one answer, the preferred solution likely will be the less expensive route of adapting current radars with new signal-processing algorithms that will be able to "infer" the presence of HIWC. "We can measure convection and reflectivity in the atmosphere, where there is lot of moisture, so we can measure a high probability of HIWC at a certain point in space. That's just a software change in the existing box," says Harrah.

Specifically, researchers believe the location of the HIWC event can be inferred by bringing together evidence from the existing data or which can be gleaned from new modes. Convection can be mapped using a NASA-developed mode that measures vertical winds. Higher reflectivity at lower altitudes—indicating higher visible water amounts around the convective area—is another clue, while radial winds that advect moisture away from the convection "chimney" will also help locate the danger area. "Looking at those winds, we can infer where it should be and using outside air temperature and other parameters we can fine-tune it," says Harrah. Preventing nuisance alerts will be key. "If pilots turn it off, that's the worst possible result," he adds.

For the test campaign, which included 10 flights over 20 days, the goal was to record both instrumented weather and standard radar data as the DC-8 flew in known HIWC conditions, and then see if by comparing the data a potential HIWC radar signature could be identified. The instrument suite included an isokinetic evaporator probe (IKP), a pitot-style forward-scattering device that measures ice water content, and three devices to gather data on particle shape and size. The trio was made up of a cloud droplet probe for particles 2-50 microns, a particle-imaging probe (PIP) for 100 microns to around 6.2 mm, and a 2DS stereoscopic probe for 10 microns to 1.2 mm.

"We're trying to relate these ice water content-level measurements to what we what radar signatures are being recorded," says Tom Ratvasky, in-situ probes co-principal investigator for NASA Glenn. "The data we are collecting and the technology we are working on for a more sensitive radar could be offered to assist the current fleet to avoid hazards. It will also help development of real-time nowcasting tools for detecting HIWC conditions, which the FAA is very interested in. The flights will also help with pilot education," he notes.

For the HIWC campaign, the normally NASA Armstrong Flight Research Center-based DC-8 was temporarily housed on Florida's Atlantic Coast. From here, researchers had the option of targeting convective weather over the Caribbean and western Atlantic or nearby Gulf of Mexico. On the day of Aviation Week's 7-hr. flight, a line of thunderstorms was marching across the gulf and intensifying over Louisiana, providing promising conditions for engine icing.

Closing on the line of storms from the east, the aircraft was flown initially on the west side of the system's stratiform clouds at 37,000 ft. Turning north, the DC-8 was flown through the edges of the storm, avoiding the areas of maximum turbulence red-painted on the radar just as any commercial airliner crew would do. Careful measurements of water content, droplet size, radar data, air temperature and other parameters continued throughout the flight, as the aircraft made several passes around a north-south oriented track through the storm. The aircraft then descended, and the pattern of observation was repeated at 34,000 ft. and 29,000 ft.

Good HIWC data was successfully gathered, and ice buildup on the air data and total air temperature probes around the cockpit was noted by the crew, even though the radar was indicating green or black. Several crews experiencing ice core events have also reported temperature anomalies, and for the first time on any research flight, the NASA campaign recorded total air temperature probe indication changes from well below freezing to freezing, and the temporary failure of the aircraft's pitot tubes. Later in the campaign, the DC-8 also flew into Tropical Storms Danny and Erike, the first time that an aircraft equipped with both an ice water measurement suite and pilot weather radar was able to record conditions associated with such events.

PETER MERLIN/NASA

To evaluate standard radars for HIWC warning, Honeywell RDR-4000 weather radar data was collected from simultaneous scans above, level and below the flight path and compared with data from the ice-measuring instruments.

GUY NORRIS/AW&ST

Throttles are staggered and individually altered every few minutes to mitigate potential engine core icing while flying in HIWC conditions.

Freeze Flying

NASA pilots develop test techniques for hazardous engine icing conditions

Guy Norris Fort Lauderdale, Florida

Flight testing for engine core icing by necessity involves deliberately flying a large research aircraft into atmospheric conditions that are known to cause turbofans to lose thrust, flame out and even sustain damage.

So how do you fly such a test program efficiently and gather useful data without endangering the aircraft, its engines and the crew? Although the CFM56-2 engines powering NASA's DC-8 have no history of uncommanded power reductions, or "roll back," test planners were aware that very few engines of any make have been purposely subjected to sustained and repeated exposure to high ice water content (HIWC) conditions.

"We need to make sure we don't flame our engines out, so we worked with General Electric, Boeing icing experts, NASA Glenn and Langley," says Wayne Ringelberg, lead HIWC project pilot for NASA. A former U.S. Air Force test pilot with heavy, multi-engined aircraft experience, Ringelberg worked with NASA Armstrong Flight Research Center chief pilot Nils Larson to develop an appropriate piloting approach.

"We ran a systems-safety working group just on the icing hazard mitigation to see what we thought the hazards are, and what we think we can do. It turns out a lot of it was 'we don't know for sure' because the phenomenon is quite unknown," says Ringelberg. "We had a sense we were probably not highly susceptible but we just didn't know," he adds.

The agreed mitigation procedure involves staggering the four throttles as soon as the ice particle instruments indicate the aircraft has entered air with high ice water content above 0.5 grams/cu. meter. "Once we hit that level we are in it," says Larson, who is also a former Air Force test pilot. "Every five minutes or so, you tweak them," he adds. "We are flying on autopilot and the throttles are only staggered in the 2-5% range. We also only move one throttle at a time." The slight variation in N1 (fan speed) is expected to be enough that if icing were to strike, only one engine at a time would be vulnerable. But there are no guarantees, says Larson. "Everyone's guessing here, there are a lot of unknown unknowns."

NASA flight engineer Tim Sandon continuously ran both anti-icing ignitor loops on each engine as a precaution. "We leave them on 20 minutes after exiting the ICI [ice crystal icing] area and leave them on prior to descent, as that's a risk area," says Ringelberg.

The campaign also is aimed at educating crews for "seat of the pants" HIWC warning signs. Even though nothing might be showing up on the weather radar, there are plenty of clues to be had, says Larson. "Other crews didn't think they were in icing because sometimes on the windscreen it looks like water. That's because the particles splatter when they hit the windscreen and melt. Sometimes there's St Elmo's fire and sometimes there's a sound like a 'whoosh'—similar to the sound of an emptying drain." Descriptions of this rain-like effect baffled scientists for years, helping to compound the puzzle over HIWC. Pilots have also noted speckling on the windscreen, humidity changes, an ozone-like smell, crackling on the radios and a sound like rain on the cockpit roof.

Cold Case

Almost 60 years after the first known core-icing encounter, researchers are homing in on fixes

Guy Norris Fort Lauderdale, Florida

High ice water content (HIWC) research is underway to tackle what appears to be the relatively recent thrust-loss ice problem affecting modern turbofan-powered airliners. Yet there is evidence of unexpected power-loss events in convective weather since the 1970s, and for turboprops the trail reaches all the way back to the 1950s.

However, the stimulus for today's icing work has its roots in the unforeseen airframe icing event in 1994 that caused the crash of an American Eagle ATR 72 in Roselawn, Indiana. Investigators concluded that freezing drizzle had created a ridge of ice on the wing's upper surface aft of the deicing boots and forward of the ailerons. The ice, they believed, contributed to an uncommanded roll and subsequent loss of control. As a result the NTSB rec-

ommended changes to the icing certification requirements.

"The outcome of that by the NTSB was a recommendation to understand the icing environment that incudes supercooled water droplets and mixed phase environments—mixed-phase liquid particles and ice particles," says NASA Glenn Research Center icing researcher Tom Ratvasky. "So we went out and characterized that environment for supercooled large droplets [SLD]." An SLD can be 100 times larger than the tiny, human-hair diameter-sized droplets involved in normal icing, and are more likely to adhere to parts of the aircraft's surface beyond ice protected areas.

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The Engine Harmonization Working Group, a subcommittee to the 1999 Ice Protection Harmonization Working Group (IPHWG), was chartered to look for SLD-specific hazards for engines. "The review came out saying there were no problems with SLD. The outcome of the engine harmonization working group looking at event data said the majority of problems they were seeing were in and above clouds at high altitude and at temperatures not able to support large droplet icing," says Ratvasky.

The engine working group included icing experts Philip Chow from Honeywell and Jeanne Mason from Boeing, both of whom were already studying core icing incidents from the 1990s and early 2000s. "They were showing data from these events, and that's when it dawned on them that these had been triggered by a different kind of icing that appeared to be all glaciated, not a mixed phase," says Walter Strapp, a co-principal investigator in the NASA HIWC study and former physical scientist at Environment Canada.

The focus of many of the 1990s' thrust-loss studies had been on the AlliedSignal (later Honeywell) LF502-powered Bae 146, including a 1992 incident in which an Ansett-operated aircraft had lost power on all four engines over Western Australia. However, it was a 2002 event in the U.S. involving a McDonnell Douglas MD-82 in which the aircraft descended to 17,000 ft. before being able to restart its engines that produced one of the biggest clues. Although not caused by ice building up in the core of the aircraft's Pratt & Whitney JT8D-217 engines, the evidence showed ice particles had blocked the inlet of a pressure sensor which sent an erroneous message to the autothrottle. The MD-82 was also equipped with SLD ice detectors, but because these did not trigger, the event became a turning point in the understanding that engine failure was more likely linked to ice particles.

"It was a new discovery, but in fact it wasn't quite new," says Strapp. "They knew about it in the 1950s because they had a problem with the Bristol Britannia and flameouts in its Proteus engines." The issue began in April 1956 when two of the four turboprops on a BOAC Britannia flamed out at 20,000 ft. over Africa on a route proving flight to Nairobi. Kenya. The event was a mystery as the engine had successfully passed through intense ice-certification tests in Ottowa and, just as in recent events, no airframe icing was present. The only clue to the presence of ice particles was a thin white "witness line" along the null point on the leading edges.

As a result, Bristol, Rolls-Royce and the certification authorities "did a lot of work back in the 1950s characterizing the atmosphere. It was work that, in essence, we repeated. But it was no longer traceable and we didn't know how accurate it was," says Strapp. "However, they knew a lot about ICI [ice crystal icing] and by time we got onto HIWC in 2004 this was not common knowledge. We didn't think you could get icing from just dry ice crystals. You can get the same conditions at turboprop altitudes if you are flying in the tropics, and they were," he adds. Part of the reason the lessons were forgotten was the unusual reverse-flow configuration of the Proteus and the fact that the more popular pitot-style engines that succeeded earlier generations were not susceptible to ICI. "It went off people's minds," says Strapp.

Pilots were surprised by core icing in the Proteus-powered Bristol Britannia during African proving flights in 1956, well after ice certification tests in Canada had been completed.

The knowledge base began to grow again with the start of investigations into the BAe 146 issues. "People just didn't know what was going on," says Strapp. "There were wild theories about water being wafted high up into the atmosphere and confusing things going on like the total air temperature anomaly. Some people were interpreting this as a massive stratospheric event in which air was coming down during a super-severe system, but of course it was all red herring stuff. There was a much simpler explanation," he comments, referring to the false air data readings caused by ice particle contamination and the impact of HIWC on engines themselves.

North American, European and Oceanian groups have since joined forces on HIWC research that will also benefit science and forecasting, says Strapp. "Atmospheric science hasn't measured these phenomena well at all, so this project gives science an incredible opportunity. It will improve modelling and remote-sensing. Also looking at cloud micro-physics and trying to understand how you get high ice water and low radar reflectivity is key. That's a big unknown and strikes at the root of our lack of understanding about the development of ice."

SPACE

Fuel Bounce

SpaceShipTwo relaunch in 2016 with propulsion, safety changes

Guy Norris Las Cruces, New Mexico, and Los Angeles

Virgin Galactic confirms that following a series of successful hot-fire rocket tests, it has reverted to an improved form of the original rubber-based fuel for powering the company's suborbital SpaceShipTwo (SS2), the second version of which is nearing completion in Mojave, California.

Virgin Galactic—which plans to resume flights of SS2 in 2016—used a recently developed and more energetic nylon-based fuel for last October's ill-fated fourth and final powered flight (PF4) of the prototype SS2, during which the vehicle broke up following the copilot's earlier-than-planned unlocking of the feathering tail mechanism.

Company officials recently hinted they were considering a return to the rubber-based hydroxyl-terminated polybutadiene (HTPB) fuel used in initial test flights. The switch was confirmed by CEO George Whitesides at the International Symposium for Personal and Commercial Spaceflight in Las Cruces.

Perfecting the propulsion system has been the most challenging aspect of the suborbital spaceplane project. Virgin Galactic based its original power plan on a scale-up of the basic HTPB-fueled hybrid motor used in the original X-Prize-winning SpaceShipOne, but in 2014 announced it was opting to use a polyamide-based grain to achieve a step change in thrust and propulsion consistency. Meanwhile, parallel development of the HTPB fuel continued through 2014, and by the time PF4 occurred, so much improvement had been made that Virgin decided it would revert to the original fuel.

According to Whitesides, the change not only provides adequate power but also results in a lighter and simpler installation. The switch to a polyamide-based grain involved changes to the pressurization system that feeds liquid nitrous oxide into the solid fuel of the rocket motor. Those changes, now no longer required, included additional piping to improve initial combustion, as well as adding helium to stabilize the motor toward the end of the burn.

Virgin Galactic chief pilot Dave MacKay says, "The extended downtime since the accident has given the Virgin Galactic rocket motor team time to take over development of the commercial hybrid motor. We are pleased to report the new design demonstrates superior thrust and beautiful, smooth, beyond-full-duration burns at a lighter system weight and with less system complexity."

MacKay—at the Society of Experimental Test Pilots symposium in late September—described several other vehicle changes that have been made as a result of lessons learned from the loss of the prototype. Virgin Galactic has completed an in-depth systems review of both the SS2 and WhiteKnightTwo (WK2) vehicles "with a focus on the human factors using a different mindset," MacKay said. "Modifications are being made to improve human factors to the cockpit hardware and software. We are running a safety interlock to prevent both a premature unlock or premature locking of the feather."

