

A New Black Aircraft?

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Nominate yourself, a peer, or a person you know who embodies these traits and is on a course to change the future of aerospace and defense!

**All submissions must be received
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Questions? Contact Carole Rickard Hedden at
carole.hedden@aviationweek.com



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DEPARTMENTS

- 8-9 Feedback
- 10 Who's Where
- 12-13 The World
- 14 Up Front
- 16 Leading Edge
- 18 Reality Check
- 19 Airline Intel
- 20 In Orbit
- 21 Washington Outlook
- 51 Classified
- 52 Contact Us
- 53 Aerospace Calendar

THE WORLD

- 12 First flight** on route to certification for Cirrus Aircraft's single-engine Vision SF50 personal jet
- 13 Global Precipitation** Mission gets early workout to produce 3-D view of precipitation inside a cyclone

PROPULSION

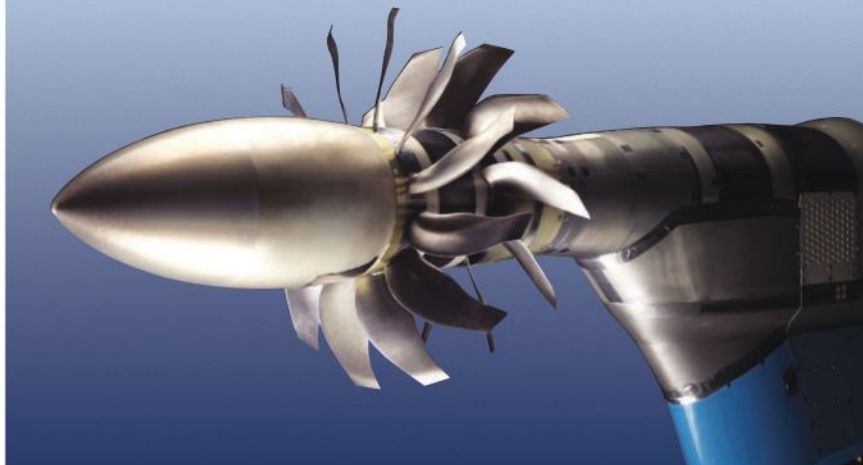
- 22 Europe's research** into open rotors is focused on the barriers that could keep them off the next narrowbodies
- 24 Complex technology**, skills and incentives are new dynamics in the hunt for fresh engine-assembly sites

SPACE

- 26 NASA casting** wide net for the technology it wants for its proposed Asteroid Redirect Mission

22

Under Europe's Clean Sky program, Airbus and Snecma research teams have concluded that a 2030-timeframe short/medium-range airliner with counter-rotating open-rotor engines is technically feasible and will meet new International Civil Aviation Organization noise limits.



DEFENSE

- 27 South Korea** finally decides to procure F-16s and F-35s, but is still aiming for sweetened deal
- 29 Lockheed Martin** is warned: F-35 production rate increases will be deferred if problems are not fixed
- 30 'I have nothing** for you,' says USAF when asked about photos of blended wing-body aircraft flying over Texas
- 31 Raytheon U.K.** developing upgrades for its precision-guided bomb that would not need aircraft integration
- 47 IRAD experiencing** renewed level of business interest as the defense sector heads into the latest revamp
- 48 Saab working** to deliver the JAS 39E at lower development, purchase and operating costs than its predecessor

- 49 KAI urges Seoul** to back the medium-sized aircraft it has proposed for the KF-X indigenous fighter program

RELATIONS WITH RUSSIA

- 32 Sanctions on** certain Russians have not impinged on Western A&D industrial bases to any great extent
- 33 U.S.-Russian chill** over the invasion of Crimea has not extended to civil space operations such as ISS launch

- 34 NATO works** to bolster credibility of its defense guarantee to Eastern Europe with airpower

AIR TRANSPORT

- 35 Inmarsat's unorthodox** analysis of satellite data offered investigators best hope of finding MH370



ON THE COVER

22 Based on the results of research including tests of this 1/7th-scale model in the LLF wind-tunnel at DNW in the Netherlands, Airbus has concluded a next-generation narrowbody airliner with open rotors is technically feasible, but economic viability must be improved and engine-airframe integration demonstrated in flight. Clean Sky Joint Undertaking and Airbus photo. Also, exclusive photos on page 30 show what seems to be a new classified aircraft flying over Amarillo, Texas.



40 Aerospace taking a cautious approach to understanding the new materials and processes that additive manufacturing enables.



47 Wall Street is starting to worry that many defense contractors are not investing enough in research and development (see related Viewpoint on page 54).

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36 SFO hopes new traffic flow system will prevent taxiway bottlenecks during upcoming runway closures

37 Regulatory changes in early 2000s and Turkey's strong economy paved the way for the Pegasus's growth

38 Hawaiian Airlines using contrasting approaches to tweak long-haul and domestic operations

46 NASA will lead effort to speed the development and certification of carbon-fiber structures

VIEWPOINT

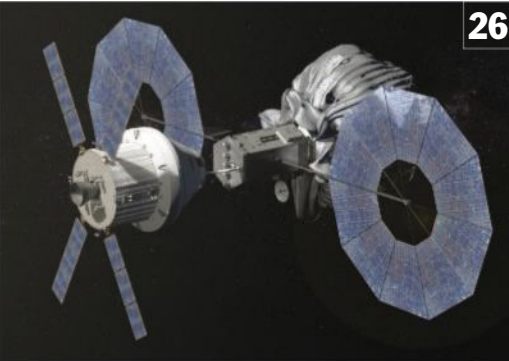
54 Defense industry offers best way to harness the benefits of change and retain U.S. technological superiority

ADVANCED MANUFACTURING

40 Aerospace comes to grips with the challenges and opportunities of additive manufacturing

43 Engine parts are just tip of a surfacing iceberg of aerospace propulsion additive-manufacturing applications

45 Aerospace is a key component as U.S. initiates \$600 million drive to revitalize manufacturing



26

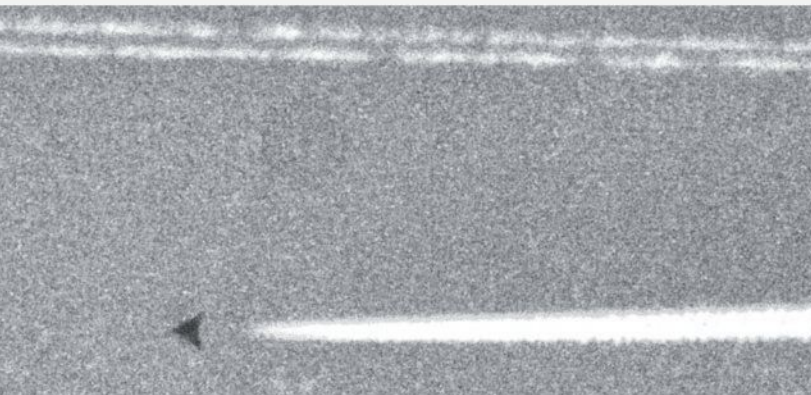


29

On the Web

A round-up of what you're reading on AviationWeek.com

On this week's Check 6 podcast, Aviation Week editors discuss how sanctions imposed on Russia after its annexation of Crimea **might affect Western aerospace companies**. Read Senior Business Editor Michael Bruno's article on page 32, then go to AviationWeek.com to listen to the podcast, or download this and previous Check 6 podcasts from the iTunes store: ow.ly/uMUWe



DEAN MUSKETT

Read International Defense Editor Bill Sweetman's article about an unidentified flying object over Texas on page 30, then click through to his Ares blog post for more photos [ow.ly/v3Hvp]. AviationWeek.com/Ares

READER COMMENT

In response to last week's Commander's Intent column entitled "Is Saab's New Gripen The Future Of Fighters?," 'Stefan' wrote: "Ironically former Lockheed Martin Chief Executive Norman Augustine **predicted only one fighter would be affordable in 2054**, with the Air Force and Navy sharing it and the Marines getting use on a leap year." ow.ly/v3b3Y

COLUMBIA'S SHADOW

It has been 11 years since the space shuttle Columbia came apart over the American Southwest. Read Senior Space Technology Editor Frank Morring, Jr.'s reflections on **how the disaster still influences NASA today**, then click through to our 2003 cover story, which correctly identified the fatal cause [ow.ly/v36k3]. AviationWeek.com/OnSpace

FUTURE MARKETS

In 1998, Bombardier was the leader in the up-and-coming regional jet market. Then came Embraer's "E-Jets." Read Editor-in-Chief Joseph C. Anselmo's Things With Wings blog post and his article from the archives **about Bombardier's ill-fated plan** to solidify its market dominance. [ow.ly/v39AU]. AviationWeek.com/ThingsWithWings

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WAKE UP TO MANPAD THREAT

As a current airline captain and former fighter pilot I strongly disagree with the opinion expressed by reader Clyde Romero regarding the potential for damage from man-portable air-defense systems (Manpads) (*AW&ST* March 17, p. 8). A missile hit can produce damage far beyond an uncontained engine failure. He notes that C-5s and C-17s have survived such attacks, but these are sturdy military aircraft.

The Airbus that was struck barely survived, and it is a testament to superior airmanship that it did. If an airliner is hit, it will be a blow that could cripple the entire airline industry. I see the same foot-dragging on this matter that preceded a decision to reinforce cockpit doors pre-9/11. Cost-analysis studies will continue to fuel reasons to postpone action until a manpad attack against a civilian airliner happens. I can only hope that I am never proven right.

Victor Velazquez
YPSILANTI, MICH.

'INDEFENSIBLE' DEFENSE BUDGET

Bill Sweetman defends the U.S. 2015 defense budget in his "Commander's Intent" commentary (*AW&ST* March 10, p. 16), but he is way off base.

This regressive defense budget marks the beginning of the end of U.S. world supremacy. The political and economic world hegemony by the U.S. and the standard of life enjoyed by it citizens during the last 100 years cannot be sustained without unquestionable military superiority. Human assets in quality and quantity are a fundamental part of this and to believe that technology and weapons systems can replace them is, politics aside, misleading.

With the U.S. castled within natural borders due to its military shrinkage, it is easy to picture the world 50 years from now: That U.S. has lost access to world markets and, as a consequence, double-digit unemployment is rife. Across the ocean, look for a European Union left impoverished and defenseless, experiencing an expanded format of the old USSR.

Gonzalo del Puerto
MADRID, SPAIN

WHY NO FAIL-SAFES?

Once again the search is on for a little orange box on the bottom of the ocean (*AW&ST* March 24, p. 20). With

satellite connectivity available worldwide, why are we still relying on a non-networked device to record crucial data about airplane performance and critical cockpit actions?

There needs to be a standard for virtual flight boxes on aircraft that connect and download all "black box" data to a central depository. Routine downloads as well as those that occur when triggered by a series of unexpected events should be mandatory.

There also needs to be a foolproof method to prevent the cockpit cabin from overriding the recording to the black box.

Of course the perennial stumbling block is money. Funding could be a coordinated approach with the airline industry installing the needed hardware and governments providing free satellite connectivity for black box data.

I believe most people would be willing to pay a couple bucks per flight for the peace of mind that—even if the flight goes horribly wrong—investigators can determine what happened, well before said aircraft is recovered.

John J. Brice
MEADVILLE, PA.