Changes also include a safety catch added to the landing gear handle to preclude inadvertent actuation during critical flight regimes. "We have also carried out a thorough review of crew resource management [CRM] procedures and standard call-outs. Despite higher workloads and split-responsibility allocation, some irreversible processes must be cross-checked.

"Prior to future flights, the flight crew will unfasten their emergency oxygen handle from its Velcro housing to allow for one-handed operation. Plans are in the works to practice powered-flight CRM with representative displays in a centrifuge under boost accelerations, and prior to test flights a final integrated simulator session will consist of multiple nominal full-mission profiles for the benefit of both the crew and control room," he adds.

VIRGIN GALACTIC

Systems work is underway following installation of the main oxidizer tank into SS2, the first vehicle built by The Spaceship Co.

Production staff at Virgin Galactic affiliate The Spaceship Co. (TSC) are "working three shifts" as they near completion of SS2 serial No. 2, Whitesides says. Although largely unchanged from the first vehicle, the new spacecraft will have slightly larger horizontal stabilizers to counter the tail-stall condition experienced during tests in September 2011. Following the incident, which occurred on glide flight 16, SS2 was modified with larger, one-piece, horizontal strakes.

Assembly of the second suborbital vehicle was brought forward following the loss of the prototype SS2 in last October's test accident. Since the new aircraft sat on its own wheels in May, "we have made a lot of progress, largely on systems installation. The airframe and propulsion system is sound and we require very few changes since our accident," Whitesides says.

"The next steps will be installing systems along the wings and finishing the avionics inside the cabin as well as putting in the seats," Whitesides says. "We've been working on developing better seats. We just now finished, a couple of weeks ago, new versions of our pilots' seats, which will be integrated into the vehicle. Another important milestone we just finished last week was our fatigue test of the cabin. Over the past year and a half we have done a 10,000 cycle pressure test of our cabin. That's important because we are building a reusable spacecraft, and we were very happy to get through that.

"When we return to flight, we will do so with a vehicle that's not just ready to glide but will also be able to transition quickly to powered flight tests," MacKay says. "The upcoming flight test program will be a joint effort of the TSC and Virgin Galactic and will consist of a mix of regression testing and envelope expansion."

Meanwhile, WK2 is also close to returning to flight following an annual inspection. The aircraft will be used to carry SS2 for initial captive-carriage flights early in 2016, leading to glide and powered flight tests later in the year.

Gallery *Take a look at recent milestones in the assembly of the second SpaceShipTwo:* **AviationWeek.com/SS2-2**

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Second in a series celebrating Aviation Week's 100th anniversary

Wings Around the World

Airliner technology milestones and the moving story of air transport

JPATOKAL/WIKIMEDIA

Guy Norris Los Angeles

On a bright New Year's Day morning in 1914, an enthusiastic crowd that had gathered at the yacht basin in St. Petersburg, Florida, cheered with delight as a fragile-looking Benoist XIV floatplane left the water and pointed its blunt nose in the direction of nearby Tampa. Squeezed into the tiny cockpit were pioneer aviator Tony Jannus and Abe Pheil, a former St. Petersburg mayor who had bid $400 to become the first fare-paying passenger on the world's first scheduled, fixed-wing airline flight.

Percival Fansler, the local businessman behind the St. Petersburg-Tampa Airboat Line recalled: "[T]he idea popped into my head that instead of monkeying around with [the Benoist XIV] to give 'jazz' trips, I would start a real commercial line from somewhere to somewhere else. My experience in Florida led me to conclude that a line could be operated between St. Petersburg and Tampa." As the aircraft prepared to depart, Fansler said prophetically: "[W]hat was impossible yesterday is an accomplishment today, while tomorrow heralds the unbelievable."

The scheduled airline, like so many that would follow, did not last long. Flights ended after four months and 1,205 passengers carried, but history had been made. Tom Benoist, the designer of the biplane pusher used for the services, concluded that "we have not made much money, but I believe we have proved that the airplane can be successfully used as a regular means of transportation and commercial carrier." Yet it is doubtful that even in their wildest dreams Benoist or Fansler could have imagined the transport evolution to come.

CITY OF ST. PETERSBURG, FLORIDA

Tony Jannus at the controls of the Benoist XIV c. 1914.

Fast forward to 2015, just over a century after Jannus's first flight; the global air transport system this year alone will carry almost 3.5 billion passengers—nearly half the world's population. In 2014 airlines transported 3.3 billion passengers, which was the population of the entire planet in 1965. The airline industry has become a vital element of the socioeconomic well-being of modern civilization. According to the International Air Transport Association, more than $820 billion—1% of the world's gross domestic product— likely will be spent directly on air transport in 2015.

Nearly 3.5 billion passengers will travel this year on more than 54,000 scheduled air routes that crisscross the globe.

In a 2014 report, the Swiss-based Air Transport Action Group (ATAG) notes that it has taken 100 years to fly 65 billion passengers, but forecasts it will take only another 15 years to fly the next 65 billion. According to ATAG, based on 2012 figures, the industry supported more than 58 million jobs worldwide, directly and indirectly boosting the global economy by $2.4 trillion. The global air transport fleet is expected to encompass 27,000 aircraft at the end of 2015, with scheduled departures increasing to more than 35 million, or roughly 67 departures per minute for the entire year.

But this astonishing growth began very gradually and despite the promising early start in the U.S., it was in post-World War I Europe where airlines in 1919 first began scheduled services that took hold in England, France and Germany. The following year, Dutch carrier KLM made its first flight from London to Amsterdam; it is now the oldest continuously operating airline in the world. In contrast, the pace of progress in carrying passengers in the U.S. was relatively slow because the country was served by a dense network of overnight trains; aircraft operators were primarily focused on the expansion of air mail routes across the continent.

The frustration was quietly evident in an editorial penned in September 1920 by Col. Lester D. Gardner, president and editor of Aviation Week's predecessor *Aviation and Aeronautical Engineering* magazine. Commenting on the extension of the New York-Omaha, Nebraska, air mail route to San Francisco, he noted that: "[F]or commercial

purposes, its importance promises to become just as great. In fact, the performance of the air mail will undoubtedly act as an incentive to prospective air transport firms by suggesting that if airplanes can carry mail on schedule from coast to coast, they can likewise transport passengers."

In that same edition, an advertisement by the Glenn L. Martin aircraft company similarly tried to change the broadly held view, in the U.S. at least, that flying machines were only for war. "Airplanes are no longer merely military requisites," it opined. "They are commercial necessities for they are transportation. People in all lines of activities are coming more and more to the realization of the practicability of the airplane. The unusual opportunities an airplane passenger, mail or express service offers as a profitable investment should appeal, when fully understood."

SMITHSONIAN NATIONAL AIR AND SPACE MUSEUM

Game changers: BAC Aerospatiale Concorde (foreground), Boeing 307 (rear) and Dash 80—the 707 prototype—(right).

The following month, Gardner pointed to the success of airlines from London to Paris as a bellwether. "Figures issued by the (British) Air Ministry show that for the week of May 24-30 there were 84 flights in which a total of 138 passengers were carried—during the week of Sept. 12-18, 128 fights made; 295 passengers carried—These data are very encouraging. The gains in numbers of passengers, goods and flights all indicate greater confidence by the public in this form of transportation."

Confidence grew as speed, range, safety and altitude capability slowly improved. Thanks to a series of key technology breakthroughs in structures, aerodynamics, propulsion and systems from 1919 onward, the airline industry was on an accelerated course toward the global economic engine it is today. Though by no means meant to be comprehensive, some of the most significant kick starters follow.

Gallery *See more on key contributors to the development of commercial air transport:* **AviationWeek.com/AviationLinchpins**

Technology Steppingstones

CANTILEVER MONOPLANES

Part of the DNA of the modern airliner can be found in the Junkers F.13, a four-passenger, low-wing cantilever monoplane that was clad in corrugated metal skin. First flown in 1919, the

SOFTEIS/WIKIPEDIA

Hugo Junkers-designed aircraft was an instant step change from its wood-and-fabric biplane contemporaries, and highly durable. The skin, made from an aluminum alloy called Duralumin, was partially stressed and helped the wing spars carry shear loads. The success of the F.13 paved the way for other metal-skinned early airliners developed by Fokker as did the William Stout-designed Ford Trimotor, which first flew in 1926.

ENGINE-COOLING DRAG

Although the development of monoplane airliners saw significant increases in cruising speed—up to around 120 mph in the case of the Ford 5-AT version of the Trimotor—the main factor was more-powerful engines. While relatively little attention was paid to reducing airframe drag until the mid-

NASA

1920s, work at the National Advisory Committee for Aeronautics (NACA, forerunner to NASA) led by Fred Weick, head of Langley's new 20-ft. dia. Propeller Research Tunnel, focused on reducing the high drag of radial engines. Weick's work, paralleled to some degree by studies at the National Physical Laboratory in the U.K., led to the low-drag engine cowling, which improved cooling and cut drag by two-thirds. In 1929 barnstormer pilot Frank Hawks set a new speed record in a Lockheed Air Express fitted with the new cowls. The cowlings enabled a 20-mph-speed increase to 177 mph. Jerry Vultee of Lockheed later sent NACA a telegram saying the record would have been "impossible without new cowling."

STREAMLINING AND STRESSED SKIN

As awareness of the efficiency benefits of monoplane designs grew in the late 1920s, Boeing focused its design talent on a single-engine mailplane called the Boeing 300 Monomail, which took to the air in 1930. The all-metal stressed skin aircraft featured a highly stream-

SAN DIEGO AIR AND SPACE MUSEUM ARCHIVES/WIKIPEDIA

lined, semi-monocoque fuselage with retractable undercarriage. While early metal skins provided torsion and shear loads, stressed skin also absorbed bending loads. Developed theoretically by Herbert Wagner in Germany in the late 1920s, the first practical stressed-skin wing structure was independently devised and constructed by Jack Northrop for his X-216H flying wing.

By riveting stringers to the inside surface of the wings, the loads could be shared with the spars. Similarly fuselage ribs and skins could be integrated into stressed shell constructions that were stronger, yet lighter, and enabled aerodynamically cleaner designs. Boeing's all-metal Model 247, which first flew in 1933, integrated stressed skins,

retractable gear and advanced features such as an early autopilot, trim tabs and deicing boots. The initial 247s were sold to United Airlines whose parent company, United Aircraft and Transport Corp. also owned Boeing. When the latter therefore declined an order for 247s from Transcontinental & Western Air (TWA), the airline sought proposals for a similarly sized aircraft from competing manufacturers. In 1932, TWA awarded a contract to Douglas Aircraft for a twin-engine 12-seater dubbed the Douglas Commercial (DC-1).

By the time the DC-1 flew in 1933, more-powerful Wright Cyclone R-1820 engines were available, which enabled Douglas to quickly develop the enhanced DC-2. This provided the platform for the wider fuselage DC-3 variant which seated 21, increasing capacity by 50% over the DC-2. Yet the aerodynamics of the wider fuselage caused only a small increase in drag, resulting in an aircraft of unprecedented economic efficiency. Sales of the DC-3 mushroomed among U.S. airlines and, by the outbreak of World War II in Europe, the popular twin was carrying around 75% of domestic traffic.

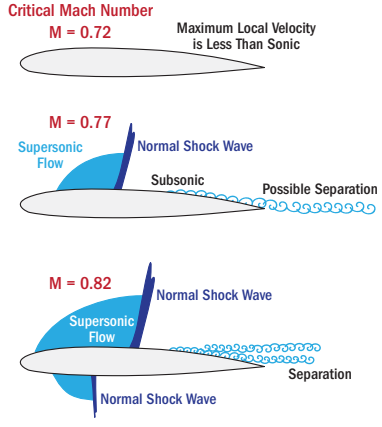
PRESSURIZATION

In the mid-1930s, U.S. airlines grew increasingly interested in the potential development of larger, longer-range four-engine airliners. In response Douglas developed the tricycle-gear configured DC-4E (Experimental), which, in a later phase, was to incorporate cabin pressurization. TWA, which along with American, Eastern, United and Pan Am, contributed funds toward the DC-4E program, also launched its own "over-the-weather" research program with the modified DC-1 and later a Northrop "Gamma" testbed fitted with oxygen for the crew and supercharged engines. In 1937 Lockheed also conducted high altitude tests of a specially modified Electra with an all-new pressurized fuselage.

Responding to interest in a pressurized aircraft from TWA and Pan Am, Boeing also began development of the Model 307 Stratoliner which married the Model 299 (B-17) wings, tail and landing gear with an all-new semi-monocoque fuselage with a circular cross-section. The skin was designed to be gas-tight, but also to allow for the inevitable constant leak from minor gaps and imperfections. At the same time it had to carry stress loads set up by internal pressure. Pressurization expands the cabin, putting the skin in tension and, for a cylinder, exerting a circumferential stress twice that of the longitudinal stress. The pressurization system used air from General Electric Type B-1 superchargers fitted to the aircraft's Wright Cyclone engines.

COMPRESSIBILITY

As more powerful fighter aircraft were developed during World War II, pilots began to encounter compressibility effects at high speeds. These typically begin to occur at speeds over 250 mph when air around the aircraft becomes compressed and increases in density



COLIN THROM/AW&ST

Shapes and Sizes

Search for cabin comfort leads to twin-aisles and twin-decks

The airline passenger experience in the 1920s could not be characterized as pleasant. Major improvements were needed, particularly addressing noise in the cabin. "The noisiness of the airplane engine constitutes an ever-present difficulty, much greater in importance than has generally been realized," wrote Edward P. Warner in Aviation Week's predecessor, *Aviation*, Oct. 30, 1922. Warner went on to become assistant secretary of the Navy for aeronautics and president of the International Civil Aviation Organization. "I have talked with a considerable number of my fellow passengers on the European lines," he continued, "most of whom had never flown before and a considerable number of whom apparently had no desire to fly again, and in nearly every case where the passengers declared that 'once was enough,' their antipathy could be traced to the noise which renders conversation absolutely impossible during the journey in most machines and which leaves some of the inexperienced travelers partially deaf for an hour or more after finishing the trip."