SOLID SONAR NEEDED

The case of the missing Malaysian airliner underscores again that all aircraft should be fitted with a sonar pinger that is activated by water pressure to send alerts once a minute so naval ships with sonar could locate an airliner lost at sea.

Remember, Northwest Orient Airlines Flight 2501 is still missing more than 60 years after crashing in Lake Michigan.

Lorne B. Smith
CLAREMONT, CALIF.

LOCATION OF LOCATORS

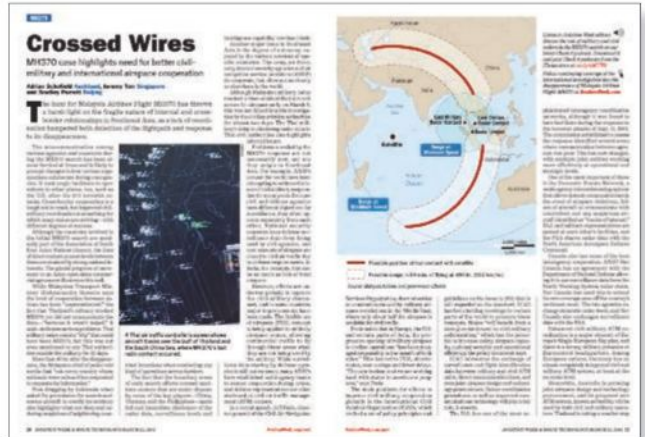
There should be a separate locator device on a commercial airliner that receives GPS positions and retransmits them on a satellite radio link. This tracker should be located outside the cabin and cockpit. At a minimal cost, it could send location, altitude and air-

craft registration numbers every 5 min. and be battery-powered for up to 8 hr.

John M. Bonds
CUPERTINO, CALIF.

FUEL FUNCTIONS

I am surprised that fuel management was not a central part of the discussion by more of the experts



interviewed following the disappearance of Flight 370. There are main and auxiliary tanks in the wings and the center fuselage, and fuel from all of them would be required to keep the aircraft aloft for 7 hr. after the diversion.

Someone who knew how to operate the fuel panel had to be active in the cockpit. We may never know the motive, but this was most likely a high-jacking either by the crew or someone with enough knowledge of the 777 to willfully cause this harm.

Pan Am Capt. (ret.) I.J. Moore
EL CAJON, CALIF.

SPACEX BREAKS MOLDS

I agree with much of Antoine Ge-lain's commentary "Separating Hype from Reality" (*AW&ST* March 17, p. 18), and certainly with his conclusion, but his analysis of SpaceX is incomplete. The company does not define its primary disruptive innovation as "a new application [in a new] market" or "a new business model," but as its manufacturing processes.

The Falcon 9 is designed from scratch for ease of manufacture and eventual partial reuse. SpaceX builds most major components in-house, with domestic labor, which allows for a much greater degree of control over manufacturing than, say, Boeing's global outsourcing, which led directly to the 787 fiasco.

If results to date are anything to go by, Europe's Arianespace should be worried.

This can be measured by its own apples-versus-oranges claim of cost parity between ArianeV ISS delivery flights with Falcon 9 v1.1 delivery-and-return. The latter should be a much more expensive proposition.

If SpaceX really has achieved two-way missions for the same cost per kilogram as Arianespace's one-way trips, bet on SpaceX.

Donald F. Robertson

SAN FRANCISCO, CALIF.

SPACEX STANDS ALONE

Antoine Gelain misses the point with regard to launcher competition from SpaceX. It is not "just another player, trying to break through." It operates on a different premise from all other launch providers. Its primary goal is not profit, but the commercialization of space with the ultimate aim of the colonization of Mars.

With no shareholders to please or quarterly earnings targets to meet, SpaceX's commercial launcher business is a means to an end. Also, while

reusable engines have "been thought of before," no launch provider (other than NASA) has ever done it or invested serious effort into recovering the first stage as SpaceX is doing.

Mike Schriber

SAN DIEGO, CALIF.

SPACE EQUATION SANS RUSSIA

Extending operational funding for the International Space Station (ISS) sounds good (AW&ST March 24, p. 18), but how much of that money will go to the Russians to get us there? Our commercial companies working on manned flight to and from space should be encouraged to pick up the pace.

Paying the Russians for taxi service, while dumping sanctions on them for their questionable behavior on the ground, makes little sense.

Congress should rewrite laws restricting our commercial spacefaring companies. The U.S. needs its own manned flight to the ISS and beyond. Not in 10 years but now, so we do not have to depend on or pay Russia.

Peter J. Peirano

RIDGEWOOD, N.J.

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, 1200 G St., Suite 922, Washington, D.C. 20005. Fax to (202) 383-2346 or send via e-mail to:

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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.

STATELY PACE

In Graham Warwick's "Small Problem" commentary (AW&ST March 17, p. 20), the bold open sentence beneath the headline states: "Unmanned aircraft use threatens to become ungovernable unless FAA acts quickly."

I say, why the rush? Long-time readers should check their *Aviation Week and Space Technology* edition of June 8, 1998. Turn to page 52 and read a full page article: "FAA Mulls Rulemaking On UAV Operations." Yes, 16 years of "mulling."

Any of us who took that long to come to a cogent decision in our respective lines of work would have been fired long ago.

Everett Ratzlaff

ERIE, PA.

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David Gorney



Wayne Goodman



Malina Hills



Bob Sanchez



Brian Moore

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David Koopersmith has been named Philadelphia-based vice president/general manager for vertical lift for *Boeing Military Aircraft* (BMA). He has been vice president of attack helicopter programs/AH-64 Apache and AH-6 program manager/senior site executive for Boeing in Mesa, Ariz., and will be followed by **Kim Smith**, who has been vice president for environment, health and safety in the Engineering, Operations and Technology Div. Koopersmith succeeds **Leanne Caret**, who is now vice president/CFO for Boeing Defense, Space and Security in St. Louis. **Chuck Dabundo** has been appointed vice president of BMA Engineering in Philadelphia and chief engineer. He has been vice president for cargo helicopters/H-47 program manager and will be succeeded by **Stephen Parker**, who has been director of international cargo helicopter programs.

Stan Deal has become leader of Seattle-based *Boeing Commercial Aviation Services*. He succeeds **Lou Mancini**, who plans to retire. Deal has been vice president/general manager of supply chain management and operations for Boeing Commercial Airplanes.

David Gorney (see photo) has been appointed executive vice president of *The Aerospace Corp.*, El Segundo, Calif. He will remain head of the Space Systems Group. **Wayne Goodman** (see photo) has been named senior vice president of the Operations and Support Group, succeeding **Jerry "Mike" Drennan**, who plans to retire. Goodman has been vice president of Space Program Operations and will be followed by **Malina Hills** (see photo).

John Williams has been named country director and **Reghu Raman** field service representative for India for the Wichita-based *Beechcraft Corp.* Williams was president of his own consulting firm and had been a member of Boeing's leadership team in India. Raman was vice president of Air Works India, an authorized service center for Beechcraft.

Kathleen Cantillon has become global director of communications and reputation for AAR, Wood Dale, Ill. She was managing director at ASGK Public Strategies and had been director of communications for Exelon.

Bob Sanchez (see photo) has been

appointed military and government program development manager for *Universal Avionics*, Tucson, Ariz. He was a business development executive for military programs for BAE Systems.

Japan Air Self Defense Force Col. (ret.) Toshihiko Seki has been named head of air power programs for the *Northrop Grumman Corp.*, based in the company's Tokyo office.

Brian Moore (see photo) has been promoted to assistant manager of *FlightSafety International's* Cessna Learning Center in Wichita from Beechcraft relationship manager. He succeeds **Randy Annett**, who has been promoted to manager of FSI's Learning Center in Tucson, Ariz.

USAF Lt. Gens. John E. Hyten and Darren W. McDew have been nominated for promotion to general. Hyten expects to be elevated to commander from vice commander of Air Force Space Command, Peterson AFB, Colo., and McDew to commander of Air Mobility Command from commander of its Eighteenth Air Force, at Scott AFB, Ill. Lt. Gen. **Bradley A. Heithold** has been named commander of Air Force Special Operations Command, Hurlburt Field, Fla. He has been vice commander of U.S. Special Operations Command at the Pentagon. Maj. Gen. **Anthony J. Rock** has been nominated for promotion to lieutenant general and assignment as chief of the Office of the Defense Representative-Pakistan of U.S. Central Command at the U.S. Embassy in Islamabad. He has been vice director for strategic plans and policy for the Joint Staff at the Pentagon. Rock succeeds Lt. Gen. **Gregory A. Biscone**, who has been named inspector general of the Air Force. Maj. Gen. **Thomas J. Trask** has been nominated for promotion to lieutenant general and assignment as vice commander of U.S. Special Operations Command at the Pentagon. He has been director of the Center for Force Structure, Requirements, Resources and Strategic Assessments at U.S. Special Operations Command Headquarters, MacDill AFB, Fla.

HONORS AND ELECTIONS

Dianne VanBeber has been appointed chair of the board and **Chris Stott** as president of the New York-based *Society of Satellite Professionals International*. VanBeber is vice president-investor relations and communications of Intelsat, and Stott is chairman/CEO of Mansat. New members of the board of directors are: **Ed Giovannini**, vice president-programmer sales for Ericsson; **Erwin Hudson**, chief technology officer for Wildblue; **Dave Rehbehn**, senior marketing director for Hughes Network Systems; and **Alan Young**, chief technology officer for Encompass Digital Media.

Gary Dempsey, who is president of Flight Services—The Americas, of Jet Aviation Holdings USA Inc., has been elected chairman of the Alexandria, Va.-based *National Air Transportation Association's* board

of directors. **Andy Priester**, president/CEO of Priester Aviation, was elected vice chairman; and **Gregory Schmidt**, president/CEO of Pentastar Aviation, treasurer. **Curt Castagna**, president/CEO Aerolease/Aeroplex Group, was reelected to the board. Three new members are: **Guy Hill, Jr.**, chairman/CEO of Hill Aircraft; **Marty Hiller**, owner/partner of Marathon Jet Center; and **Mark Larsen**, vice president-large fleet, fractional fleets and government contracts for StandardAero Business Aviation.

Mike Minchow, manager of completions and avionics sales for Duncan Aviation, Lincoln, Neb., has been elected to the board of directors of the *Aircraft Electronics Association*.

Thomas Miller, director of operations/senior vice president-regulatory affairs at Gama Charters Inc., has been named to the board of governors of the Alexandria, Va.-based *Air Charter Safety Foundation*. ☼



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AIR TRANSPORT

ANA Goes for 777-9X

All Nippon Airways has selected Boeing's 777-9X over the Airbus A350 to replace its 777-300ERs. This was regarded as a key contract for Boeing to win, following Japan Airlines' decision last year to order Airbus A350s for its own 777 replacement needs. The 20 777-9Xs are among deals totaling 70 aircraft approved by ANA's board on March 27, the most orders the airline has ever announced at once. ANA says the 777Xs will replace its 19 777-300ERs used on international routes, and will be delivered in fiscal 2021-27. ANA operates 54 777s, which comprise -200s, -200ERs and -300s. The airline plans to purchase six additional -300ERs to support international growth until the 777X deliveries begin. The -300ERs are due to arrive in fiscal 2018-19. ANA is also ordering 14 more 787-9s, which will bring its total 787 order to 80 aircraft, of which 44 will be -9s. The carrier has taken delivery of 27 of its 36 orders for the 787-8. Airbus was not shut out, as ANA has ordered 30 A320-family aircraft for narrowbody replacements—seven A320neos and 23 A321neos. They will replace 737-500s and the current A320s. The A320neos will be delivered in fiscal 2016-18 and the A321neos in fiscal 2017-23.

Etihad Shareholdings Probed

The European Commission has launched an investigation into Etihad Airways' shareholding and control of several European airlines, including Air Berlin and Air Serbia, Aviation Week has learned. The EC is also looking at Delta's stake in Virgin Atlantic. Commissioners have doubts whether the Etihad and Delta investments are in line with EU rules on ownership and effective control of airlines. The tests of ownership and control are separate, and both have to be met to achieve compliance and for an airline to keep its EU "nationality" and traffic rights. The EC has requested information on Etihad's influence and control of Air Berlin and Air Serbia from the German and Serbian governments. Abu Dhabi-based Etihad appears to be seeking to boost its stake to 49 from 29.2% in financially struggling Air Berlin.

Lost in Airspace

After "potentially catastrophic" wrong-airport landings in November by Atlas Air and January by Southwest Airlines,



CIRRUS AIRCRAFT

the U.S. National Transportation Safety Board has issued a safety alert asking airline pilots to be more careful. In the Southwest incident, the pilots had initially planned to fly an instrument approach to the Branson Airport in Springfield, Mo., in clear weather on the night of Jan. 12 but changed to a visual approach once they saw what they thought was the airport. Instead of Branson, the Boeing 737-700, landed on Runway 12 at the M. Graham Clark Downtown Airport, a general aviation facility 6 nm northeast of Branson. Downtown's Runway 12 is approximately aligned with Runway 14 at Branson, but is roughly half the length. "Although the correct destination airport was depicted on their cockpit displays, the flight crew reported flying to the airport that they visually identified as their destination," says the NTSB. "Once the airport was in sight, they did not reference their cockpit displays. The airplane stopped at the end of the 3,738-ft. runway after a hard application of the brakes." In the November incident, pilots of an Atlas Air Boeing 747-400F mistakenly landed at Col. James Jabara Airport in Wichita in night visual conditions. They had been cleared for a GPS instrument approach to Runway 19L at McConnell AFB in Wichita, 8 nm south-southwest of Jabara, but went visual after seeing what they thought was the landing runway. McConnell's 12,000-ft. runway is roughly aligned with Jabara's Runway 18, but is about twice as long. Investigations are continuing.

SPACE

MHI To Build Launcher

Full-scale development of Japan's next

major space launcher is scheduled to begin on April 1, following the formal, and expected, appointment of Mitsubishi Heavy Industries (MHI) as prime contractor. Chosen by the Japan Aerospace Exploration Agency (JAXA), MHI will develop, build and operate the rocket, which will be based on the current H-IIA and related H-IIB series, say MHI and JAXA. A new engine fueled by liquid hydrogen, the LE-X, has been under development as the technological foundation for a replacement for the H-II series, which is criticized as too expensive. The new launcher, which has been called H-X during its pre-development phase and presumably will be named H-III in service, "will be internationally competitive, incorporating a wealth of the latest technologies and simultaneously achieving supreme reliability and a low-cost structure . . .," says MHI. JAXA says costs will be halved. The first launch is scheduled for 2020. Variable combinations of solid-fueled boosters, from none to six, will be used to suit various missions, with throw weights to geosynchronous transfer orbit of 2-6.5 tons. MHI has been operating the H-IIA since 2007 and the more powerful, rarely used H-IIB since last year. With that background, the choice of MHI as prime contractor for the new launcher has been a formality.

Launches Slip

A serious fire at a U.S. Air Force radar facility has knocked the Cape Canaveral spaceflight tracking range off line, forcing delays in launching a classified National Reconnaissance Office spacecraft on a United Launch Alliance Atlas V, and the latest SpaceX Dragon

Cirrus Flies Conforming Vision Personal Jet

Cirrus Aircraft has taken a step toward certification of its single-engine Vision SF50 personal jet, with the initial flight of the first conforming aircraft, designated C-Zero. The March 24 flight from Duluth (Minn.) International Airport, lasted about 1 hr. and was used to test controllability, maneuverability, basic flight envelope and speed performance.

The flight of C-Zero follows the 500-plus hr. accrued by proof-of-concept aircraft V1, which has been flying since 2008. C-Zero initially will be used to verify changes made to the design based on data gathered by V1, followed by a few months of final development testing before certification and performance validation flights begin.

FAA Part 23 certification will involve three conforming aircraft, with the next two to fly in the fall. These will be used for systems and avionics certification, along with function and reliability testing. The company plans an 18-month program leading to certification in 2015. "We anticipate fulfilling the first of our 500-plus customer reservations late next year," says CEO and co-founder Dale Klapmeier.

The seven-seat, all-composite aircraft is designed to fill a niche between high-performance piston singles and light jets. Powered by a Williams FJ33 turboprop, the aircraft will cruise at 300 kt. and operate at altitudes up to 28,000 ft.

cargo capsule to the International Space Station on a Falcon 9. The Air Force apparently has no backup tracking capability, and the two launches were not immediately rescheduled.

BUSINESS AVIATION

More Delays for Learjet 85

Bombardier is pushing back the first flight of its Learjet 85 once again, after discovery of a systems issue that requires a software update. The Canadian manufacturer is not specifying the problem, nor is it predicting when the aircraft might fly. The aircraft was anticipated to take to the air in March after FAA granted a flight-test permit in February. Bombardier quietly rolled out the aircraft to its employees in September, but President and CEO Pierre Beaudoin had said first flight awaited the completion of systems integration. The company wanted to ensure the systems "responded the way they should," Beaudoin had said during the company's first-quarter earnings call. The flight has already been delayed by at least a year as Bombardier ironed out problems with the aircraft's composite program.

DEFENSE

RAF Retires Tristars

The U.K. Royal Air Force (RAF) has formally retired its long-serving Lockheed L-1011 Tristar transport aircraft. Final operational flights took place on March 24 with a refueling sortie over the North Sea before the remaining aircraft were retired to Bruntingthorpe Airfield in Leicestershire for possible breaking on

March 25. The RAF purchased three former Pan Am and six ex-British Airways Tristars after the Falklands War to fulfill the strategic transport role and bolster the aerial refueling capability. The missions have now been handed to the Airbus A330 Voyager aircraft operated by the Airtanker consortium.

MBDA in Anti-Ship Missile Deal

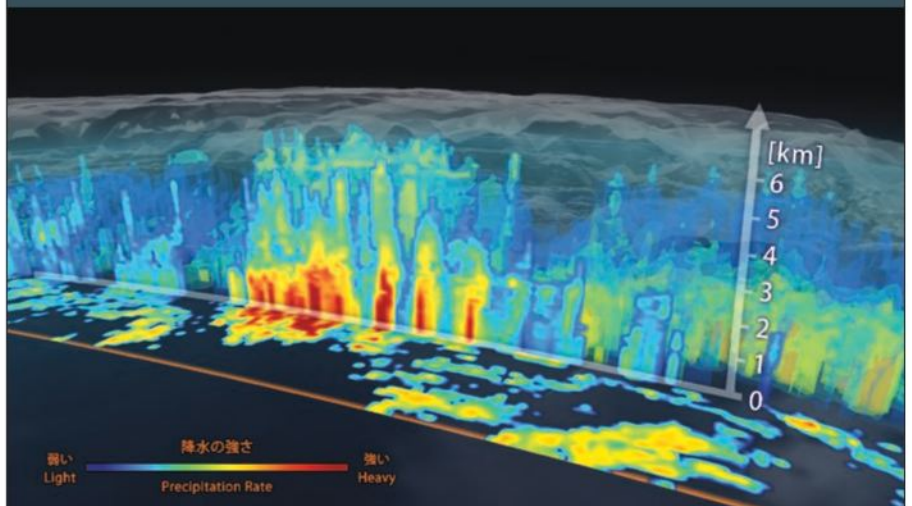
MBDA has been awarded a \$500 million (\$830 million), Anglo-French contract to demonstrate and build a new-generation helicopter-borne anti-ship missile. The weapon—the Future Anti-Ship Guided Weapon (Heavy) in the U.K. or Anti-Navire Leger in France—will equip the Royal Navy's AgustaWestland AW159 Wildcat naval helicopters and French navy AS565 Panthers and NH90s.

Qatar's Shopping List

Qatar plans to purchase aircraft, helicopters, missile systems and surveillance equipment for its armed forces, worth \$23 billion. Qatar plans to buy two Airbus A330 multi-role tanker transports, three Boeing 737 airborne-early-warning-and-control aircraft, 24 AH-64 Apache attack helicopters, 22 NH90 utility helicopters, as well as Patriot surface-to-air missile systems and the Javelin man-portable missile system. Qatari officials made the surprise announcement on the final day of the Dimdex defense exhibition in Doha on March 27.

A Stormy First Light

Instruments on the Global Precipitation Mission (GPM) got an early workout March 10 to produce this 3-D view of precipitation rates inside a cyclone over the Pacific Ocean 1,000 mi. east of Japan. Red marks the heaviest downpours, as measured by the Japanese Dual-frequency Precipitation Radar. NASA's GPM Microwave Imager provided overhead views of the same storm, as checkout continues following the spacecraft's launch on Feb. 27 from the Japan Aerospace Exploration Agency (JAXA) facility on Tanegashima Island. Developed jointly by JAXA and NASA, GPM is a follow-on to the two nations' joint Tropical Rainfall Measuring Mission, but with broader surface coverage from its 65-deg. inclination orbit and more capability to distinguish among different types of precipitation. It will work as the "core" spacecraft in a fleet that includes 11 others monitoring atmospheric water, allowing researchers to cross-reference data from across the constellation (AW&ST Feb. 3, p. 41).



JAXA/NASA



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COMMENTARY

Golden Age

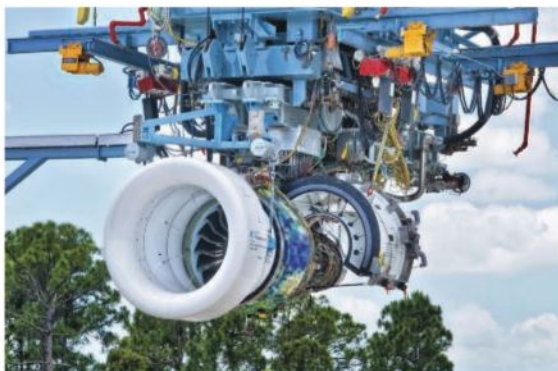
How four aeroengine companies are pacing industry innovation

Aviation, like most industries, is defined by periodic “golden Ages,” characterized by bursts of innovation and exciting competition. Examples include air travel in the 1930s, with the arrival of DC-3s and long-range Clipper Ships; the Jet Age in the 1960s, with aircraft manufacturers besting each other with stunning innovations such as the Boeing 747, Lockheed L-1011, and McDonnell Douglas DC-10; and perhaps the last decade for business aviation, with the creation of entirely new product categories and the arrival of Embraer as a bold new competitor.