Passengers board an Imperial Airways Handley Page HP.42 somewhere in Africa.

FLICKRIVER/SHORPY.COM

While aircraft such as the Boeing 247, DC-1 and DC-2 advanced the state of the art, the 7-ft., 8-in.-wide cabin of the DC-3 represented a step change in comfort. However, passengers disliked the tail-sitter's sloping floor, in part prompting Douglas to consider a tricycle gear arrangement for its much larger DC-4E follow-on study. Passenger experiences on long-haul flights were equally mixed in Europe, where the majority of services were operated by Britain's Imperial Airways and KLM of the Netherlands to their country's respective colonial interests.

In the 1930s, Imperial offered routes to Africa, the Middle East, India, Southeast Asia, Australia and New Zealand using a combination of seaplanes, trains and slow flying airliners such as the 24-seat Handley Page HP.42/.45, a 130-ft.-span biplane with four Bristol Jupiter engines. Unpressurized

thus changing the forces acting on the airframe. In a dive, pilots found that controls were difficult to move, or in some cases, reversed or froze. The situation escalated as the aircraft neared the speed of sound, a speed ratio dubbed the "Mach" number in honor of the 19th century gas dynamics physicist Ernst Mach.

Taming this problem became paramount as speed increased with the introduction of jet-powered airliners. Complications that were encountered as the aircraft reached a critical Mach number (close to the speed of sound, or transonic) included "Mach tuck," in which the aircraft nose would pitch down as the center of lift moved aft, as well as buffeting and reducing elevator effectiveness. To address these issues, designers introduced several features, including an all-moving trimming tail, to overcome the effect of compressibility on elevators. The device helped the Bell X-1 pass through the "sound barrier" in 1947 and the following decade it was introduced into commercial service on high-speed airliners such as the Boeing 707 and Convair 880. Other mitigating features included thinner, reduced camber airfoil sections and swept wings.

SWEEPBACK

Wing sweepback allows jet airliners to cruise at high subsonic speed because it delays the shock waves and drag rise associated with the onset of compressibility effects. German aircraft such as the Me-163 and Me-262 appeared with modest leading-edge sweepback dur-

BOEING

ing World War II, mostly for stability rather than drag reduction. Germany's breakthrough high-speed aeronautical research was subsequently seized on by Boeing for the design of its B-47 jet bomber. The aircraft's swept wings and pod-mounted engines provided the template for the majority of airliner configurations developed over the past six decades.

FATIGUE LIFE AND FAIL SAFE

The combination of higher operating altitudes and pressure cabins, added to dramatically increased operating cycles, meant early jet airliner manufacturers were unwittingly entering unknown territory when it came to airframe fatigue. This was revealed to the industry through a string of catastrophic inflight breakups in 1953 and 1954 involving the de Havilland Comet 1, the first jet-powered airliner to enter service. Wreckage salvaged from one of the crashes 500 ft. beneath the Mediterranean Sea revealed evidence of an explosive decompression. This concurred with results from pressure tests of a test fuselage and wings under repetitive loads in a water tank, which ended with catastrophic structural failure after the equivalent of only 3,060 flights. Stress concentrations around the windows were much higher than expected, with forces near corners of a radio aerial window calculated at more than 40,000 psi. The stresses fatigued the materials around small rivet holes, causing the explosive development of a crack several feet long.

The Comet accidents led to much greater scrutiny of analysis and test-

and flying at low altitude, the London-Cape Town, South Africa, journey in 1932 spanned 72 flight hours, four changes of aircraft and more than 1,200 mi. of train travel. On the Cairo-Cape Town route alone there were 27 main airfields and 30 intermediate stops. Mechanical issues and weather constraints heaped on more unplanned stops. On one occasion after a forced desert landing in the Middle East, the captain sent his passengers out to collect dry animal dung in their hats to use as fuel so they could stay warm overnight.

The advent of more-powerful engines and pressurized cab-

GUY NORRIS/AW&ST

Boeing studied several double- and single-deck options for the 747 before settling on the wide-body single deck with upper-mounted flight deck familiar today.

ins in the late 1930s, pioneered by Boeing's Model 307 Stratoliner, allowed U.S. transcontinental flights to operate up to 20,000 ft., above most of the weather and fly direct routes over mountainous areas. Thanks to more advanced cabin booster pump experience—gained during operation of the B-29 bomber (which had a pressurized crew cabin) in World War II—airlines were able to offer, in post-war DC-6 and Constellation aircraft, a comfortable cabin altitude of 8,000 ft. while the aircraft were at cruise altitudes of up to 20,000 ft.

Aircraft capacity was also increasing as piston-engine development reached its peak. Unusual configurations included the ill-conceived Bristol Brabazon, a 230-ft.-span, eight-engine behemoth, aimed at the transatlantic market. While the Brabazon was configured around a single, staggered deck level, other manufacturers opted for more sensible double-deckers. These included Boeing's B-29/C-97-derived two-deck Stratocruiser and the 189-ft. wingspan Lockheed Constitution. Both utilized "double-bubble" fuselage cross-sections, the former evolving from marrying a larger upper section to the original B-29, while the Lockheed design echoed features of the Curtiss C-46.

Another twin-decker was the French-built Breguet 761, nicknamed the Deux-Ponts. Configured to seat 135 in a high-density layout, this aircraft—like all the large pistons—was soon made obsolete by the arrival of jets. The Deux-Ponts' nemesis was Sud-Aviation's Caravelle, the world's first airliner with tail-mounted jets; it debuted in 1955. The aft positioning of the engines resulted in an uncluttered wing and a quiet cabin, and was adopted by a string of competing companies in the following decade for short-, medium- and long-haul designs. These included the Douglas DC-9, Tupolev Tu-134 and Tu-154, BAC One-Eleven, Fokker F28, Boeing 727, de Havilland Trident, Ilyushin IL-62 and Vickers VC10.

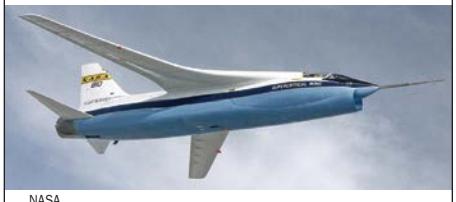
The development of the gas turbine also spawned an intermediate generation of turboprop airliners that offered efficiencies as good as, or better than, the best piston trans-

FAA

ing of fatigue life, particularly since de Havilland's initial fatigue testing had indicated failure at 16,000 cycles—well beyond the planned 10,000-cycle design life. The accidents also led to changes in design philosophy across the industry and the adoption of a fail-safe design for airliners that requires multiple load paths to maintain structural strength in the presence of a crack or damage. Later changes would mandate that airliner structures must also be damage tolerant, meaning they can withstand damage until it is detected and repaired. Some critical aircraft structure parts, such as landing gear, are designed for safe-life, meaning the part is guaranteed for a certain life span before replacement.

SUPERCRITICAL WINGS

While early jet airliners relied on wing designs with conventional cross-sections, aerodynamicists including Richard Whitcomb at NASA Langley and Dietrich Kuchemann at RAE Farnborough realized that more performance could be gained by tailoring the airfoil for transonic conditions. The focus was to delay the onset of the supersonic shock wave over the wing, which causes wave drag, thereby allowing more efficient cruise performance at a higher Mach number. The resulting airfoil cross-sections were much flat-



NASA

ter on the upper surface, blunter at the nose and inversely cambered at the lower aft wing surface. The flatter upper surface helped maintain a smoother boundary layer, while the blunt leading edge attenuated the suction peak and the scooped out lower aft surface gave aft loading to generate increased lift. The overall outcome: The shock wave moved further aft over the wing and reduced in intensity.

WINGLETS

Another aerodynamic improvement feature, now widespread across the modern airliner fleet, is the drag-reducing winglet. Developed initially in response to the 1973 oil crisis, NASA flight-tested a Whitcomb-designed winglet on a Boeing KC-135 in 1979, but it was not until 1988 that a similar-looking feature debuted on the Boeing 747-400. Airbus meanwhile adopted a lower profile end-plate wingtip device which projected above and below the end of the wing. The shape was first introduced on the A310-300 as part of several efficiency advances including an inflight fuel transfer system to optimize center of gravity, and lightweight structures including the first all-composite tail fin.

The device was also used on the Airbus A320 and, in a much larger form, on the A380. The A330 and A340 meanwhile adopted more conventional winglets. Airbus also adopted a larger upward swept elliptical winglet, similar to the blended design used on the 737, for the reengined A320neo. A larger winglet, integrated into a wing-

ports, combined with high reliability and power. While the U.K. and Soviet Union pursued longer-range turboprop programs such as the Bristol Britannia and IL-18, respectively, the most success through the 1950s and '60s was enjoyed in the short- to medium-range market with the Fokker F27, Nord 262, Handley Page Herald, Vickers Viscount, Vanguard and Lockheed Electra.

However, Boeing's Model 367-80 jet prototype ultimately paved the way for the vast majority of today's turbofan-powered configurations. With an initial 132-in. cabin cross-section identical to that of the Stratocruiser, the "Dash 80" was considered too small for the preferred six-abreast seating Boeing envisaged. The cross-section was therefore extended to 144 in. for the KC-135 tanker variant, which was initially designed for commonality with the 707. But Douglas Aircraft's decision to widen the cabin of its competing DC-8 to a more comfortable 147 in. galvanized Boeing into a further 4-in. width extension for the 707. Although a costly decision, it established the benchmark for Boeing's single-aisle configurations right up to today's 737 MAX.

The leap to the widebody, or twin-aisle airliner, was stimulated by the booming economy of the 1960s but defined, somewhat ironically, by the growing assumption that supersonic airliners would soon dominate the world's trunk routes. In early 1966, just as Boeing and Pan Am were finalizing contracts for the development of a double-decker configuration for a 350-seat 747, the manufacturer conceived the idea of a single wide deck. Given expectations that 747s would ultimately be relegated to freight duties, the main deck was sized to carry two 8 X 8-ft. containers. The fuselage cross-section was based on a large circle drawn around the requirement, and the cockpit placed out of the way above the deck in the now familiar upper deck hump to allow loading through the nose section. The Airbus A380, which made its maiden flight in 2005, was the first jet airliner to be configured with seating along the full length of two decks.

RISE OF THE REGIONALS

Conditions for the birth of a generation of small jet airliners tailored specifically to regional markets emerged in the late 1980s as the routes feeding U.S. hub-and-spoke airports grew in length and frequency. But it was Germany's Lufthansa CityLine that began the revolution in 1990 when it ordered Bombardier's CRJ100/200, a stretched 50-seat derivative of the company's Challenger corporate jet. Embraer, a Brazilian manufacturer that previously built only small turboprop airliners, responded with an all-new twinjet dubbed the ERJ-145, which made its first flight in 1995. For the next 20 years both manufacturers continued to evolve their families to match the upward growth of the regional market, in the process killing off competition from previous incumbents such as BAe and Fokker as well as would-be hopefuls like Fairchild/Dornier. With capacity demands growing and increasing fuel prices making 50-seat aircraft operating costs difficult to sustain, the average size of regional jets has continued to evolve upward to the current 70-120-seat sectors covered by the larger CRJ

NASA

tip extension, is also incorporated into the A350. McDonnell Douglas also tested a form of bifurcated winglet on a DC-10 in 1981 and introduced a 7-ft.-tall upper winglet with lower vane on the MD-11 in 1990.

The winglet reduces vortex-induced drag by diffusing the tip vortex flow downstream of the wingtip and, in addition, it increases lift at the wingtip by inhibiting the flow of higher-pressure air below the wing to lower-pressure air above. The winglet increases higher effective span without adding much span or a significant increase in wing-root bending. However, for more recent Boeing designs such as the 767-400, 777, 787 and 747-8, the preferred option has been a swept, or raked, wingtip extension. For all-new wing designs with no span limitation, the raked tip could be integrated for less weight and higher aspect ratio than the winglet alternative. A foldable raked tip will be a feature on the 777X.

LAMINAR FLOW

As aircraftmakers strove for even greater fuel efficiencies in the 2000s, the potential saving from introducing an operationally supportable form of laminar flow gained ground. By maximizing the amount of smooth, uninterrupted airflow over the aircraft's skin designers hope to reduce skin friction, as well as delay the onset of drag-generating turbulent flow. Experiments to control laminar flow, either passively, actively or with a hybrid system combining both approaches, were conducted in the U.S. and Europe. There are two main methods for achieving laminar flow: passively, by retaining a smooth surface profile and keeping it clean from dirt and insects; and actively, by removing the boundary layer, sucking it into the wing leading edge via very small holes. Despite the introduction of a hybrid laminar flow control system with few moving parts on the vertical and horizontal tails of the 787-9, Boeing says the system will not be used for the 777X and may not be used in the upcoming 787-10 stretch, as previously expected.

GUY NORRIS/AW&ST

The passive system for natural laminar flow (NLF) requires tight design and manufacturing tolerances and is increasingly featured in Boeing designs such as the engine cowl leading edges of the 787 as well as the winglets and nacelles of the 737 MAX. Attempts to develop technology for enabling the greater use of NLF-designed wings are being explored by Boeing and NASA as part of the Environmentally Responsible Aviation program, and in Europe by Airbus as part of the European Union's Clean Sky environmental technology research initiative.

POWER-ASSISTED CONTROLS

As airliners grew in size and complexity, the traditional methods of balancing control surface forces with set-back hinges, horn balances and aerodynamic balance tabs were no lon-

Lufthansa was the launch carrier for Bombardier's CRJ family.

ADRIAN PINGSTONE/WIKIPEDIA

and E-Jet families. And new competition has emerged—the Mitsubishi MRJ, Sukhoi SuperJet and Avic ARJ21.

FLYING BOATS

For a while in the 1920-30s, the concept of large, passenger-carrying flying boats was well suited to the world's long-range transport routes, which lacked the key infrastructure, such as hard runways, for land-based aircraft. Water-based operations also found favor because most major international trade routes started and ended at seaports. But the global construction of hard runways and improvements in long-range transport aircraft at the end of World War II signaled the end of the golden era of flying boats. Indeed, the pursuit of very large flying boats produced two of the biggest white elephants in aviation history—the Hughes H-4 Hercules, popularly known as the "Spruce Goose," and the Saunders-Roe Princess. The 320-ft. span, wood-built Hercules was developed as a strategic transport by Hughes Aircraft, but was not completed until the war ended; it flew only once, in 1947. The Princess had a span of 219 ft. and was the largest all-metal flying boat ever built; it failed to find an operator and was scrapped in the 1950s.

Pre-war flying boats that were more successful include Dornier's 157-ft. wingspan Do X, which was powered by 12 engines, and the Sikorsky S-42 which, because of its high wing loading and Pratt & Whitney R-1690 Hornet engines, had a higher cruising speed. Other later notable designs included the Shorts S.23 Empire, Martin M-130 and, perhaps the ultimate commercial flying boat, the Boeing 314. All these designs incorporated the transverse hull step, which enabled the aircraft to start planing on takeoff and break the surface suction. They also featured high thrust-line engines to stay

Pusher-puller engines reduced asymmetric power-loss impact on Dornier's huge Do-X.

SAN DIEGO AIR AND SPACE MUSEUM ARCHIVES/WIKIPEDIA

ger sufficient. Hydraulically boosted controls were tried out by Douglas for its experimental DC-4E but rejected in favor of conventional aerodynamic balanced controls in the production DC-4. The competing Boeing 307 would instead emerge as the first airliner to have hydraulically boosted elevators and rudder. Later generations incorporated fully powered control

ORBITAL

systems with redundancy provided in the form of split control surfaces, each driven by its own actuator, power source and control system.

Flight-control system redundancy and sophistication took another step forward with the leap to first-generation widebody jets in the 1960s. One of the most advanced was the direct lift control (DLC) in Lockheed's L-1011 TriStar, which was designed to control the deflection of the inboard spoilers during final approach to provide vertical speed control without significant changes in pitch attitude. The DLC produced a constant pitch attitude approach and worked automatically in manual or autopilot operation. The short-bodied L-1011-500 derivative was also the first widebody airliner to incorporate a digital autopilot instead of an analog system. The combined autopilot and DLC enabled Category IIIb autoland capability on the TriStar.

The L-1011 also incorporated an active control system that increased stability by automatically and symmetrically deflecting the outboard ailerons to counter turbulence. The action was triggered by wing-tip and tail-mounted accelerometers, which activated the control surface movement, redistributing lift across the span and reducing wing bending. Versions of the maneuver load alleviation (MLA) system were later introduced by Airbus on the A330/A340 and A380 and by Boeing on the 777F and 787, respectively. The MLA on the 787 progressively extended spoilers during high-G gust and turbulence conditions to reduce wing-bending stress.

The 787 was also equipped with an automatic gust load alleviation system which extended the spoilers and deflected the ailerons to reduce wing-bending in turbulence with the autopilot engaged. A similar system on the A320 alleviates gust by dumping lift via negative outboard and inboard spoiler deflection, and using elevator deflection to pitch the aircraft. The 787 also featured an autodrag function to help the flight crew descend from above to capture glideslope while maintaining airspeed at idle thrust by deflecting the ailerons downward—and outboard two spoilers upward—if the landing gear is extended and flaps are down for landing.

FLY-BY-WIRE

Fully integrated load alleviation has been made easier by the increasing use of fly-by-wire (FBW) flight control systems. Flight controls are electrically

AIRBUS

signaled from the cockpit controls instead of being mechanically connected by cables. As well as reducing weight

clear of spray, and a deep hull shape which was, in each case, a unique compromise between aerodynamic and hydrodynamic requirements.

SUPERSONICS

The production of supersonic military aircraft in the 1950s sparked dreams of developing a commercial faster-than-sound airliner, particularly in the U.K., where studies were initiated in 1954. The French also began a supersonic transport (SST) project, and in 1962 the two national efforts were merged into the joint Concorde development program. The same year, the Soviet Union revealed that it too had embarked on development of a supersonic transport, the Tu-144, an externally similar, slender-delta configured SST. The Concorde, sized to carry 120 passengers across the North Atlantic at a cruise speed of Mach 2.02, was powered by four Rolls-Royce/Snecma Olympus 593 turbojets. Although the engines used after-burning for takeoff and acceleration, sustained supersonic flight was maintained in supercruise mode without afterburner.

Key design features included ogee/oogival-shaped double delta wings, which produced lift via leading-edge vortices that exhibited the same flow pattern over a wide range of Mach numbers and angles-of-attack. Other notable innovations included computer-controlled variable engine inlet ramps to manage the shock and reduce inlet velocities, electrically controlled analog fly-by-wire flight controls and a droop-nose section for improved visibility on approach and

Concorde's slender delta wing developed lift-generating vortices.

ONERA

landing. Neither Concorde nor the Tu-144 were configured with a horizontal tail, although production versions of the Tupolev were fitted with retractable nose-mounted canards for slow speed handling. The Tu-144 ended commercial passenger service in 1978, although the type's final flight came in 1997 as part of NASA's High Speed Commercial Transport (HSCT) research program. Environmental concerns about noise and sonic boom severely limited Concorde's commercial prospects by the time it entered service with Air France and British Airways in 1976. Following the crash of an Air France aircraft in 2000 and the collapse of air traffic in 2001, the aircraft was retired in 2003.

U.S. interest in supersonic airliners focused on larger and faster (Mach 3) concepts, but the proposed Boeing 2707-300 project was canceled by the U.S. government in 1971. NASA's industry-supported HSCT project briefly revived interest

and complexity, the systems can be programmed to keep pilots within the aircraft's flight envelope, improve handling characteristics and reduce pilot workload. The first commercial airliner to employ an electrically signaled, analog-controlled FBW was the BAC Aerospatiale Concorde; the first digital FBW system entered service on the Airbus A320 in 1988.

ADVANCED ALLOYS AND COMPOSITES

For most of the 20th century, aluminum alloy made up the bulk of virtually all aircraft structure, but from the mid-1980s onward the industry saw a slow but steady increase in the use of nonmetallic fiber-reinforced plastics such as carbon-fiber reinforced polymer (CFRP) composites. A series of new heat-treated alloys and lighter-weight aluminum-lithium alloys have been developed to counter the composite challenge, the latter weighing around 10% less than the widely used 2000 series alloys that have been present in various forms for aircraft since the 1920s, while retaining the same strength as 7000 series. Despite reliable stiffness, fatigue and corrosion properties, the use of Al-Li has been limited, largely due to high lithium production costs. The material was, however, selected by Bombardier for the fuselage skins of the C-Series, and in future single-aisle designs Al-Li is expected to be cost competitive with composites.

A hybrid material incorporating fiber and aluminum called Glare was selected by Airbus for the fatigue-critical upper fuselage skin sections of the A380. The material, which is a laminate of fiberglass prepreg and aluminum alloy, is less dense but stronger and more corrosion resistant than standard aluminum.

Composites attracted interest from manufacturers because of their high strength, low weight and durable corrosion and fatigue properties. They are also preferred for their stiffness,

BOMBARDIER

AIRBUS

which enables higher-aspect-ratio wings, as well as their adaptability to different geometries. Following initial use in fairings and flight control surfaces, composites are now increasingly a part of the primary structure; they form 50% of the 787 airframe and 53% of the A350.

However, composites remain more expensive than aluminum alloys, which still comprise around 47% of industry material use compared to just 5% for CFRP. They also pose damage detection and repair challenges, despite extensive support work done in this area by Airbus and Boeing. This is one reason why many industry watchers expect single-aisle designs to come will likely combine composite wings with metal fuselages. Future composite research is meanwhile focused on out-of-autoclave thermoplastics and thermoset composites, both of which could help reduce the manufacturing cost of the material.

in commercial SSTs in the 1990s, but commercial and research interest has since refocused on technologies for environmentally acceptable, low-boom designs for business jet applications.

NEW SHAPES

As aircraft manufacturers look for leaps in efficiency for future airliners, the tried and trusted "tube and wing" formula that has faithfully served the air transport industry for almost 100 years is set to change. The next cycle of airliners to replace the A320neo and 737 MAX will most likely not benefit from a major innovation, but designers already are pondering potentially radically different configurations for future generations. Driven by ambitious environmental performance targets, researchers are evaluating a range of potential new airliner shapes including hybrid/blended-wing-bodies, double-bubble fuselages and flying wings, as well as advanced tube-and-wing airframes with truss-braced high-aspect ratio wings and highly integrated propulsion systems.

Hybrid wing body and other novel concepts are under study for future, higher-efficiency airliners.

NASA

Foundational work to support these developments is ongoing as part of industry, FAA and NASA programs in the U.S., and in Europe under the multinational, industrial and academic Clean Sky initiative. Aerodynamic studies continue on a range of blended-wing body shapes which, as the name suggests, feature a combination of flying wing and fuselage bodies to generate lift across the span of the entire aircraft. The broad upper-aft section supports podded, open rotor or distributed hybrid propulsion systems, advanced versions of which are designed for efficient fuel burn as well as low noise and emissions. New structural concepts are also under study for blended-wing configurations, which offer lower weight than tube-and-wing shapes.

Wind tunnel tests of the "D8" double-bubble wide fuselage concept indicate that with extra lift from the body, low drag and embedded engines aft of the wings, a 180-seat version flying at Mach 0.74 could be as much as 70% more fuel efficient than current aircraft. Similar tests of a long-span, low-drag truss-braced wing indicate that the flutter weight penalty is small enough to make the configuration feasible for future energy-saving airliners.

Gallery *See more about milestones in airliner technology development:* **AviationWeek.com/AirlinerTech**

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Branching Out

Cebu Pacific targets long-haul markets to help fuel expansion

Adrian Schofield Manila

Like many low-cost carriers, the Cebu Pacific story is all about growth. The Philippine airline is not just content to increase its core narrowbody operation, however. It is also channeling its expansion into widebody and turboprop fleets to push its proven model into new markets.

The growth imperative is driven by the airline's management mantra: lowest unit cost will always win. This theme underlies all of Cebu's business decisions, says Chief Executive Advisor Garry Kingshott. Steady, sustainable expansion and high aircraft utilization drives down unit costs. So while the execution may change slightly, the fundamental strategy has always remained the same.

Studying the most successful low-cost carriers (LCC) such as Ryanair shows that they find a way to grow their business consistently, Kingshott notes. "The wonderful thing about growth is that it gives you a natural hedge against cost increases," he says.

This philosophy has seen Cebu carve out a dominant position in the Philippine domestic market, where it has overtaken legacy rival Philippine Airlines with a share of about 60%. Cebu also uses its fleet of 41 Airbus A320-family aircraft to operate short-haul Asian routes, and over the past few years it has built up a fleet of six A330s for flights to the Middle East and Australia. On the other end of the spectrum, it has ATR 72-500 turboprops to serve smaller domestic airports. Plans to add next-generation aircraft types will boost its capabilities further.

The airline has also proven to be a financial success during its expansion. It increased its net profit by 64% to 5.2 billion Philippine pesos ($112.9 million) for the six months through June 30, and both its profit margin (on the basis of earnings before interest, tax and amortization) and return on equity have stayed above 20%.

Cebu was launched in 1996 and reinvented itself as an LCC in 2005. The airline's first goal under the LCC model was to build a network in its home market that would be very difficult for anyone else to compete with, Kingshott says. It builds traffic by "offering affordable travel to a highly under-penetrated market," he says. The Philippine population of 100 million is one of the largest in Asia, yet only has 0.24 air trips per person per year.

At the low-cost end of the market in a nation consisting of 7,000 islands, one of the airline's main competitors is ferry service. So Cebu planners examined ferry schedules to find out where the traffic was and what fares were charged to determine where it could be competitive.

It has also targeted intercity bus routes. For example, the airline saw a route between cities on the north and south coasts of Mindanao that had 300 bus services a day. While it is only a 35-min. flight, the carrier could see there was enough traffic for it to be a viable market.

Such moves have helped Cebu develop what Kingshott describes as its "fortress Philippines" domestic operation. The carrier is still adding to the domestic network, although Kingshott says the pace of growth is constrained somewhat by airport infrastructure and air traffic control limitations.

Cebu Pacific's Airbus A330s have enabled the carrier to extend its reach to the Middle East and Australia.

Cebu began looking beyond the domestic market in the early 2000s. Because most Philippine airports are daytime-only, the carrier found itself with an increasing number of aircraft sitting idle overnight. Its desire to increase the utilization of these aircraft prompted its decision to begin nighttime service to short-haul international markets such as Hong Kong and Singapore.

Frequencies and destinations have been added to grow the international network to its current size, with multiple flights per day from four cities in the Philippines. Its A320s now reach Japan, China and most of Southeast Asia.

The range of Cebu's narrowbody fleet will be extended further when it begins taking delivery in 2017 of the 30 A321neos it has on order. They could potentially serve New Delhi and Mumbai in India, and Perth in Australia. As much as a third of the world's population will be within the range of these aircraft from Manila.

Cebu has a unique advantage with its international markets. The Philippines has one of the largest overseas worker populations in the world, with an estimated 10 million Filipinos living abroad. They tend to travel back to the Philippines for important family events, and many employers provide annual trips home.

This is a "natural market" that Philippine carriers such as Cebu can tap,

says Kingshott. Cebu has tended to target the countries with the largest expatriate Philippine populations for its international routes. The overseas workers "cannot necessarily fill your planes, but they can be the base load to build upon," he says.

Targeting expatriate communities further afield is the main driver behind Cebu's move into widebody aircraft. This is also another example of the airline looking for new growth avenues.