We are arguably in the midst of another Golden Age. However, this one is not for aircraft, it is for gas turbines. Responding to the imperative for step-change improvements in fuel efficiency, four well-heeled aeroengine OEMs—two American and two European—have staked out bold and distinctive product development strategies that will shape new aircraft development for the foreseeable future. Backed by billions of dollars of annual R&D spending, this four-way battle is driving innovation in ways unforeseen just a few years ago. As a result, four major reengining programs are planned, with more on the horizon.

In one corner is the former champion, Pratt & Whitney. After seeing its commercial market share plunge to about 10% in recent years, from 90% in the late 1960s, Pratt is now resurgent with the geared turbofan (GTF) architecture (see photo).

The GTF is redefining the whole 70-180-seat segment, has created the massive wave of single-aisle reengining and underpinned the launch of the Bombardier CSeries and Mitsubishi Regional Jet. Not long ago, the GTF was considered by many to be the result of a quirky vision held by a certain few eccentric executives in East



PRATT & WHITNEY

Hartford, Conn. Today the market recognizes the major gains in propulsive efficiency, simplicity, noise and maintenance costs enabled by the GTF.

The second contender is the reigning heavyweight champion, General Electric. Leveraging its scale, advanced technology and broad gas turbine portfolio—it is also the industrial gas turbine market leader—GE has created a new range of aeroengines, such as GEnx, Leap and Passport, that employ advanced materials, manufacturing processes, 3-D aerodynamics and systems.

GE is aggressively attacking aeroengine weight through the introduction of ceramic matrix composite titanium aluminide in the hot section and expanded use of organic matrix composites in the fan section. GE will “print” the fuel nozzles for its Leap engine via additive manufacturing,

and is introducing innovations including a novel debris rejection system. In contrast to Pratt, GE is betting heavily on advances in thermal efficiency, aerodynamics and weight reduction to answer the bell.

In the third corner is Rolls-Royce, the European champion. Just a few weeks ago, Rolls unveiled an ambitious product development roadmap that builds on its unique three-spool architecture (AW&ST March 3, p. 20). Rolls plans to offer a new engine dubbed Advance based on a re-cored XWB, which incorporates a composite fan blade and fan case.

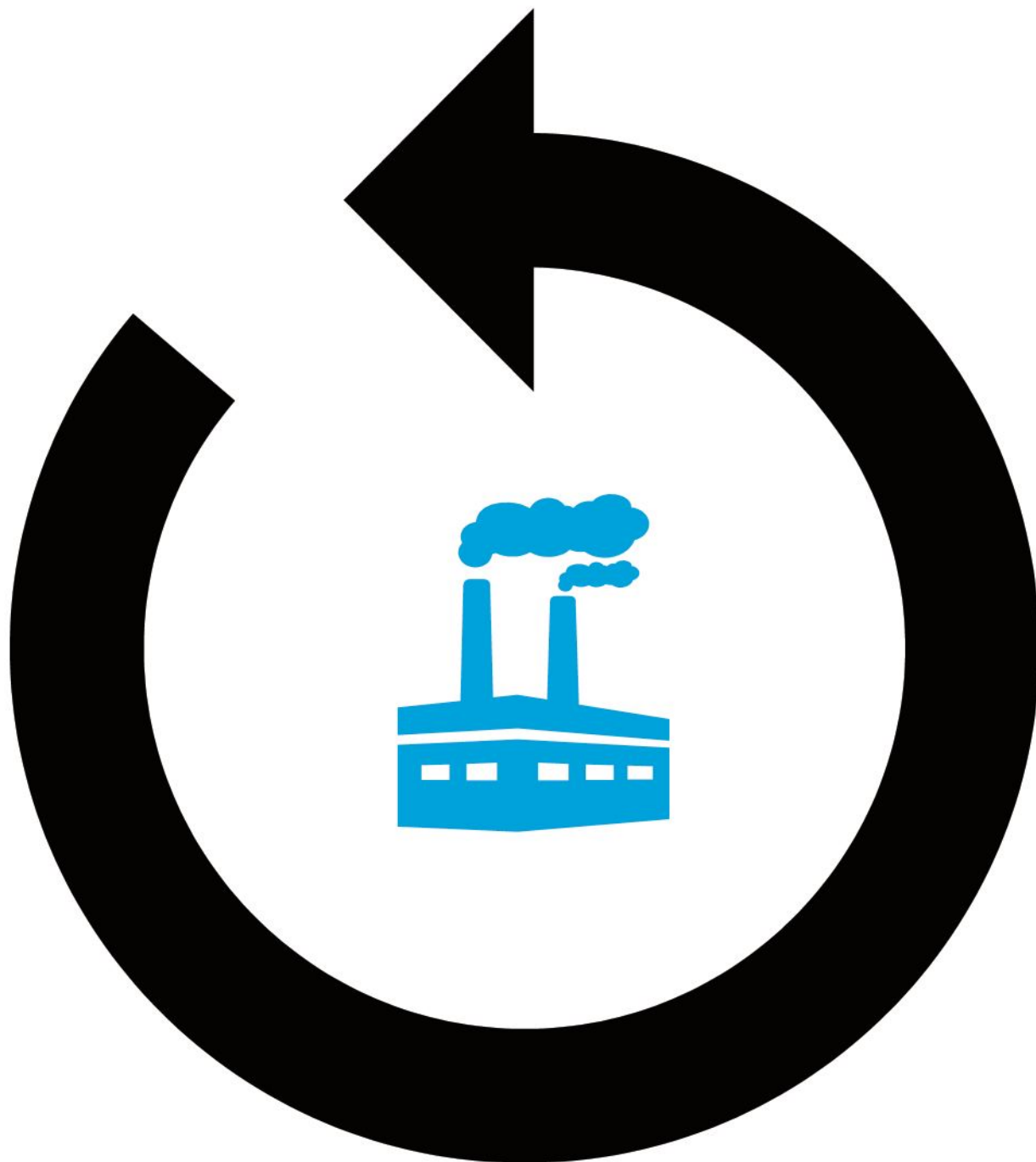
Although no specific application has been announced, Rolls indicates the engine could be available by 2020. Could this be aimed at an A330neo and/or an A380neo? Speculation abounds. More significantly, Rolls has embraced Pratt's GTF architecture with another new engine, the UltraFan, which is planned for 2025. The UltraFan will aim to offer an astounding 15:1 bypass ratio and could yield a fuel burn improvement of 25% or more versus today's Trent 700.

Finally, there is Safran, the rising contender from France. Safran, best known for its role in the *uber*-successful CFM International, is now staking out its own space. It is a 50% partner on the Leap engine, it led the development of the hot section of the SAM146 on the Sukhoi Superjet, and it is now pushing into the business jet market with its new Silvercrest model. And Safran continues to expand its cooperation with GE, pushing beyond engines to nacelles via its Nexcelle joint venture.

Safran's rise means the “Big Three” in aeroengines are now the “Big Four.” An intriguing question: With two of the Big Four increasingly aligned, will Pratt and Rolls be pushed into greater collaboration or possibly a joint venture similar to CFM?

The arrival of a Golden Age does not mean guaranteed prosperity for aeroengine OEMs. Risks abound—technological, supply chain, financial and execution—in what promises to be another exciting decade of gas turbine development. One thing is certain: The outcome of this epic four-way battle will pace aircraft product strategies for the foreseeable future. ☛

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COMMENTARY

Racing Inspired

It worked for Indy cars, now the Gurney flap could be a key to better helicopter rotors

Dan Gurney, American racing car driver and constructor, is providing inspiration to European helicopter manufacturers, with AgustaWestland planning in 2015 to fly an active rotor incorporating the aerodynamic device that carries his name.

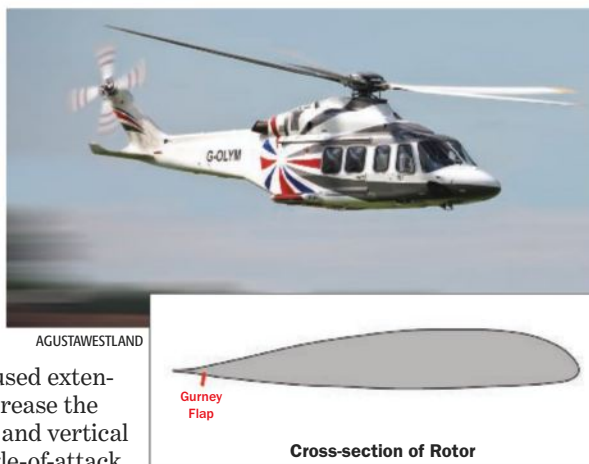
The Gurney flap (see diagram) is a small tab set perpendicular to the flow at the trailing edge of a wing. It has the effect of increasing lift with minimal impact on drag. In the early 1970s, he first used the eponymous device on the rear wing of a racing car to increase downforce.

Fixed Gurney flaps are used extensively on helicopters to increase the effectiveness of horizontal and vertical stabilizers over a wide angle-of-attack range. Now, with funding from Europe's Clean Sky research program, AgustaWestland is to use active Gurney flaps to increase the performance of helicopter rotor blades.

Rotor design is a compromise between hover and forward-flight requirements, and the ability to squeeze more performance from conventional blades is reaching its limits. "In the 1980s and '90s we saw big gains. Now they are smaller. We have more powerful computational tools, but are only getting incremental gains," says Simon Spurway, AgustaWestland principal engineer. "The next step is active rotors."

Under Clean Sky's Green Rotorcraft program, Airbus Helicopters is leading work to see how much further a conventional blade can be passively optimized. The manufacturer also is heading a project to develop active blade twist, which Spurway says poses fail-safe design challenges. AgustaWestland, meanwhile, is in charge of the active Gurney flap project.

Projecting from the lower surface



close to the trailing edge, and just 1-2% of blade chord in height, the flap produces counter-rotating vortices that increase pressure on the lower, pressure side of the airfoil and decrease pressure on the upper, suction side. The vortices help the boundary stay attached to the trailing edge and increase the maximum lift coefficient for only a small penalty in drag coefficient.

In forward flight, rotor blades experience different conditions as they rotate. On the advancing side, forward speed adds to rotational speed and increases lift. On the retreating side, forward speed subtracts from rotational speed, and blade pitch must be increased to maintain lift. As airspeed rises, the retreating blade begins to stall and the pilot must add power to overcome the rising drag.

Retracted on the advancing side, the active Gurney flap is deployed on the retreating side to delay the stall. Covering the middle section of the blade, the flap locally improves lift and allows

the outer section of the retreating blade to be offloaded. This reduces the power required to maintain airspeed and lowers fuel consumption and emissions, an overall goal of Clean Sky.

The system is being developed in stages, beginning with wind-tunnel tests of a two-dimensional airfoil, completed in January at the University of Twente in the Netherlands. The representative blade section was held at a fixed but adjustable angle of attack, and the flap was deployed to pre-set heights to determine its aerodynamic effect.

Next will come 2-D dynamic tests, planned for year-end in a wind-tunnel at Italian aerospace research center CIRA. This scaled airfoil section model will oscillate in pitch at rates representative of a rotor blade in normal operation. The active Gurney flap will be deployed using the schedule and rates anticipated for the full-scale flight system.

Tests of a subscale four-blade rotor model are planned for the first quarter of 2015, in a wind tunnel at Politecnico di Milano. Less than 1 meter (3.2 ft.) in diameter, with blades just 95 mm (3.7 in.) in chord, this model will allow the active flaps to be tested on rotating blades in controlled conditions. "We will look at different deployment schedules—rapid, sinusoidal, multi-harmonic—and assess performance as progressive blade stall is encountered," Spurway says.

A full-size main rotor with active Gurney flaps is to be tested on a whirl tower in March 2015, using flight-rated electrical actuation and control systems supplied by Microtecnica. Flight tests on an AW139 (see photo) are planned for June 2015. The fourth AW139 built will be modified with an active rotor controller installed on the hub under an enlarged "beanie" fairing. This will provide electrical power distribution and power electronics for the actuation systems in the blades.

The program is picking up pace. "The blades are in manufacture. Structural test specimens are being configured, to prove it is safe to fly. The rotor head controller has been prototyped," Spurway says.

Gurney's modest bent-metal flap is taking on a new complexity and capability. ☞

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Boeing is increasing the production rate of 737s to 42 aircraft per month.

COMMENTARY

The Best-Kept Secrets

Boeing and Airbus guard market strategy well

Could a quite spectacular speculative bubble pop in the next few years? Most of the world's airlines are ordering a lot of commercial transports, perhaps more than they need. If this is the case, cancellations may not be far behind, to be followed by a serious industrial crisis. In light of overcapacity, manufacturers would have to slash production rates. Such a worst-case scenario is said to be a hot topic behind closed doors in Toulouse and Chicago because both major manufacturers are selling significantly more aircraft than they currently produce.

Their backlog is impressive, to say the least—more than 5,000 aircraft each—while last year they delivered a combined 1,274 “next-generation” single-aisles and widebodies. Most industrial segments can only dream about enjoying such a bounty.

But is everything as rosy as financial analysts claim? This key question must remain shrouded because both Airbus and Boeing zealously guard details into the inner workings of their backlogs. This much is known. Last year, an estimated 650 aircraft were definitively parked.

Although the ongoing financial upturn has led to slightly increased production rates—mostly for the A320 and 737 series—the two rivals do not plan to expand beyond that. They certainly fear the damage a global downturn could inflict to their industry. And they also believe some customers, including startups and low-fare players, are excessively optimistic

when devising long-term fleet planning and could face serious difficulties when it comes to paying for their orders. Manufacturers are experts in overbooking and most probably sell some aircraft to more than a single customer to avoid the risk of having to park white tails in front of their final assembly lines, where they'll gather dust for who knows how long.

The key question, today, is to try to determine if the airline industry will continue to be dominated by economic cycles—as it has been in the past several decades—or will instead enjoy a long-lasting stability. The International Air Transport Association's recent robust financial forecasts indicate its 240-member airlines will post nearly \$20 billion in combined annual profits after achieving disappointing results over the past several years. However, again, this does not mean airlines are insulated from financial losses farther down the path, which could force them

to cut capacity and cancel aircraft orders.

Contrary to the projections of other experts, Paris-based ID Aero—a noted consultancy covering the airline industry, including in-depth traffic analyses—does not see a downturn materializing later in the decade. Chief Executive Jacques Delys is adamant that if a downturn were to occur in the next three years it would be of limited scale. Since the 1970s, he says, airlines routinely entered into a series of downturns—of limited duration—about every 8.5 years. During those periods some aircraft deliveries had to be delayed and rescheduled, usually by two years.

Based on past experience, Delys adds, the next downturn could in theory begin in late 2015 or early 2016, and some aircraft deliveries could be put on hold starting in 2017. But this is not the most probable scenario, he says. After all, in the next 20 years, airlines will need to take delivery of an estimated 23,000 aircraft, either to replace the aircraft that age out of their fleets or to create additional capacity. Traffic growth is expected to average about 5% per year—less than 2% in mature markets such as the U.S. and significantly more in the Pacific Rim and other burgeoning regions. This year, traffic growth is spiking above predictions, at 6.6%, while seat-load factor in the last few weeks increased 0.8% to 78.5%, according to ID Aero's calculations.

Delys, like other dependable economists and analysts, acknowledges that there is no concrete information available regarding Airbus's and Boeing's backlog management plans. However, cancellations, including regional twin-jets, last year covered 346 aircraft at the most. Cancellations peaked at 467 in 2011, at the end of a serious crisis.

To maintain flexibility, airlines also could begin to favor medium-size twin-jets, which are easier to adapt to various types of routes. This use of twin-jets explains why average capacity is increasing more slowly than previously expected—to no more than 170-180 seats—a market segment that may encourage Boeing to develop a successor to the 757. Airbus has no such plans afoot.

In other words, the situation is and will remain fluid. ☞



By Jens Flottau

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COMMENTARY

Alliance Reset

Oneworld grows at the expense of Star, but how much does it really matter?

For the past three weeks, it seemed like the airline world stood still. The fate of Malaysia Airlines Flight 370 overshadowed every activity and has been in the minds of most in the industry. That will continue to be the case for a long time as, hopefully, more and more information about the crash becomes available and lessons can be learned.

At the same time, business continues—including at Malaysia Airlines. The carrier will send representatives to Sao Paulo this week for a very important meeting of the Oneworld alliance that marks a major shift in the world of the global alliances. The US Airways part of American Airlines as well as TAM Brazil are officially exiting the Star Alliance and joining Oneworld.

The alliance shifts should lead to more evenly distributed market shares among Star, Oneworld and SkyTeam; Star has been by far the largest. The exits are both the results of mergers—of US Airways and American in the U.S. and LAN and TAM into Latam in Latin America. Star lobbied hard to keep its existing members and add their merger partners, but power dynamics worked against it. US Airways followed the lead of its much bigger partner, American, and TAM followed the way of Latam CEO Enrique Cueto, a long time Oneworld participant.

While the changes don't erase Star's presence in Latin America, they do greatly diminish it; the alliance will need years to recover some of the lost ground. Although Avianca is turning into a well-run, profitable and steadily growing operation, it does not solve Star's biggest problem in the region: representation in Brazil. That responsibility will fall on its sister company, Avianca Brazil, which has the same major shareholder and similar brand but is a separate unit with separate management.

Avianca Brazil is growing fast,

too, and can provide some valuable feed for Star long-haul arrivals at Sao Paulo's Guarulhos International Airport. However, it does not have its own long-haul operation that would

equity stakes, but Gol gave up its long-haul flying after its painful acquisition of Varig. And Gol, which originally started as a low-fare carrier, still does not have the appropriate business model for alliance membership.

Maybe these details are not so important after all. Many airlines are now growing through deep bilateral deals and joint ventures rather than by joining alliances. And in certain cases, such as Gol's, it does not seem imperative that a local airline providing feed to its international partners be part of a global club.

There are other examples elsewhere. Virgin Australia has links to many different legacy carriers and is partially owned by three (Etihad, Singapore Airlines and Air New Zealand), but isn't in any alliance. Aer Lingus exited Oneworld and is thriving on its own.

The math is different for TAM, however. It has to be in the same alliance as



KEITH GASKELL

TAM Brazil is switching alliances, from Star to Oneworld, following its merger with LAN Airlines.

complement Star's inbound flights.

SkyTeam is in a similar situation, though it has no local member in Brazil. Delta Air Lines and Air France-KLM have bilateral relationships with Sao Paulo-based low-cost carrier Gol Linhas Aereas Inteligentes that include small

its Latam Group sister company, LAN Airlines, and it needs feed at its international destinations, most importantly in the U.S. and Europe. American has Dallas/Fort Worth and Miami to offer, and Iberia can fly TAM passengers on from Madrid, which is already Latam's first point of entry to Europe. So it looks like Star, which lost first Varig and then TAM, will just have to concede that Brazil isn't working out right now. ☹



COMMENTARY

Milsat Savings

Unneeded Cold War capabilities boost cost

The Pentagon spent a lot of money deterring nuclear war with the Soviet Union, and not all of it went for nuclear weapons. In order to mount a credible threat, U.S. military planners designed an orbiting set of Battlestar Galacticas called Milstar that were designed to maintain secure com-links between the president and his designated successors and the strategic forces responsible for waging what B-52 pilot T.J. “King” Kong memorably termed “thermonuclear combat” in Stanley Kubrick’s classic anti-war film *Dr. Strangelove*. The satellites were big (see photo) and expensive. Ultimately six were launched, beginning a little more than two years after the Soviet Union ceased to exist. The mission continued with the Advanced EHF (Extremely High Frequency) birds, and is only now being trimmed in a belated—and partial—acknowledgement that the Cold War ended a generation ago (*AW&ST* March 10, p. 30).

“Advanced EHF and Milstar provide about 3% of the capacity for U.S. military operations today,” says Rich Skinner, business development director at Northrop Grumman Communication Systems, noting that a terrorist car bomb parked outside a critical ground node can be a threat to secure milsatcom now.

Yet the threat of the electromagnetic pulse released by nuclear weapons continues to drive some satellite requirements, even as tight military budgets drive the need for new ideas in procuring military space systems. A just-released study by the Aerospace Industries Association (AIA) suggests a common-sense approach to cutting military space costs. One trick, note panelists assembled by AIA to release the report—“Easing the Burden: Reducing the Cost of National Security Space Capabilities”—is to let the military act more like a commercial customer in buying space assets, and let the industry be more like a commercial manufacturer. Input from a workshop held May 29-30, 2013, produced 19 recommendations for greater cost effectiveness in the way the Pentagon and intelligence community procure spacecraft.



Among them are calls for more “stability” in setting requirements and buying systems; better contracting practices; greater use of commercial hardware, including hosted payloads; cuts in the “unseen costs” government imposes on its milspace suppliers; better standardization for competition in component purchases; and industry actions to “make products more cost competitive and capture greater market share” to spread costs over a broader base.

Some results are already in. Boeing was able to save \$150 million on three Wideband Global Satcom birds by adopting such seemingly simple methods—with government support—as using a single contract line-item number for each spacecraft, and basing

payments on performance in a fashion similar to the one it follows with its commercial satcom customers.

“This is a very stable program,” explains Jeff Trauberman, Boeing vice president for space, intelligence and missile defense. “It was already in production and had finished its design and development phase. We have a big commercial satellite business [and we told the government] if you could adopt some of the processes and procedures we use in our commercial satellite business, you can get these very same satellites for less money.”

The company is also moving to adapt innovations it made for the commercial satcom market for use by military customers. One example is the Boeing 702 SP “all-electric” satellite bus, developed for commercial satcom operators and approaching its first launches next year. Because the spacecraft are smaller, Trauberman says, they can be launched in tandem on a variety of rockets, allowing savings on both the launch and cost of carrying heavier chemical propellant.

Meanwhile, Northrop Grumman is taking a stab at saving taxpayer money by rationalizing the requirements for military spacecraft to avoid capabilities that are not needed for particular applications. A good target, says Skinner, is the aforementioned strategic command and control capabilities built into Milstar and Advanced EHF spacecraft.

“These satellite systems, because they met everybody’s idea of threat needs, are really expensive,” Skinner notes. “So we went through an exercise to decide how inexpensive we might build satellites, not to replace Advanced EHF, which you still need to meet that high-end nuclear-protected system, but to supply just tactical support.”

By descoping the requirements, Skinner explains, a jam-resistant tactical satellite can be built for about \$350 million. Because the satellite would be smaller than traditional military spacecraft, it could fly on a SpaceX Falcon 9 instead of an Evolved Expendable Launch Vehicle such as Atlas V or Delta IV—“a cheaper commercial launch,” he adds. “The bumper sticker, if you would, is ‘80% of the capacity for about one third of the price.’”