When the carrier was considering how to expand the scope of its international operation, it was faced with two alternatives, Kingshott says. It could either follow the example of LCCs such as AirAsia, Jetstar and Lion Air by establishing joint-venture franchises in other markets or build its own widebody fleet.

Despite its popularity in the Asia-Pacific region, Kingshott says the overseas franchise model "does not pass the business test." It is very hard to find an example of an airline that has been successful with this approach, he contends. There is risk in having to take on an overseas partner and operate in an unfamiliar regulatory environment.

The rationale behind the franchise model is that airlines can gain traffic rights to fly between foreign markets. However, liberalization within the Asean bloc is increasingly making this possible without the need for overseas joint ventures, Kingshott notes. For example, Cebu could carry traffic between Singapore and Kuala Lumpur under current rules if it wanted to.

So Cebu decided it made more sense to establish widebody operations within the existing airline in a regulatory environment with which it is very familiar. The airline would simply bring its brand—already well-known to Filipinos at home and abroad—to long-haul markets.

That is not to say the long-haul operation is without risk, however. After all, the prevailing wisdom is that "long-haul, low-cost has never worked," Kingshott says. "A lot have tried it and failed."

Cebu started its own long-haul operation in 2013, but this part of its business has yet to make a profit. It lost about 1 billion pesos in 2014. However, the carrier is forecasting that the long-haul business will be very close to breaking even this year.

Alex Reyes, who heads Cebu's long-haul operations, says this division is now performing well. It has one of the lowest unit costs for long-haul operations in the world, partly because it has a high seating density of 436 in its A330s.

Last year's results were affected by multiple route launches, as Cebu added four long-haul destinations in a five-week span starting in September. It also added four of its six A330s since the beginning of 2014. Reyes says long-haul routes take 12-18 months to reach maturity, much longer than in domestic markets.

One of the six A330s is used in the short-haul network. This essentially gives Cebu a spare aircraft if needed, since it can be replaced on short-haul routes with two A320s, says Reyes. The larger aircraft have proven to be very effective on high-traffic routes such as Singapore and Hong Kong.

Cebu Pacific has targeted countries with large Philippine expat communities for its international routes, noting 'they cannot fill planes, but can be the base load to build upon'

Cebu's original business case for the widebodies envisaged 8-10 aircraft as an optimal number, so it will probably lease up to two more aircraft within the next few years, says Kingshott. It has scope to add at least one more destination with its current A330 fleet, which will probably be Honolulu early in 2016.

Longer term, Cebu wants to extend its reach even further. The carrier has already begun talks with Boeing and Airbus about a longer-range aircraft such as the 787 or A350 to replace the A330s, says Reyes, and both manufacturers have been making sales pitches.

The airline has made it clear that the aircraft it selects must have the capability to reach London and North American cities from Manila non-stop. There are an estimated four million Filipinos living in the U.S., and Kingshott estimates this is rival Philippine Airlines' most profitable market. "We have to find a way of tapping into that [market]," he says.

Cebu can begin returning the A330s to lessors in six years. That means the airline needs to be considering replacements now, says Kingshott. The 787/A350 aircraft would be owned, as is Cebu's usual practice. It made an exception with the A330s, recognizing they would be an interim option until more advanced-technology aircraft could be purchased.

On the narrowbody side, Cebu has grown its fleet through new deliveries and by the purchase last year of struggling LCC Tigerair Philippines, which has five A320s. Cebu will not increase its narrowbody numbers much over the next few years, as A320 deliveries will largely replace six of its 10 A319s that are being sold.

However, while total numbers may not grow, capacity will rise, as the new deliveries are larger than the aircraft they replace. The A320s seat 180, versus 156 in the A319s. The A321neos are being added partly for growth and partly to replace A320s. They will likely be configured with more than 230 seats, says Kingshott.

Cebu's turboprop fleet will be increasing most dramatically. The carrier currently has eight ATR 72-500s, and it has ordered 16 ATR 72-600s. The -600s will replace the -500s, so the turboprop fleet will double.

The ATRs are used for connecting small Philippine communities. While much attention has focused on Cebu's new long-haul services, the turboprops actually have the highest profit margins in the airline's fleet. There is still plenty of scope for new markets for these aircraft to serve, as only 30 of the 90 airports in the Philippines can accept jet aircraft.

Cebu is shifting all of its ATRs to the Cebgo unit and switching the remaining Cebgo A320s to the parent company. This will allow the subsidiary to specialize in turboprop operations, while Cebu focuses on jet services. Streamlining will help each operation keep costs low as they contribute to network growth both at home and abroad.

Blind Spot

MH17 probe: Conflict zone procedures in urgent need of repair

John Croft Washington

The Dutch Safety Board (DSB) says there is a gaping hole in the safety-driven culture of the airline industry—an accurate assessment of what lies below. In its conclusions on the crash of Malaysia Airlines Flight 17 (MH17), the board is calling for an overhaul to airspace management, the creation of new risk assessments, and customer accountability disclosures to better protect passengers and crew from geopolitical strife.

In its final report on the July 2014 downing of the Boeing 777-200ER in eastern Ukraine, the board issued 11 recommendations related to flights over conflict zones, including new international standards to require "states dealing with an armed conflict in their territory" to publish "at an early stage" specific information on the "nature and extent of threats" and the potential consequences for civil aviation.

MH17 was cruising at 33,000 ft. over a known battlefront between Ukrainian forces and Russian separatists en route from Amsterdam to Kuala Lumpur when a 9M38-series missile launched by a Buk surface-to-air missile (SAM) system detonated just above and to the left of the aircraft's nose, instantaneously killing the pilots, causing an inflight breakup of the structure and the deaths of all 298 passengers and crew on board.

Other than to identify the missile and warhead and define an area from which the SAM was likely launched, the DSB does not assign blame (see article below). That aspect of the investigation—whether "punishable offenses have been committed and who can be held responsible in terms of criminal law"—is being handled by a Joint Investigation Team made up of police and "judicial authorities" from the Netherlands, Australia, Malaysia, Belgium and the Ukraine, says the DSB.

What is known in hindsight is that the risks to civil aviation above the conflict zone had been increasing over time, and flight restrictions in the form of Notices to Airmen (Notam) prohibiting air activities below certain altitudes were not adequate.

Eight helicopters and eight fixed-wing aircraft had been shot down in the region since April 2014, and three such incidents took place in the days leading up to the July 17 shoot-down of MH17, according to the DSB (see chart on page 63). Two—an An-26 cargo aircraft flying at about 20,000 ft. on July 14 and an SU-25M1 close-air support jet at roughly the same altitude on July 16—occurred at altitudes where Ukrainian authorities say a SAM was the only possible culprit. An analysis by the Dutch military, however, concluded that a shoulder-launched missile was the most likely weapon in the An-26 shoot-down.

In response to the escalation, the Ukrainian air force, through Ukrainian air navigation service provider UkSatse, issued a Notam June 6 restricting flights to altitudes above 26,000 ft. On July 14, UkSatse unilaterally increased the minimum altitude for the region where MH17 was shot down occurred to 32,000 ft. The DSB says the "underlying reason" for the change is unclear. "Because the An-26 flew below the altitude of [23,000-24,000 ft.], which was regarded as safe to military aviation, the [Ukrainian] authorities did not see the attack as a risk for civil aviation that flew above [32,000 ft.]," it says. The Buk missile system can reach altitudes as high as 80,000 ft.

In total, the DSB says there were 28 Notams in force for eastern Ukraine July 17, eight involving airspace restrictions, yet the high-altitude routes in the region were treated as business as usual: No specific threat advisories were issued to the crew of MH17 other than an alert for possible loss of GPS in Ukrainian airspace. The DSB says 160 flights by 36 airlines operated over eastern Ukraine July 17 until the airspace was closed after the MH17 downing. Only one airline (not named but presumed to be British Airways) had previously decided to stop flying over Ukraine due to the unrest, and that decision occurred before armed conflict broke out in the eastern region of the country. "Insofar as the DSB was able to ascertain, no other operators changed

FRAGMENTS OF TRUTH

Tony Osborne London

With investigators concluding Malaysia Airlines Flight 17 (MH17) was shot down by a missile fired from a Buk surface-to-air missile system, attention turns toward the perpetrators.

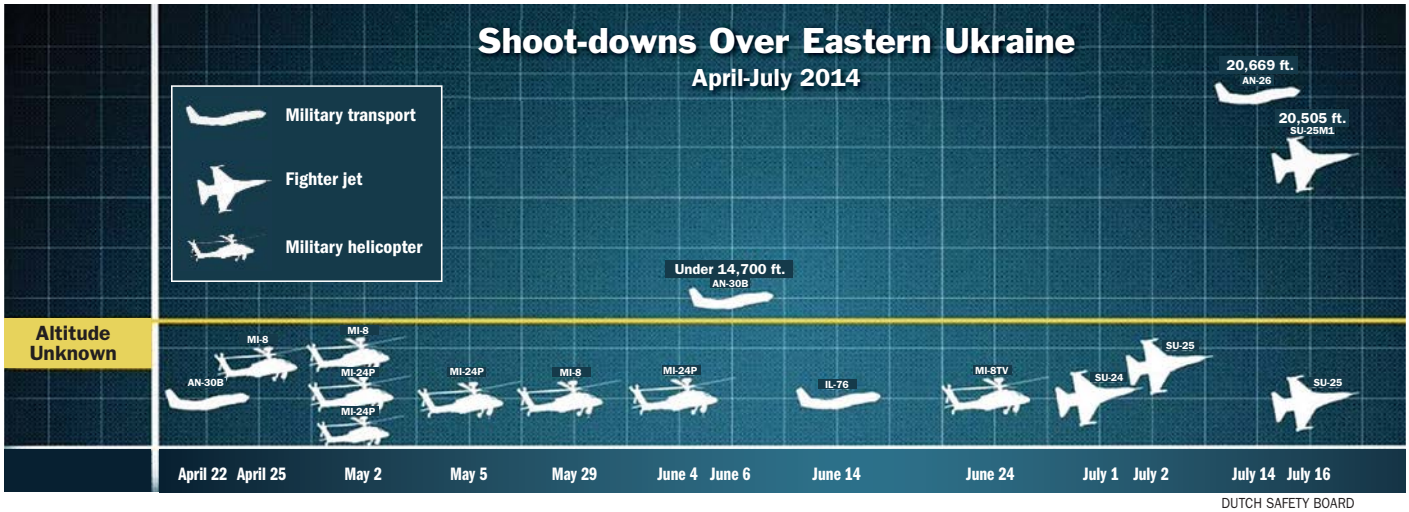
International rules prevent the Dutch Safety Board (DSB) from apportioning blame in its Oct. 13 final report, but it did identify a 320-sq.-km (124-sq.-mi.) region—well within an area controlled by Russian separatists—from where it believes the missile was launched.

While DSB chairman Tjibbe Joustra says "additional forensic investigation" is needed "to confirm the launch site," there appears to be a high level of surety. The report also details data provided by the Kiev Research Institute for Forensic Expertise that significantly narrows the potential launch area to 4 sq. km of land near Snizhne, also previously identified by journalists and researchers using open-source intelligence, including imagery and social media.

The ongoing international criminal investigation team, led by the Dutch police, indicates "persons of interest" it feels would be of importance to the probe. While finding witnesses willing to make a statement has been a big challenge, the team's hopes for an eventual arrest is "undiminished," it said in reaction to the DSB's report.

One focus has been on the movement of a Buk missile launcher vehicle apparently carried on a low-loader trailer away from the launch site and into Russia. The team also has access to a number of missile parts, not illustrated in the report presumably because of their forensic value.

To no one's surprise, Russia called DSB's report biased. Moscow insists the missile was launched from Ukrainian government-controlled territory and was a 9M38 missile, a weapon manufacturer



DUTCH SAFETY BOARD

their flight routes for safety reasons related to the conflict," says the DSB.

Investigators determined that the chain of responsibility for making overflight decisions is flawed. Passengers rely on carriers to guarantee that the airspace is safe, while carriers rely on states' ability to close airspace if needed. "However, in practice this system does not yet work as it should," says the DSB. "Given the system weaknesses found, [we] find the system is in urgent need of improvement."

As laid out in the Convention on International Civil Aviation (aka the Chicago Convention), a state has the sovereign right to manage its airspace but is also responsible for making sure that airspace is safe. Standards published by the International Civil Aviation Organization (ICAO) are designed to help countries make such decisions, but the DSB says those standards "evidently provide insufficient guidance for taking a considered decision about airspace management."

After the accident, ICAO formed a task force to study how nations and airlines can share risk data and to create guidelines for developing risk assessments to determine when airspace should be closed. The work is ongoing, but an intermediate result was the creation of a Conflict Zone Information Repository, available to the public on ICAO's website.

Complicating decisions to shut down airspace may be the revenues that air navigation service providers, including UkSatse, earn through overflight fees. In its investigation, DSB studied 10 other areas with ongoing conflicts, including Afghanistan, Iraq, Somalia and Syria, and determined that only one state—Libya—had closed its high-altitude airspace. "It is also notable that in most cases examined here the states concerned did not issue any Notams containing information about the conflict, which airspace users could have used in their own risk assessment," states the DSB.

While acknowledging ICAO's progress in making conflict zone information available, the DSB recommends that the organization develop standards that will allow states to "take unambiguous measures if the safety of civil aviation may be at risk," and it create a "platform" for states to exchange "experiences and best practices" for conflict zone overflight risk assessments.

In addition, the DSB recommends states better define their responsibilities for using airspace over conflict zones and create regulations requiring airlines to perform risk assessments before overflying conflict zones. A recommendation to the International Air Transport Association—to require operators to provide "public accountability" at least once per year for routes that overfly conflict zones—would empower passengers to judge how well airlines are complying. "The ball is now in the court of the states and the aviation sector," says the DSB.

Almaz-Antey says the Russian army stopped using in 2011—although social media images taken earlier this year suggest it may still be in the Russian inventory.