As the annual U.S. income tax deadline approaches, that sounds sensible. ☼



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COMMENTARY

Space Shutdown

Bolden outlines need for U.S.-Russia civil space cooperation

As a Marine general who came of age during the Cold War, Administrator Charles Bolden may have found it odd to be defending Russia along with NASA's fiscal 2015 budget request to the House Science space subcommittee.

Badgered last week by Rep. Mo Brooks (R-Ala.), who represents the district that includes the Marshall Space Flight Center, over the possibility Russia may "deny access" to the International Space Station (ISS), Bolden noted that Russia depends as much on U.S. power, communications and "navigation" at the ISS as the U.S. does on Russia's Soyuz capsules. Without U.S. access, "the partners would probably have to shut the space station down; if you are thinking that the Russians will continue to operate the International Space Station, it can't be done," Bolden said. Russia has proved to be a reliable partner over the years, he said, and that is unlikely to change over the Crimean crisis. But if it does, he said, "I will go to the president and recommend that we terminate [the Space Launch System] and Orion, because without the International Space Station, I have no vehicle to do the medical tests [or] the technology development. And we're fooling everybody that we can go to deep space if the International Space Station is not there." Development of the heavy-lift Space Launch System to carry the Orion crew vehicle into deep space is managed at Marshall, and Brooks quickly changed the subject. ☼

BORDER INSIGHTS

When it comes to those in the Capitol who are consumed with military matters, Republicans are more concerned about potential confrontation than cooperation. Leaders of the House

Armed Services subcommittees wrote to the president urging him to share with Ukraine key information the U.S. may have about the "aggressive posture of Russian forces" along Ukraine's eastern border. Specifically mentioned were classified data and unclassified reports such as recent comments by U.S. Air Force Gen. Philip Breedlove, commander of European Command, about the build-up (see page 34).

In a separate letter to Defense Secretary Chuck Hagel, the chairman of the strategic forces subcommittee



NASA

"We're fooling everybody that we can go to deep space if the International Space Station is not there."

—CHARLES BOLDEN
NASA Administrator

provides a bit more detail. "Despite recent comments made by Russian Federation President Vladimir Putin, it is my belief that Russian forces may intend to advance farther into Ukraine," Rep. Michael Turner (R-Ohio), writes. "I am concerned that if this information is not presented to Congress or shared with the larger international community to include countries such as Ukraine, there will be little or no opportunity to deter or prepare for further Russian advances." ☼

TAKETH AND GIVETH

The Export-Import Bank, girding for another fight for its existence in Congress, supplied its third loan

benefitting the MRO unit of Delta Air Lines. Last week, Brazil's low-cost carrier GOL netted \$40.7 million in Ex-Im Bank-backed financing for an engine services contract with Delta Tech Ops—the third such deal in two years, the bank reports. Tech Ops has a five-year agreement to overhaul the airline's CFM56-7Bs. More than 50% of GOL's engine maintenance is provided by Delta.

Meanwhile, Delta remains a plaintiff in three lawsuits against Ex-Im related to backing aircraft purchases by some of the airline's competitors and has lobbied for restrictions on the bank. The latest lawsuit, filed in January along with the Air Line Pilots Association and Hawaiian Airlines, seeks to stop aircraft financing for Air India.

The bank is quick to point out the benefit to its legislative and legal rival. "I am pleased that our financing will help support high-quality jobs for Delta employees in Atlanta," said Ex-Im Bank Chairman Fred P. Hochberg in a May 2013 press release announcing a previous \$45.5 million loan guarantee for GOL. ☼

WORK RELEASED

The Senate Armed Services Committee voted to advance the nomination of Robert Work to replace Ashton Carter as the next deputy defense secretary. Sen. John McCain (R-Ariz.) had placed a hold on the process because of questions he had

about delays to the Littoral Combat Ship and integration challenges. While McCain remains disappointed in the answers he received from Work, the hold has been lifted, according to a congressional aide.

The committee also approved nominations for Michael McCord as the next Pentagon comptroller and Christine Wormuth to be the next undersecretary for policy. Vice Adm. Michael Rogers was also approved by the committee to become a four-star admiral, director of the National Security Agency and commander of U.S. Cyber Command. The nominations still must pass in the full Senate before taking effect. ☼

AIRBUS

Open Answers

Noise looks to be less an issue for open rotors, but can safety be achieved at an economical price?

Graham Warwick **Brussels**

On the surface it may seem like a “me-too” effort a quarter-century after the U.S. demonstrated in flight that open-rotor engines can deliver dramatic fuel-burn savings over conventional turbofans. But Europe’s research is tightly focused on the two barriers that could prevent open rotors from being considered for the next generation of all-new narrowbody airliners: noise and safety.

Under Europe’s Clean Sky program, research conducted by teams led by Airbus and Snecma has concluded that a 2030-timeframe short/medium-range airliner with counter-rotating open-rotor engines is technically feasible and will meet new International Civil Aviation Organization Chapter 14 noise limits, the companies declared to the Greener Aviation 2014 conference here this month.

Design studies have shown open-rotor engines are the best candidates for low fuel burn and emissions, says Airbus powerplant safety engineer Charlie Rulleau. The next hurdle is to improve the aircraft’s economics, in particular reducing the weight penalty of meeting blade-off safety requirements, which could negate the fuel-burn benefit of open rotors.

“We have confirmed the feasibility of the design. Now we need to improve the economic viability to be able to propose a product,” Rulleau says.

Under Clean Sky, Snecma is developing a geared open-rotor demonstrator engine that is scheduled for ground testing at the end of 2015. Airbus is working on engine-airframe integration, alternative configurations and certification issues. The goal is to establish economic viability by 2017,

then proceed into an open-rotor flight demonstration, planned by 2023 under the follow-on Clean Sky 2 program.

Flight tests of Snecma’s demonstrator engine mounted on the aft fuselage of an Airbus A340-600 were planned under Clean Sky, which wraps up in 2017. But delays have deferred the flight demonstration to Clean Sky 2, which will begin this year, and the objectives have been modified to focus more on engine-airframe integration and certification issues. The demonstrator platform is now planned to be an A340-300, but that could change as a result of Airbus’s continuing studies.

Open rotors burn less fuel than turbofans because they can have large diameters for ultra-high bypass ratios without the drag and weight penalties of a large nacelle. General Electric demonstrated the GE36 Unducted Fan in flight in late 1980s, but the concept was shelved when the fuel crisis ended. Work was revived earlier this decade and, with funding from NASA, GE wind-tunnel-tested refined blade designs for increased performance and reduced noise. But NASA did not continue the project, leaving Snecma—GE’s partner in narrowbody-engine joint venture CFM International—and Europe’s Clean Sky program to take

the lead in advancing the maturity of the open rotor as a possible successor to CFM’s Leap engine.

Key to economic viability will be the weight penalty incurred to protect the aircraft from damage caused by a rotor burst or blade release. A turbofan can contain a released blade, but an open rotor will require shielding of the airframe and systems. In Airbus’s baseline concept, which has pusher open-rotor engines mounted on the aft fuselage and a conventional T tail, shielding of the rear fuselage and tail adds about 0.5 metric tons (1,100 lb.) to the aircraft’s weight.

Too high a weight penalty would negate the open rotor’s fuel-burn advance over turbofans. “The design is at low maturity; it is not a good solution,” says Rulleau. “The next step is to improve the engine and shielding design to reduce weight.” Initial rulemaking for certification of open rotors requires a fail-safe hub to prevent a rotor burst and blade-release mitigation “at the aircraft level” through shielding, he says, adding that the fail-safe hub design is still at low maturity, but tests have shown the blades can withstand bird impacts.

Airbus studied but rejected an aircraft configuration with “puller” open rotors mounted in the conventional underwing location because cabin noise “was above the target by more margin than available technology can mitigate,” Rulleau says. The aft-mounted location “is not far from the target,” he says. Airbus is studying three possible configurations, including rear-fuselage and tail designs that would acoustically shield the open rotors to reduce the noise levels reaching the ground.

“Buyers of next-generation short/medium-range airliners will expect big steps in aircraft economics, at least a

Airbus has zeroed in on a tail-mounted engine location to minimize cabin noise.

40-percent fuel-burn-per-passenger improvement,” says Vincent Garnier, Snecma vice president of marketing strategy for civil engines. “That is a very high mountain to climb.” Options under evaluation are turbofans with bypass ratios beyond 15 and the counter-rotating open-rotor (CROR) engine. “They offer different mixes of fuel-burn and noise benefits, and the engine and air-frame architecture will be very closely coupled,” Garnier told the conference, organized by the Council of European Aerospace Societies and France’s 3AF.

To power a 2030-timeframe narrow-body, Snecma is studying both a counter-rotating turbofan with 16% lower specific fuel consumption and 20 dB lower noise than the CFM Leap-1 and the CROR, which can reduce fuel burn by 26% but noise by only 10 dB.

“Why is Snecma pushing open rotor? Because it has the strongest propulsive efficiency potential and poses the greatest challenges and uncertainties,”



Wind-tunnel tests indicate aircraft powered by open-rotor engines will meet noise limits.

Garnier says. “Clean Sky is a great learning vehicle, and what we learn will have wide application. It is helping build a team of partners to build a consensus and a community.”

Snecma has confirmed the geared open-rotor’s target efficiency and that it is “Chapter 14-compliant with margin,” Garnier says. “It is still a long road to the next-generation short-/me-

CLEAN SKY

dium-range airliner, and we will need absolute confidence before we change architectures. We will need more demonstration steps, and possibly another build of the CROR.”

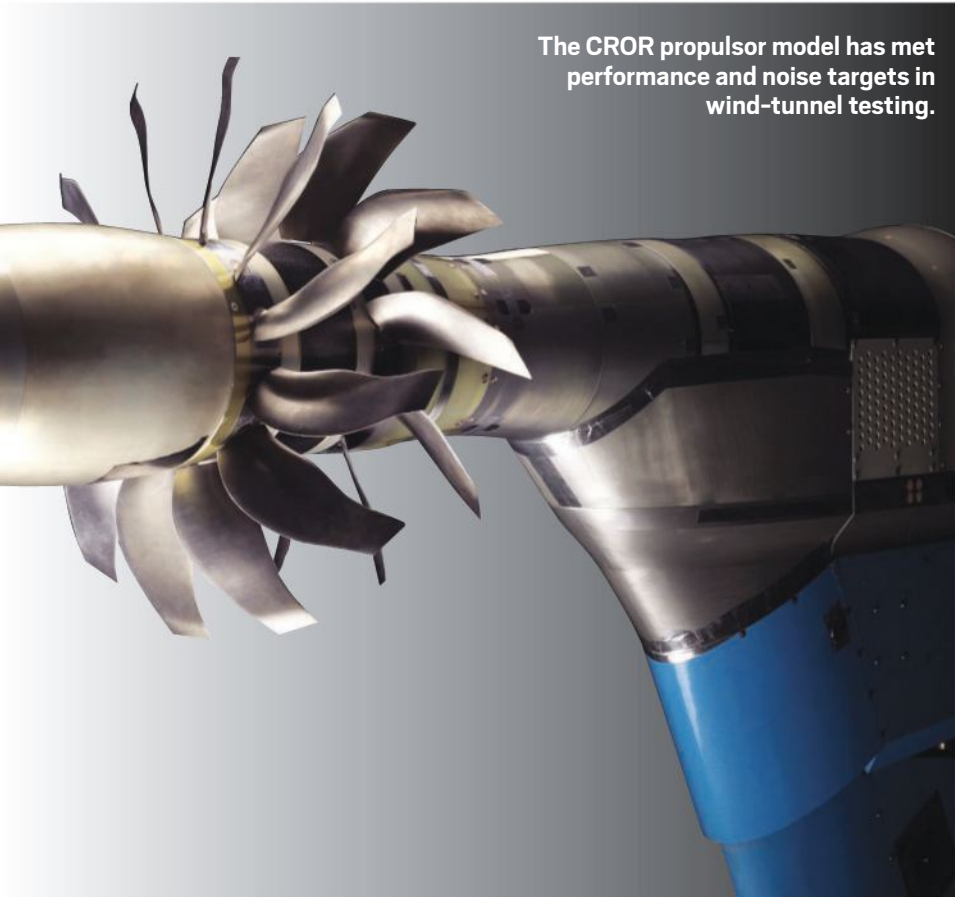
Snecma validated its efficiency and noise projections with tests of a scaled CROR model in French research agency Onera’s SM1A wind tunnel last year. Tests of the HERA propulsor rig at speeds up to Mach 0.30 measured noise at the three certification points: takeoff, sideline and approach. “We assessed noise level versus Chapter 14, blade performance and validated successive blade design optimizations,” says acoustic engineer Rasika Fernando.

Three generations of blade sets were tested, HERA1, 3 and 5. Snecma achieved a 5.2 EPNdB noise reduction and a 1.1% efficiency increase between the HERA1 and 3 blade sets, both for the original direct-drive CROR design. Another 2.7-EPNdB noise reduction and 0.5% efficiency improvement were reached with the HERA5 blade set, the first for the geared CROR.

“We achieved good optimization of performance and certification noise. Our blade designs are now compliant with Chapter 14,” Fernando says. The CROR ground-demonstration engine now under construction will use the HERA5 blade set. Meanwhile, “more blade design optimization is underway to further improve efficiency and reduce noise,” he says.

Airbus’s design studies under Clean Sky have included three large wind-tunnel test campaigns, involving isolated and semi-installed open-rotor propulsor tests and a 1/7th-scale full aircraft model. The tests, in the large low-speed facility (LLF) at DNW in the Netherlands, involved blade designs from Snecma, Rolls-Royce and Airbus itself. There were “only slight differences” between the HERA results and Airbus’s tests in the DNW-LLF, “a cumulative 1-dB difference when projected to flight,” says Fernando.

Clean Sky’s goal is to enable open rotors to be a viable option to power the next generation of single-aisle airliners, but in the end operators, regulators and the public will decide whether they are prepared to trade lower noise for higher fuel efficiency and lower emissions, the conference was told. “The next generation will have to bring something massive [in terms of improvements], or the trend of aviation will be altered,” Garnier said. ☺



The CROR propulsor model has met performance and noise targets in wind-tunnel testing.

SNECMA



Nearly 95% of the Leap engines produced at the Lafayette site will be -1Bs to power the Boeing 737 MAX family.

New Pastures

Complex technology, skills and incentives are dynamics driving a hunt for fresh engine-assembly sites

Guy Norris **Lafayette, Ind.**

Aero engine manufacturing has always required a resource pool of skilled engineers but the unprecedented boom in production volumes and the introduction of more complex non-metallic materials are altering the traditional landscape for engine makers as they seek out new assembly sites to meet the surge in demand.

General Electric is in the vanguard of this sea change in manufacturing strategy, the latest manifestation of which is the siting of a \$100 million assembly plant for the CFM Leap-1 engine in Lafayette, Ind. The factory is planned for a greenfield site in the backyard of nearby Indianapolis-based Rolls-Royce and is located close to the campus of Purdue University, a research partner to GE in areas including advanced manufacturing and propulsion. GE plans to break ground on the new facility in June.

While GE's policy of expanding key production facilities beyond its main large commercial engine sites at Evendale, Ohio, and Durham, N.C., can be traced to 1991—when GE and Snecma opened a GE90 composite fan blade

production plant in San Marcos, Texas—the new Indianapolis site epitomizes the changing trajectory of this policy. The Lafayette production line is the seventh new GE facility in the U.S. to be announced in the past seven years. It is also the latest to be closely linked with a major educational and training center. The reciprocal alignment is designed to help feed the pipeline of engineers and managers needed by GE to fuel its expansion, while at the same time injecting valuable research, development and other benefits back into the educational facility.

There are other reasons for GE's evolving assembly strategy. The company has not forgotten the lessons it learned about the importance of suppliers and factories during the battle with Pratt & Whitney over the alternate engine for the F-35 Joint Strike Fighter. The expansion policy factors in the benefit of spreading the supply chain across broader swathes of the nation and reaping the associated political benefits. It also takes advantage of the new willingness of states to actively compete for high-tech manufacturing companies

and the incentives that come with that strategy, as amply demonstrated by the largesse on display by several states during the recent bidding war for Boeing's 777X assembly work.

Although numbers have not been disclosed, GE opened the contest for the Leap site last summer; Indiana was chosen over six other states. The engine maker adds that Indiana State “along with the Indiana Economic Development Corp., the city of Lafayette, and Tippacanoe County have provided technical support and incentives to ensure a smooth and successful start-up.” The engine maker says it will also partner with Ivy Tech at Lafayette for skills and training support as it begins the hiring process for Leap production.

“We run a very vigorous process when we pick a place to be a GE facility, says GE Aviation President/CEO David Joyce. “Those are 20- to 40-year decisions and we do not take them lightly. Lafayette came out [on top] in a very aggressive selection process.”

But underlining the entire policy is a clear acknowledgment that the latest and future generations of com-

mercial turbofans are becoming more complicated to make. The search for performance improvements has driven the greater use of composites beyond the fan to include the containment and casing systems, as well as the increasing application of parts made from lighter-weight ceramic matrix composites and titanium aluminide.

In the case of Lafayette, which will handle final engine assembly as well as Leap core production, the line itself will be highly advanced with several

After a scheduled rebuild, the first Leap-1A engine is about to enter a new test phase.

new technologies, including automated vision-inspection systems and radio-frequency parts management to track parts on the shop floor. Purdue will assist in the design of the processes and assembly line.

Similar synergies with higher education centers can be seen throughout GE's lineup of new sites in several southern and central states. They include two facilities in Mississippi—one in Batesville, the first of the newer GE sites, opened in 2008, and one in Ellisville; both are associated with universities in the state. Similar links with local universities have been forged around recently established GE facilities at Auburn, Ala., Greenville, S.C., Dayton, Ohio, and Asheville, N.C. GE says the new sites already support more than 2,500 new jobs. An additional 200 positions are expected to be needed at the Indiana facility within five years.

Further investment of more than \$3.5 billion in plant and equipment is planned between 2013-17 at sites worldwide, but principally within the U.S., says Joyce. "Beginning in 2015, the Leap engine will experience a dramatic production ramp-up for the remainder of the decade. The Leap is now in its development stage—and yet, we have already sold 6,000 Leap engines—before it enters service on single-aisle aircraft in 2016. Because of the huge Leap backlog, we have to move fast. We break ground in Lafayette this year and begin hiring in 2015," he adds.

The Indiana site will bring together the Leap's high-pressure compressor, turbine and combustor sections using components and sub-assemblies from GE and Snecma operations, and from the two companies' CFM joint-venture global supply chain. The Leap will also



CFM

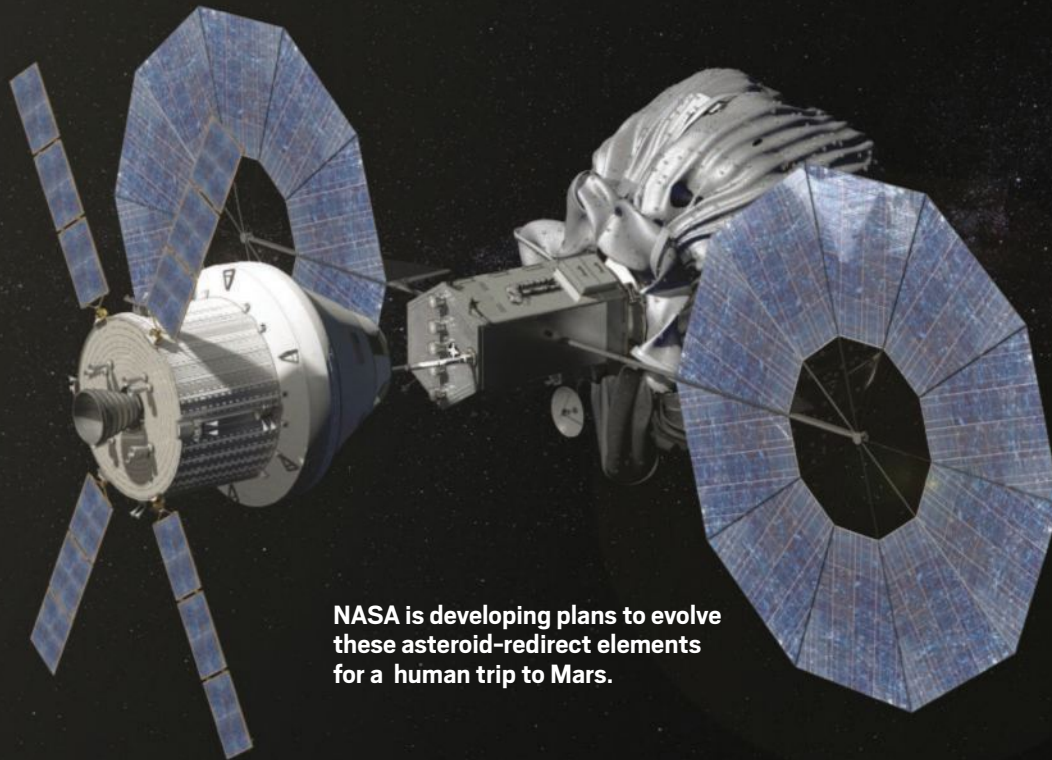
be produced at GE's existing engine site in Durham, as well as at Snecma's Villaroche site in France, where assembly of the first Leap-1B test version for Boeing's 737 MAX is getting underway. Indiana will mostly produce Leap-1B for the 737 MAX line, while Villaroche will principally support the Airbus A320neo line. Both sites, as well as Durham, will have capacity for additional production of any Leap version, including the -1C for Comac's C919.

The built-up for production comes as testing of the Leap moves into high gear. The initial Leap-1A for the A320neo program entered ground tests in 2013 and the first engine will be flight-tested this September on GE's Boeing 747 flying testbed. The Leap-1A is scheduled to power the first CFM-equipped A320neo for the start of flight tests in 2015 and will enter service in 2016. The first Leap-1C for the C919 is also complete and will fly on the testbed as early as May. The C919 is currently set to enter service in 2017, although CFM is maintaining its original engine development schedule, which will see the -1C certificated in

mid-2015. Ground tests of the Leap-1B are scheduled to get underway in June, with airborne evaluation beginning in early 2015 on one of the 747 testbeds. The first -1B powered 737 MAX is due to make its maiden flight in 2016 and set to enter service in 2017.