Almaz-Antey tried to preempt the DSB report by delivering results of its own live but static tests using the forward fuselage of an old Ilyushin Il-86 airliner as a surrogate for the Boeing 777 to prove the missile used was Ukrainian. The company says the test results were forwarded to the Netherlands but were sidelined.

The Dutch did not specifically say which was used—a 9M38 or the improved 9M38M1 missile—both of which can be fired from the Buk. The report refers only to use of a 9M38-series missile.

Both versions can carry the 9N314M-model high-explosive fragmentation warhead that features distinctive cubic and bowtie-shaped fragments, some of which were later recovered by investigators from the cockpit and wingtip of the airliner.

The Boeing 777-200ER stood little chance of survival against the 70-kg (154-lb.) warhead. It detonated about 8,000 fragments into the air meters from the cockpit. Several hundred tore into the fuselage, instantly killing the crew. The missile explosion left soot and explosive residues on the fuselage, and postmortem results show the crew was hit by hundreds of fragments. The four cockpit voice recorder microphones recorded sound peaks in the final milliseconds, including the missile detonating, helping investigators pinpoint where the warhead was set off near the aircraft.

The missile explosion caused the cockpit section to break away; as the aircraft broke up, it spread wreckage over 50 sq. km near several towns in the Donetsk region of eastern Ukraine.

Dutch investigators leading the international probe faced a treacherous task in recovering wreckage and human remains from a conflict zone. Joustra says wreckage was still being found in early October and will continue to be discovered, but he says additional finds are unlikely to change the inquiry's findings.

Bringing the Heat

Though late and costly, Sbirs is finally sparking an 'explosion' of infrared space products

Amy Butler Buckley, AFB, Colorado and Huntsville, Alabama

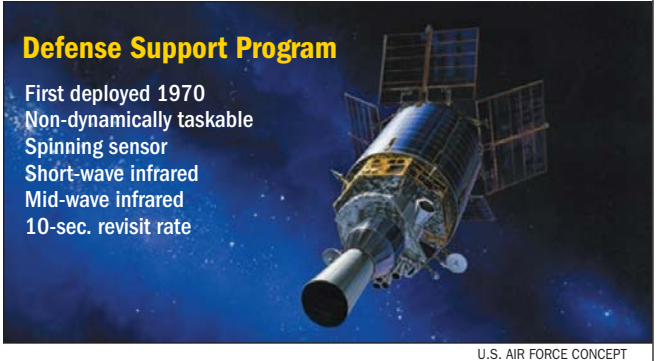
Space-Based Infrared System Fast Facts	
Original Total Program Cost	$5.2 billion for five satellites
Current Total Program Cost	$18.9 billion for six satellites
Planned First Sbirs GEO Launch	June 2002
Actual First Sbirs GEO Launch	June 2011
Planned Constellation Size	Four geostationary (GEO) satellites, two highly elliptical orbit (HEO) sensors (total of six GEO and four HEO on order)
Primary Contractors	Lockheed Martin: prime Northrop Grumman (legacy TRW): sensor provider
Program Start	1996

Sources: Government Accountabitity Office and U.S. Air Force

In less than 10 sec., every point on the face of the Earth is imaged by the U.S. Air Force's newest infrared (IR) missile warning satellite system.

The message from the operators of the new Space-Based Infrared System (Sbirs) at the 460th Space Wing at Buckley AFB, Colorado, is that missile or space launches cannot happen anywhere on Earth—or over it—without their knowing. With Sbirs, they can detect a launch faster than ever, more accurately identify the missile type, more precisely calculate its burnout velocity and trajectory (state vector) and more exactly determine an impact point.

The Air Force has not disclosed the system's precise capabilities. In part, this is due to security concerns. Sbirs, along with its less capable Defense Support Program (DSP) predecessor, is the first cue system for the Pentagon's entire ballistic missile defense architecture that protects the nation and U.S. forces abroad. It employs the sensors that would first detect a ballistic missile launch from North Korea, Iran, Russia, China or other potential aggressors. Sbirs is also responsible for "tipping" off other assets—such as ground- and ship-based radars—to detect a missile before engaging with an interceptor or warning soldiers to take cover.



U.S. AIR FORCE CONCEPT

Confident that the system's woes were worth the trouble—it is nearly $14 billion over budget and nine years late—the service is preparing for a new iteration of Sbirs, combining remote ground-based locations into one multifunctional command, control and analysis center. Officials gave Aviation Week unprecedented access to see the Sbirs center at Buckley Aug. 18 and watch operators train on the system before it goes operational next year.

With two of four of the Sbirs geosynchronous (GEO) satellites in orbit and three complementary IR payloads on classified highly elliptical orbit (HEO) satellites operating, the Air Force is finally starting to see a return on nearly two decades of technical challenges, cost overruns and delays. "This is the pivotal time in overhead persistent infrared [OPIR] history," says Col. Mike Jackson, operations group commander for the 460th. Finally getting these sensors into orbit and an "explosion" in computing power advances has allowed the service to begin using this data in ways never thought possible when the missile-warning workhorse DSP was first launched in 1970. At that time, DSP's sole purpose was to warn of a missile launch—primarily from what was then the Soviet Union.

Now, however, at least 24 countries operate and sell a variety of ballistic missile designs, making the job of missile warning more complex and, to many, more urgent. Ballistic missiles are more capable, accurate and mobile, Jackson says. "They are sold like chickens at the market in some places," he says. Missile Defense Agency (MDA) chief Vice Adm. James Syring says nations such as China and Russia are also developing more advanced countermeasures designed to fool U.S. sensors into mischaracterizing the missiles or shooting at the wrong target.

EXPANDING THE MISSION

The Sbirs development began in 1996 to address four key missions: providing missile warning (its primary focus), cueing missile defenses, offering technical intelligence about missiles, and delivering battlespace awareness of IR events globally. Operators at the 460th are greatly expanding the system's utility, thanks to new computing power never imagined 20 years ago, Jackson says.

Also contributing to the diversity of possible missions is the sheer number of sensors in orbit. Along with Sbirs GEO-1 and -2 and three scanning sensors in HEO orbit, the Pentagon continues to rely on an undisclosed number of legacy DSP satellites. Designed to last five years, DSP-16, the oldest remaining bird, is still operating after 24 years, says Col. John Wagner, commander of the 460th.

Designed with short- and mid-wave IR detectors, Sbirs can theoretically "see" any IR event—such as a forest fire, bomb explosion or plane crash. The sensors are "tuned" to look for specific events, such as the hot plumes of ICBMs, but are also constantly collecting background data from other heat events, data kept by the Pentagon. In the event of a natural disaster or bombing, for example, operators can find the information collected during that specific time and provide it to authorities.

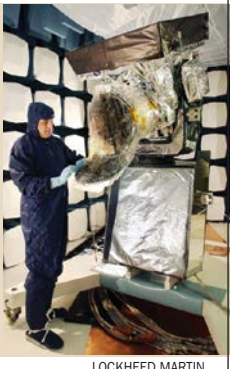
An example is the case of Malaysia Airlines Flight 17 (MH17), a Boeing 777-200ER that was shot down by a Russian-made BUK missile on July 17, 2014, killing 283

passengers and 15 crew. Mystery still surrounds the incident. The aircraft was downed en route from Amsterdam to Kuala Lumpur, and U.S. and allied officials suspect pro-Russian separatists near the Ukraine-Russia border launched the missile as tensions mounted in the region. Though the BUK, or SA-11, was initially indicated, it is likely that Sbirs data helped the intelligence community confirm the assessment.

Officials at the 460th did not disclose their specific role in this work. "This is the art of what we do," Jackson says, noting that Sbirs and satellite IR data is used to shed light on thousands of nonmissile events annually. If operators know the time of an event and Sbirs sensors were imaging the area—and they likely were, as the U.S. closely monitors Russian forces operating near the Ukrainian border—they can filter out information about a specific event. The shootdown of an airliner would produce a hot explosion, and operators could likely go through the Sbirs data to forensically image the plume of the offending missile and, perhaps, an approximate location of its launch point. The data could then be correlated against other sources of intelligence to suggest who commanded that particular missile.

Sbirs HEO

First deployed 2006
Retaskable
Scanning sensor
Short-wave infrared
Mid-wave infrared
See to the ground
Classified revisit rate, faster than DSP
Taskable focus area in Northern Hemisphere
HEO sensor weight: 530 lb.



LOCKHEED MARTIN

Sbirs data has also been used by U.S. intelligence officials as they continue to unravel the mystery of Malaysia Airlines Flight 370 (MH370), another 777-200ER, that disappeared in March 2014 while en route from Kuala Lumpur to Beijing. According to information from Malay military radar, the aircraft is thought to have crossed the Malayan peninsula and possibly crashed into the Indian Ocean. A flaperon belonging to the aircraft later washed up on the French overseas territory of Reunion Island in the Indian Ocean. The aircraft is thought to have flown in an area not highly trafficked, making it easier for Sbirs to find and track the heat signature of a 777-200ER.

Officials at the 460th declined to articulate their role in the search, and U.S. intelligence is unlikely to advertise if and how its data was used, for fear of revealing its capabilities. But Jackson says the team did participate by providing technical data to the intelligence community.

Col. Mike Guetlein, director of the Air Force Space and Missile Center Remote-Sensing Directorate, which oversees the program's development and production, says satellite IR data is being more routinely used for combat and civil search-and-rescue operations, locating crash survivors or those who perished in crashes. This is made possible because satellite IR data, and Sbirs information in particular, can be collected and processed much faster now. The system can also be used to help direct firefighters to concentrate their resources because it can show areas of the worst hot spots in burn zones.

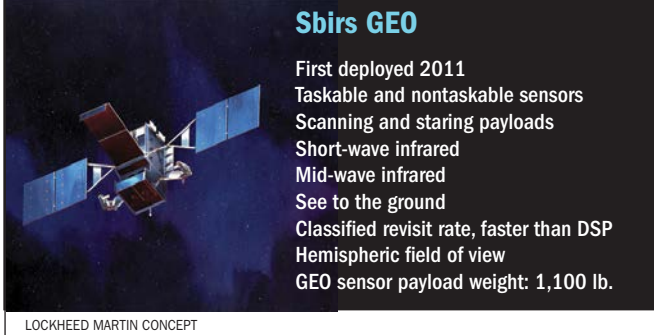
Galleries *See more technical detail on how Sbirs works at* **AviationWeek.com/Sbirs**

Video *See Lockheed Martin's video depicting how Sbirs provides continuous missile warning at* **AviationWeek.com/SbirsTech**

Guetlein says that if the art for Sbirs operators is in honing their tactics to use the same data in new ways, the science is in the growing set of algorithms used to manipulate data collected by the system. Work in the "battlespace awareness" mission for satellite IR data can take hours today, but that is shrinking quickly, thanks to computing advances. "This is where the explosion is happening," Guetlein says. As Air Force officials work on algorithms and tactics development, the U.S. Army is also working to improve its ability to relay Sbirs data to commanders in the field, pushing it to ever lower levels of command.

The Army is upgrading its mobile Joint Tactical Ground Stations —four locations outside the U.S. used to disseminate Sbirs warning messages—from mobile configurations to a fixed design. It is also conducting a block upgrade to exploit more data from Sbirs GEO satellites as well as DSP, said Army Lt. Gen. David Mann on Aug. 12. The mobile JTAGs are operating, but "not to the degree that we are really maximizing the Sbirs GEO constellation," he says. "[It is] very, very minimal." The upgrade, for which Army officials declined to identify a cost, will "allow us to fully capitalize on what Sbirs brings to us, as well as DSP and other data."

The system can also be helpful beyond its missile warning and defense roles. The Pentagon's National Air and Space Intelligence Center keeps a catalog of signatures—electromagnetic and IR—of aircraft, missiles and other military hardware operating globally. In a theater such as Syria, a multitude of systems is active, including those from Syria, Russia and forces friendly to the U.S., along with stolen allied systems used by the militant Islamic State. Sbirs can help sort out the chaos on the battlefield by providing one set of data for analysts to correlate with other sources. The system can also provide precise data on the whereabouts of aircraft, possibly validating or dispelling accusations from Turkey about Russian aircraft flying in its airspace, including an allegation that a MiG-29 intercepted Turkish F-16s, for example.

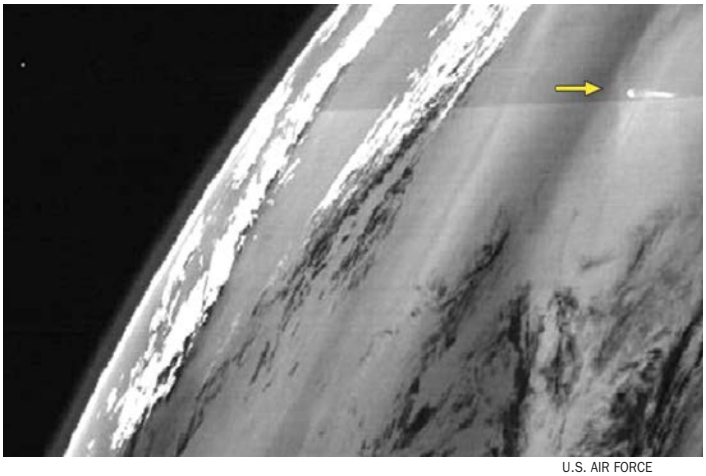


Sbirs GEO

First deployed 2011
Taskable and nontaskable sensors
Scanning and staring payloads
Short-wave infrared
Mid-wave infrared
See to the ground
Classified revisit rate, faster than DSP
Hemispheric field of view
GEO sensor payload weight: 1,100 lb.

LOCKHEED MARTIN CONCEPT

The number of heat events detected by the system is an indicator of how the Air Force has expanded the use of satellite IR data with Sbirs. The 460th detected 403 missile events in 2014, versus 193 through July 2015. However,



U.S. AIR FORCE

The only image released for public use from the Sbirs system is this one, exclusively provided to Aviation Week for publication on Nov. 20, 2006. It captures the heat plume emitted by a Delta IV predawn launch from Vandenberg AFB, California, Nov. 4, 2006, that was carrying a Defense Meteorological Satellite Program spacecraft en route to insertion into polar orbit. The plume is readily visible against the backdrop of Earth, which in the wee morning hours sees little heat and sunlight. This image was degraded by the Air Force for unclassified use.

while Sbirs operators worked about 8,000 IR events from the Sbirs mission control station at Buckley in all of 2014, they had already worked 7,000 such events through August 2015. The growth is due to a change in the tactics and methods used to detect and characterize events, a significant expansion of the types of events being monitored, says Maj. Greg Vice, director of operations at the 2nd Space Warning Sqdn. at Buckley. This work will be officially supported through a new Joint OPIR Battlespace Awareness Cell being established at Buckley and set to go operational in April 2016. It will be staffed by intelligence and Air Force officials and provide its data not only to the intelligence community but also to commanders around the globe via tactical data links.

This data is separate from the rigid nuclear command-and-control communications used by Sbirs operators to provide certified Integrated Tactical Warning and Attack Assessment (Itwaa) messages for commanders at U.S. Strategic Command. These are the official messages, dispatched in a very specific format, warning of a missile attack; they include information about the threat missile and anticipated launch point.

For Itwaa messages, each sensor must be precisely certified in a process that is intentionally grueling because of the gravity of the consequences of these messages.

Both Sbirs GEO scanning sensors are Itwaa certified (the first two years after launch) as well as the scanners on the first two HEO sensors. The starer is slated for this certification as early as next year.

INSIDE THE NEW SBIRS OPS CENTER

Amy Butler Buckley AFB, Colorado

The Air Force is on the cusp of consolidating three Space-Based Infrared Systems ground centers into one, reducing manpower and providing better-quality data products to users globally. Currently, operations are distributed among locations in Colorado at Boulder, Schriever AFB and Buckley under the original Sbirs ground architecture plan. Operators at Schriever and Boulder process GEO and HEO "monotrack" data—provided by a single sensor—and send it to Buckley for release to users globally

The new, consolidated mission control center under the Block 10 ground architecture plan is slated to be declared operational in August 2016, says Steve Aspey, systems director of the Sbirs operational support team with the Aerospace Corp., a federally funded research and development company supporting the mission. Aviation Week was invited to tour the new Block 10 operations floor before it is shrouded in classification when operations begin in earnest.

The ops center is a modern, wide space dotted with computer consoles. Personnel in an intelligence cell are off to the side. A space in the center will be occupied by each shift's director. Large screens loom over the ops center, and shift overseers can display data of their choice, including sources outside Sbirs such as television news channels.

The gravity of the mission contrasts with the youth of its operators at Buckley, most of whom were born after the ending of the Cold War that drove development of the missile warning and defense architecture. The average Sbirs operator is about 20 years old and has about six months' experience working the console. The ops floor is populated by a multinational presence, including British, Australian and Canadian military officials. These operators work 12-hr. shifts, constantly monitoring computer screens. The Sbirs operators are divided into four areas aligned with its four missions: missile defense, missile warning, technical intelligence and battlespace awareness. Though the job can at times be monotonous, Airman 1st Class Cynthia Solorzano says the time often passes quickly, especially when events are reported. Operators must react within seconds of a launch to inform U.S. Strategic Command and alert missile defenses. And the job is made more complex by adversaries' changing tactics.

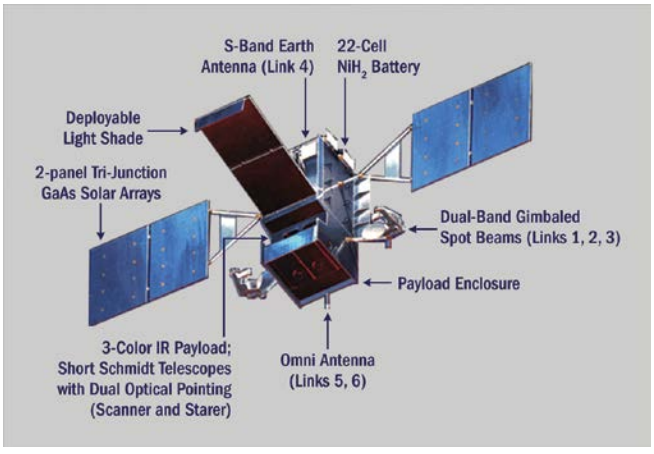
More and more, nations are testing their ability to conduct "raid attacks," firing multiple missiles at once in hopes of overwhelming U.S. sensors and defenses. "We have seen and will continue to see other countries use a ripple launch—a raid launch. . . . We have seen up to 32 launches" in one particular event within the last two years, says Col. Mike Jackson, operations group commander for the 406th

A KEY PIECE OF U.S. MISSILE DEFENSE ARCHITECTURE

For its missile defense mission, Sbirs is the first sensor likely to detect a hostile launch. The U.S. Missile Defense Agency's (MDA) command-and-control system can take data from various ground- and ship-based radars. MDA is also testing the use of airborne IR sources such as Reaper unmanned aircraft carrying the Raytheon MTS-C IR sensing ball. But radars are limited by the Earth's curvature in their ability to "see" a launch, limiting reaction time after they first see a threat; a missile must cross into the radars' footprint for detection. Airborne IR sources must be patrolling in the right place at the right time to be able to detect a launch, and their sensors can be obscured by weather or other atmospheric factors.

IR satellites have the benefit of a hemispheric view of Earth. While weather can be a factor in the timeliness of a detection, the sensors will view a threat once it pops through clouds while heading into space. In addition, Sbirs incorporates a "see-to-the-ground" capability. Officials have released little about it, but Jeff Smith, a Lockheed executive, said in 2011, on the eve of the Sbirs GEO-1 launch, that "a wider, more open shortwave" band can "see through to the ground. . . . It is opened up more, which means more clutter and more targets at the same time. That is why you can see deeper into the atmosphere." He noted that the performance is secret.

The Air Force originally envisioned what we now know as Sbirs as the Sbirs High constellation. It was to be complemented by what was formerly named the Sbirs Low constellation. Sbirs Low, however, was transferred for oversight



LOCKHEED MARTIN CONCEPT

Engineers added the deployable light shade after they discovered the original Sbirs GEO design exposed the sensitive IR sensors to sun glints and heat.

to the MDA and shelved until officials there revived it as the Space Tracking and Surveillance System (STSS) demonstration more than a decade ago. Parts for the first two satellites, built by Northrop Grumman, were pulled from storage, assembled and eventually launched Sept. 25, 2009.

STSS provided what Sbirs was lacking—a longwave IR tracking sensor designed to follow cold warheads after separation from their hot boosters and as they travel through the cold backdrop of space toward a reentry point. Together, these two systems were conceived to provide

Space Wing at Buckley AFB. "We have to train our operators to handle more than just single, strategic launches. How do we handle multiple launches from multiple locations in a very small, regional conflict? You have to learn how to hand things off as a crew. You have got to learn how to set up your screens differently."

The Block 10 will incorporate message releases for the staring sensor, the more advanced of the two sensors on the GEO satellite. While the scanner surveys the Earth in quadrants, gazing up and down in a box formation, the starer is highly retaskable and can provide an unwavering, higher-fidelity view of a particular location, augmenting the data provided by the scanner. While starer data is being used today for a variety of missions, it is not certified for use in generating Integrated Tactical Warning/Attack Assessment (Itwaa) messages, a specific format used by operators here.

Starer data was slated for infusion into the system in a later Block 20 increment, but Air Force officials accelerated it to address burgeoning threats and operational needs. "The technical capabilities are coming on almost as fast as I can train operators," Jackson says. "Sbirs is able to detect much dimmer-burning targets beyond the reach of technology at the program's inception in 1996 and has supported the identification of new threats on today's battlefield," says Col. Mike Guetlein, director of the Air Force Space and Missile Center Remote-Sensing Directorate, noting the improved sensitivity of the GEO and HEO sensors. "The Sbirs space segment, including the GEO satellite and HEO sensors, can provide continuous wideband data that can be viewed as movies of events on Earth. This data has exponentially more information than the representative returns—walking dots—that DSP provides today."

With the Block 10 system, operators can fuse the data from DSP and both Sbirs sources for a better look at IR events. Block 10 will also incorporate data from the forthcoming Sbirs GEO-3 and -4 satellites, which are being built by Lockheed Martin.

"This is the most significant change to Sbirs operations in 14 years," Aspey says of the new control station. Overall, the Block 10 ground system will provide faster, more accurate reporting by consolidating the operations and allowing the system to detect shorter-duration and dimmer IR events, Aspey says. It will also provide more frequent updates of missiles in boost phase and improved prediction algorithms to better cue missile defense sensors and interceptors.

Officials are often referring to very short-range ballistic missiles, rockets, mortars, artillery, unmanned aircraft and cruise missiles—such as those launched errantly by Russia into Iran Oct. 8—when they refer to dimmer targets. "As battlefield circumstances change, the staring sensor can also be quickly reassigned based on tipoffs or cues," Guetlein says. "The staring sensor can locate and report dim targets not detectable by the traditional scanning sensors on [DSP] and Sbirs GEO satellites."

The later, Block 20 capability is beginning its developmental testing now and is slated for initial operational capability in 2018, Guetlein said. It will provide more precision for the Itwaa messages generated from Sbirs.

"birth-to-death" missile tracking, a holy grail for missile defense advocates loath to lose track of a missile in flight.

While in its demonstration phase, however, STSS was used to validate the idea that Navy ships can aim their radars based on a cue from the STSS sensor payload.

Likewise, an MDA demonstration proved that Sbirs missile warning data could cue STSS, "so that the STSS track sensor could locate a missile for the midcourse mission, potentially simplifying the design for a future system," Guetlein says.

MDA officials have been vague about just how much they rely on Sbirs data for their flight tests, due to security concerns. In the past two years, Sbirs participated in nine flight tests and six major ground tests led by MDA, Guetlein says. The system has provided missile launch notification and included details on missile type, launch location, state vector and potential impact area. It has also provided missile burnout messages to the Ground-Based Missile Defense fire control and communications system used to alert and cue other sensors. In addition, MDA's command-and-control architecture has relied on Sbirs data to "optimize search plan selection for forward-based radars," he adds.

SCAR TISSUE NOT FORGOTTEN

Despite the optimistic talk from Air Force operators about the potential uses of Sbirs and other satellite IR data, they are well aware of the program's tattered past. The original research and development contract with Lockheed Martin was fashioned under the total system performance responsibility philosophy of the time, which allowed the service to defer most systems engineering and oversight duties to the contractor. As a cost-plus contract—meaning the government would pay for any overruns—and chasing such a complex design, the choice was a disaster, resulting in billion-dollar overruns year after year.

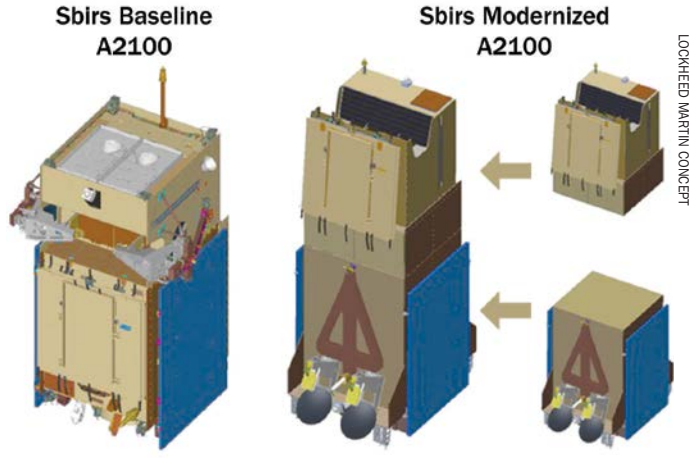
Originally expected to cost $5.2 billion for five GEO satellites, government auditors now estimate that the total program price is $18.9 billion. Technical hurdles led to deployment of the system nine years later than the 2002 time frame originally planned. The urgent need for Sbirs was underscored when the final DSP mission failed in orbit in 2007, but GEO-1 would not reach its position until four years later.

Among the embarrassing technical errors in Sbirs's history was a design that exposed the sensitive IR detectors to sun glints, prompting the need for a redesign to include a sunshade. Program officials also struggled for years with electromagnetic interference (EMI) concerns, especially critical as the HEO payloads must cohabitate with classified satellite host instruments. Leading up to the GEO-1 launch, officials discovered a possible deficiency in the satellites' computer architectures.

Also, a classified Lockheed Martin satellite that failed 7 sec. after reaching orbit in 2007 used software similar to Sbirs's, and the safe-hold mode (used for basic health and communication in the event of an on-orbit fault) failed. At the time, Gary Payton, then-Air Force deputy undersecretary for space, dubbed that spacecraft a useless "ice cube."

The safe-hold failure was caused by a timing problem with the onboard computer processors. After so many years of delays and more than $1.3 billion estimated to have been spent on the first spacecraft, the Air Force refused to risk a failure by launching Sbirs without fixing the issue.

As these problems were addressed, the government paid billions of dollars to keep the Sbirs workforce in place. The computer processor timing issue forced the team to start from scratch on the flight software to ensure they could avoid a similar, anticlimactic orbital insertion.



LOCKHEED MARTIN CONCEPT

For Sbirs GEO-5 and -6, Lockheed Martin redesigned the A2100 platform to decouple the payload from the propulsion module. This is expected to ease upgrading the payload if the Air Force decides to buy more GEO satellites.

Lockheed Martin has delivered Sbirs GEO-3, and the satellite has been put into storage until an anticipated launch in 2017. GEO-4 is in production and is slated to launch in 2016.

The Air Force and Lockheed Martin agreed in June to modify the Sbirs GEO-5 and -6 contract to allow for a "technology refresh" to the A2100 bus at no cost to the government. The new design decouples the highly integrated payload and propulsion modules of the first four satellites. It will also allow for easier technology insertion into the payload section now, as designers will not be required to interfere with the propulsion module for such work. They are slated for launch in 2020 and 2021, respectively.

However, the future beyond these six satellites remains unclear. The Air Force is continuing its long-delayed work studying alternative architectures for a future missile warning system. Though Lockheed Martin officials hope the work to simplify the Sbirs design will convince the Air Force to stick with the existing configuration, the service is open to new ideas. This is in part due to a tendency by some commanders to "disaggregate" large satellites such as Sbirs, which are increasingly enticing targets as potential adversaries such as China hone antisatellite technologies.

Furthermore, Sbirs's payload technology was developed in the 1990s, and significant advances have been made since then in focal plane arrays, leading some experts to eye constellation concepts populated with many of these sensors staring at the Earth. Air Force officials are weighing these options for a new constellation just as they are realizing that the potential for satellite IR data applications is vast. Jackson, the operations group commander, likens the expansion of capabilities from the DSP days to those of Sbirs to "transitioning from the F-15 to the F-22." Another defense official describes the growth in satellite IR uses as similar to the explosion in applications for radar developed during and after World War II.

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Unmanned Standards

Validation tests will determine if civil UAS can be certified to new standards at reasonable cost

Graham Warwick Washington

NASA

Release of interim standards for systems required to integrate unmanned aircraft into national airspace is a major milestone for the industry, but just a step along a challenging path.

Further testing is required to validate the interim minimum operational performance standards (MOPS) developed by RTCA Special Committee (SC) 228 for the detect-and-avoid (DAA) system and command-and-control (C2) datalink, and to fill the gaps remaining in the documents.

After the final MOPS are released in 2016, the FAA must complete its safety risk management process, develop technical standards and advisory circulars, and a manufacturer and operator must step forward to be first to put an unmanned aircraft system (UAS) through type and operational certification.

SC-228 will work to harmonize the MOPS with similar standards under development, though not as far advanced, by RTCA's European counterpart Eurocae and the International Civil Aviation Organization. And the subcommittee is already looking toward the next steps in developing the DAA and C2 standards for expanded UAS operations that would be completed by around 2020.

The subcommittee was formed in 2011 after the disbanding of an earlier group, SC-203, which was created in 2004 to define overarching standards for unmanned aircraft but was discontinued because of a lack of progress. "When we began, there was quite a bit of division in the community, with lots of ideas on how to proceed and what the standards should look like," says Brandon Suarez, co-chair of the DAA working group and project engineer at UAS manufacturer General Atomics Aeronautical Systems.

"Since then, government and industry have made a lot of progress in coalescing around a conops [operating concept] and a representative system," he says. "It has been a big achievement in getting a diverse stakeholder community to work together and agree at high and low levels. But there is still a tremendous amount to be done to finish the standards and prove they are feasible and achievable.

"From an industry perspective, the standards have to be cost-effective so a UAS can be certified at reasonable cost," Suarez says. The next step is to put together a representative system for verification and validation testing of the standards. General Atomics has conducted flight tests of a DAA system built to the MOPS requirements, and will support NASA in a fourth round of flight tests (FT4) of its Ikhana UAS (A General Atomics Predator B) equipped with a DAA system.

"Flying the Ikhana on FT4 will be our last chance to get a fully representative system in the air so we can give the committee the data it needs to validate the MOPS," he says. FT4 is planned for March-April 2016. NASA also has a series of hardware-in-the-loop studies planned to finish up the interim design and performance requirements for the UAS ground control station, he adds.

NASA has flown its Ikhana, a Predator B, with General Atomics' air-to-air radar in the nose.

SC-228 has succeeded where its predecessor failed because the FAA narrowed the scope of the challenge. "Phase 1 was clearly defined in 2011 as providing a near-term capability," says Suarez.

The MOPS focus on an initial scenario: civil unmanned aircraft flying to and from Class A controlled airspace (above 18,000 ft.) under instrument flight rules. The DAA MOPS does not apply to small UAS (below 55 lb.) flying below 500 ft. The C2 MOPS applies to C- and L-band links, but not to satcom.

The Phase 1 DAA will enable launch and recovery within Class D, E and G airspace, but excludes surface operations, flight within the airport visual flight rules (VFR) traffic pattern and in Class B or C airspace around airports. The FAA does not require UAS in positively controlled Class A airspace to have a DAA system, but SC-228 believes it would provide the pilot with enhanced traffic awareness, says Suarez.

The MOPS specifies a suite of sensors on the UAS to detect other cooperative and non-cooperative aircraft and software to provide the pilot in the ground control station with awareness of proximate traffic and suggest guidance on remaining well clear of other aircraft and to avoid collisions.

The sensors are: active Mode S surveillance and Automatic Dependent Surveillance–Broadcast (ADS-B) to detect aircraft with transponders and TCAS 2 collision-avoidance systems; and air-to-air radar to detect other aircraft and validate ADS-B. A separate interim MOPS for the radar has also been released.

The MOPS is not restricted to a specific class of UAS, but an air-to-air radar meeting the performance threshold will be relatively large and power-intensive, says Suarez, implicitly limiting its use to aircraft in the Predator B and Northrop Grumman Global Hawk class. In Phase 2, SC-228 hopes to bring in different non-cooperative sensors for smaller UAS.

Phase 2 of the DAA MOPS would develop system requirements needed to extend operations in Class E and G beyond transiting the airspace, and may include avoidance of other hazards such as terrain and weather. "We would like to increase terminal-area operations...and the community is interested in enabling VFR operations, but that is currently not on the FAA's road map," he says.

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Aviation Week & Space Technology
October 26-November 8, 2015 VOL. 177, NO. 21
(ISSN 0005-2175)
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Oct. 28-29—CIMData's Product Lifecycle Management Road Map for the Aerospace & Defense Industry. The Westfields Marriott. Chantilly, Virginia. See cimdata.com/en/education/plm-conferences/2015-plmrm-ad-cic
Nov. 1-6—Airshow China. Zhuhai, Guangdong, China. See airshow.com.cn
Nov. 8-12—Dubai Airshow. Dubai World Central. Dubai. See dubaiairshow.aero
Nov. 10-12—International Aviation Women's Association 27th Annual Conference. Fairmont the Palm. Dubai. See iawa.org
Nov. 17-18—APEX Technology Conference. Hyatt Regency Newport Beach. Newport Beach, California. See connect.apex.aeroevents/event_details.asp?id=505136
Nov. 17-19—NBAA2015–Business Aviation Convention & Exhibition. Las Vegas. Las Vegas Convention Center. See nbaa.org/events/bace/2015/
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Dec. 3-4—Airports Council International-North America's 2015 International Aviation Issues Seminar. Loews Madison Hotel. Washington. See aci-na.org/event/5380
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FAA Is Playing Catch-up on UAS in Civil Airspace

The U.S. Transportation secretary's announcement on Oct. 19 that the FAA will soon begin requiring registration of almost all unmanned aircraft larger than small toys is certainly welcome. A panel of people knowledgeable about unmanned aircraft systems (UAS) and representative of various interests has been assembled. Refreshingly, that task force has been told to come up with a plan quickly so that everything can be in place by mid-December (see page 70). The idea is to try to get ahead of a nightmare scenario of thousands of novices unwrapping boxes on Christmas Day and taking to the skies blissfully unaware of the hazards UAS pose to manned aircraft and innocents on the ground.

Don't mistake this for the FAA getting ahead of the curve, though. Just two weeks before, the agency was insisting it was not set up to register so many aircraft. No, this is more like a stable master announcing he will start tracking the manure left by the horses that bolted from the barn when he left the door open.

The agency has been slow in recognizing the coming tsunami of small, inexpensive, easy-to-fly UAS operated by aviation naifs. That wave was the predicable result of the convergence of cheap control systems, lithium-ion batteries, GPS navigation, high-resolution miniature cameras, selfies and social media.

But the agency seemed to think technology and consumers would wait while it figured out what to do. It has been focused on dealing with UAS of all sorts through regulation, as if a small bird—defined as those under 25 kg (55 lb.)—presents the same hazard as a Predator, and as if "enforcement" is its only tool to promote safety.

What is more, the FAA has lagged in developing rules. The FAA reauthorization act of 2012 gave the agency more than three years to integrate UAS into civil airspace in the U.S. The FAA not only missed that Sept. 30 deadline; it has not even finalized rules on small UAS. And no one expects the rules to be in place until late 2016, at best.

Worse, there has been no methodical effort to assess the actual risks UAS present to other air traffic. In the absence of data, aviators are justifiably alarmed by the increasing numbers of UAS they spot from the cockpit.

And so the FAA struggles to keep up with a growing number of requests for exemptions to the existing, restrictive rules—and to impose fines on those who fly without waivers. Meanwhile, Australia, Canada, France and the U.K. have established systems.

> "There has been no methodical effort to assess the risks unmanned aircraft present to other traffic."

Eventually, sense-and-avoid, fail-safe modes for "fly-away" events, geo-fencing, ADS-B and the like may offer affordable technical solutions to assure safe UAS operations. But educating new UAS operators about safety and their legal and moral responsibilities will always be essential. Last week's regulation announcement helps in that regard.

But it is only a beginning and so, so late.

Urgent Action Needed on Conflict Zone Overflights

Dutch authorities' conclusion that a Buk missile system downed Malaysia Airlines Flight 17 over eastern Ukraine on July 17, 2014, surprised no one. Nor will it come as news that tragic mistakes can occur in areas of armed conflict.

> "ICAO responded to MH17 with a task force, which created a website—hardly a determined effort."

Russia needs to acknowledge its role in this tragedy, as the U.S. did after the guided-missile cruiser USS Vincennes mistakenly shot down an Iran Air A300 in 1988 over the Persian Gulf, killing all 290 on board. Instead, Moscow has pumped out a steady stream of disinformation. Moscow's energetic dissembling on MH17 is doing nothing to advance the fiction that it has not been an active aggressor in Ukraine.

To say that the system for alerting carriers about the risks of overflying conflict zones had broken down would presume there was a system to begin with. There really was only a patchwork of intelligence sources and risk assessments, and an inconsistent approach to sharing information and warning air carriers.

What is more, there is at least one inherent conflict of interest. Each nation is responsible for ensuring the safety of its own airspace. Yet each also receives overflight fees from airlines. The Dutch Safety Board estimated closing the eastern Ukraine airspace would have cost air navigation service provider UkSATSE as much as €248,000 ($275,000) a day.

So far little has changed. The International Civil Aviation Organization responded with a task force, which created a website for member states to share information about conflict zones—hardly a determined effort in the face of a grave problem. ICAO has begun working on contingency flight routings for conflict zones. But much more needs to be done. Ultimately, the Chicago Convention accords may have to be amended to make clearer states' responsibilities in regard to conflict zones, and to put in place an enforcement mechanism or incentives.

The world aviation community has shown it can rally to make a safety improvement a high priority. It needs to show the same sense of urgency about overflight of conflict zones. If it does not become more engaged and focused, history suggests there eventually will be another tragedy like MH17.

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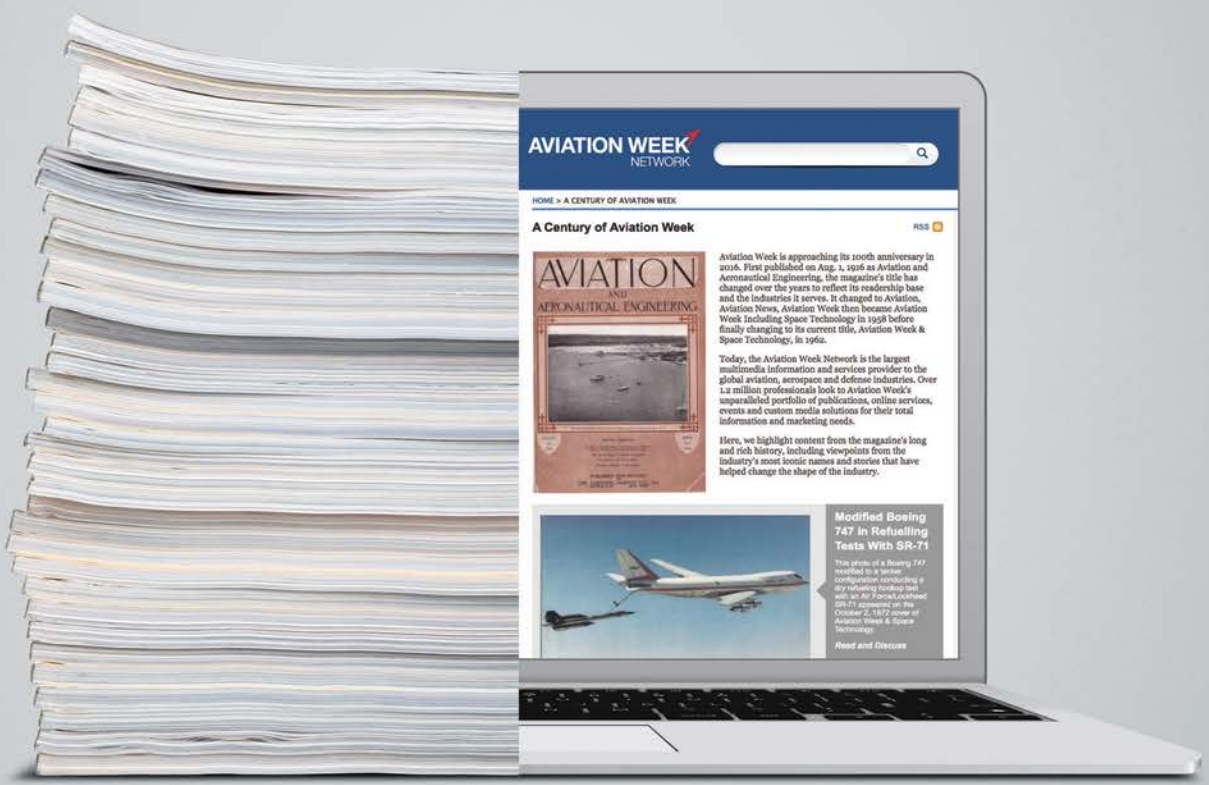

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