CFM also continues to break production records for the existing CFM56 family, in 2013 delivering the 8,500th engine for Airbus, the 10,000th for Boeing and the 25,000th overall. Production passed 1,500 engines per year in 2013, putting CFM on track for as many as 1,700 per year by 2020, when almost all will be made up of Leap engines.

Together with Snecma in CFM, Pratt & Whitney in the Engine Alliance and Honda in the GE-HondaJet business-jet engine partnership, the combined tally of GE-only and GE-partnered engine deliveries is expected to grow from 2,442 in 2013 to 2,859 in 2016. The bulk of these will be CFM56 engines for the A320 and 737 families, deliveries of which are currently expected to amount to 1,514 in 2014, 1,520 in 2015 and 1,418 in 2016, based on current orders. ☛



NASA is developing plans to evolve these asteroid-redirect elements for a human trip to Mars.

NASA

Building Blocks

NASA's asteroid-mission technology call is designed as a step toward Mars

Frank Morring, Jr. **Washington**

Technology for NASA's proposed Asteroid Redirect Mission (ARM) will be needed wherever the agency goes beyond low Earth orbit, and NASA is casting a wide net to get it.

Science, human-exploration and technology managers are keeping their eyes on Mars—or at least its two moons—as they collaborate on a suite of technologies nominally focused on the ARM. NASA is literally polling the world for exploration concepts that go beyond nudging a space rock into lunar orbit, with a new call for ideas backed with study money to flesh them out.

The “broad agency announcement” (BAA) issued March 21 is just that, open to proposals from almost everywhere (China is blocked from U.S. space cooperation by Congress). NASA says it wants proposals to include using commercial satellite buses as the basis for the robotic vehicle that would capture a near-Earth space rock and for deploying secondary payloads for mineral prospecting as well as planetary science.

In the increasingly likely event that the unfunded asteroid mission will never happen, given the lukewarm Capi-

tol Hill response to it, NASA makes it clear that it is looking for ideas that can be recycled again and again as humans explore the Solar System.

“We need to stop throwing away hardware,” says Jason Crusan, director of advanced exploration systems at NASA headquarters. “How do you do evolvable, multi-use space infrastructure? How do you use evolvable capabilities? Let’s build one integrated sensor capability and use it across [multiple missions]. Let’s build one set of elements, and evolve that element over time.”

The BAA specifically asks for ideas for a rendezvous-sensor suite that can guide a robotic capture vehicle to an asteroid and later guide the Orion crew capsule to the asteroid once it has been positioned in the distant retrograde orbit (DRO) around the Moon. That orbit is considered an ideal first step away from low Earth orbit (LEO) for human explorers.

Those same sensors also could guide a robotic asteroid sample-return mission to an asteroid or comet and an Orion and its crew to an asteroid too large

to move to DRO, and they could perhaps even help astronauts in an Orion link-up with the prepositioned habitat they would use on a journey to Mars.

“We’ve got folks thinking,” says Greg Williams, the human-exploration policy and plans chief at NASA headquarters, referring to a workshop on the ARM last June. “What we needed to do through this mechanism is find a focused way to garner and mature those ideas.”

Under the BAA call for concepts, NASA wants U.S. and international public and private engineering organizations to propose ideas for robotic mechanisms to capture all or part of a small near-Earth asteroid and for follow-on human missions to the relocated asteroid in DRO beginning by 2025.

Among specifics to be addressed are ways to adapt commercial satellite buses and other spacecraft to serve as a relatively low-cost “asteroid redirect vehicle” (ARV). Also sought under the BAA are potential partnerships for secondary scientific and commercial payloads, and similar partnerships for the Orion human missions.

NASA is considering two distinct approaches to the ARV, both of which can drive technology development for other deep-space human and robotic missions as well. In the original asteroid-redirect concept, a fairly large spacecraft would approach a small asteroid, enclose it in a flexible bag, and deflect it toward the DRO. A second approach would land a smaller spacecraft on a larger asteroid

after surveying it from orbit, and robotically pluck a boulder from its surface. In that scenario, the robotic vehicle would use its mass and that of the captured boulder to test whether an “enhanced gravity tractor” approach could be used to deflect a dangerous asteroid away from a trajectory to hit Earth.

Either approach would require high-power solar-electric propulsion (SEP) to drive the robotic capture vehicle to the asteroid and shift the object so it reaches the DRO for subsequent visits by Orion crew members. And the advanced SEP technology would enable many other missions, by intent.

“NASA is particularly interested in developing a standalone high-power SEP tug with an initial capability of approximately 40 kw that could not only permit direct application as a component of the ARV but also extend to other compelling government and commercial mission applications,” the BAA states. “NASA is also interested in block upgrade approaches to accommodate higher-power (50-300-kw) SEP systems for future exploration missions.”

The agency has concepts for evolving the Orion/ARV stack into vehicles that can explore deeper into the Solar System, including trips to the Martian moons Phobos and Demos. But so far it has no funds for a full-scale mission development, although it received \$104 million in the current fiscal year—and has requested \$160 million in fiscal 2015—to spend on SEP, detecting target asteroids and studies like the ones sought in the BAA.

Some information received by the May 5 due date will be folded into NASA’s mission concept review for ARM, and as many as 25 studies will be funded around the end of fiscal 2014 on Sept. 30. However, it remains to be seen if the ARM is actually how the U.S. will proceed in space.

Supporters of the “Moon, Mars and Beyond” approach rejected by the Obama administration continue to press for a return to the lunar surface. A functioning U.S. lunar base could be operating at one of the Moon’s poles in a decade, with a decision to build it and the resources to follow through, say some lunar-exploration experts.

The job would require a heavy-lift rocket like NASA’s planned Space Launch System (SLS); a deep-space capsule like the Orion crew vehicle; habitats shielded from the hard radiation on the lunar surface; and a lot of in-

situ resource utilization, probably with robots using additive-manufacturing techniques to build lunar base structural elements out of materials at hand.

“Asteroid retrieval is . . . the second or third thing we would do after going to the Moon and building settlements there,” says Haym Benaroya, a professor of mechanical and aerospace engineering at Rutgers University who has specialized in lunar structures. “It should not be our first goal.”

Benaroya took part in a March 25 panel organized by the George Marshall Institute to discuss building a lunar outpost. Mike Gold, director of Washington operations and business growth for Bigelow Aerospace, says his company is working in that direction with the in-

flatable habitats it has in orbit and the inflatable space station module it will use to test inflatable technology utility with human crew in space. The SLS or comparable 70-ton capability “is critical to any beyond-LEO operation, the Moon in particular,” he says.

Paul Spudis, a lunar specialist at the Lunar and Planetary Institute, agrees with the need for heavy lift to establish a lunar base, noting that NASA is doing necessary work toward a lunar base with its plans to deliver an Orion capsule into the space around the Moon.

“The existing program will provide us capability to carry out some operations in the lunar vicinity, but we don’t have a program now to build a lander,” Spudis says. ☼

DEFENSE

Offset Maneuvers

South Korea finally decides to procure U.S. aircraft, still aiming for sweetened deal

Bradley Perrett Beijing and Amy Butler Washington

After the better part of a decade of lobbying, campaigning and assessment, South Korea has not finished negotiating terms or even pricing for two U.S. aircraft types it has already selected and which, more to the point, its air force probably wanted all along.

Decisions, already flagged, to order 40 Lockheed Martin F-35s and four Northrop Grumman RQ-4s have now been formally approved. But the Defense Acquisition Program Administration (DAPA) has not yet ordered. This week it plans to begin its talks, even though both types are offered only under the U.S. Foreign Military Sales process, which means that their price is non-negotiable what Washington pays, plus an administration fee.

DAPA is making an improbable push to force Lockheed Martin into taking a stake of up to 20% in the proposed indigenous KF-X fighter program. Separately, the air force is looking at acquiring 20-60 Lockheed Martin F-16s as stopgaps to cover retirements of old fighters.

For the F-35 order especially, offsets are a key issue. South Korea is likely

to secure a deal that includes a military communications satellite as well as KF-X support. Lockheed Martin has offered more than 300 man-years’ worth of engineering expertise to assist Seoul in designing its KF-X. The F-22 and F-35 builder will also offer more than 500,000 pages of technical documentation derived from the F-16, F-22 and F-35, says Michael Rein, a company spokesman.

Also in the offset proposal is a secure satellite communications satellite; Lockheed is building the newest U.S. Air Force jam-proof satellite called the Advanced Extremely High Frequency spacecraft. It is built on the company’s A2100 bus and includes the latest security measures to avoid interference or jamming. In addition, the offset includes “necessary control equipment and technical training,” Rein says. The deal could cover delivery of the new satellite, launch and turnover of the operational system.

After a tortuous selection process, South Korea’s joint chiefs of staff announced in November that the F-35A had won the F-X Phase 3 fighter competition over the Eurofighter Typhoon

and Boeing F-15 Silent Eagle, a Strike Eagle modified with stealthy weapons bays and leading edges. But only 40 aircraft would be bought, instead of the programmed 60, to keep within the budget of 8.3 trillion won (\$7.2 billion); 20 more fighters could be bought after the 2018-22 run of F-35 deliveries. The budget has now been trimmed to 7.4 trillion won, probably because no more is needed for 40 aircraft.

Lockheed Martin's offset offer also included development of a virtual warfare center to be used for modeling and wargaming. Because the deal has been cut to 40 aircraft, there could be changes to the plan, an industry official says.

South Korea is the 10th country to announce an intention to buy the F-35 and the third customer outside of the development partners, the other two being Israel and Japan, which said in 2010 and 2011, respectively, that they would buy. Seoul plans to take delivery in 2018 of its first F-35As, which will be included in the Pentagon's low-rate, initial-production batch.

Northrop Grumman RQ-4 Block 30 Global Hawks will enter South Korean service from 2018. DAPA says it will sign a letter of offer and acceptance with the U.S. government this month and then begin formal negotiations.

South Korea has sought RQ-4s since 2005, but its requirement became more urgent after two North Korean attacks in 2010. Since then, South Korea has developed a concept called Kill Chain, in which sensors would detect preparations for North Korean attacks, apparently with the aim of preempting them.

"The high-altitude UAV is the key weapon system for the Kill Chain by monitoring North Korea around the clock to detect early signs of provocations," DAPA says in a statement translated by the Yonhap news agency. "It is expected to greatly improve the South Korean military's surveillance capabilities."

The defense ministry said last year it expected to "adopt" the RQ-4 in 2017, though Northrop Grumman officials said then that deliveries would be made in 2018-19. The aircraft will have equipment for imaging but not signals intelligence, so they will conform to the U.S. Air Force's Block 30 standard. Weight and space for signals-intelligence equipment will be available should South Korea want such systems and the U.S. agree to supply them.

In return for the F-X Phase 3 deal,

DAPA will ask Lockheed Martin to cover as much as 20% of KF-X development, local media report. DAPA can reconsider its order for the stealth fighter if the company does not show a positive attitude in negotiations, Yonhap reports, citing an armed forces official.

The threat seems improbable after the long process of F-35 selection. Most air force officers wanted the F-35, government officials say. Moreover, it was chosen with knowledge of Lockheed Martin's offer of technical support for the KF-X, which does not seem to have included substantial investment.

The KF-X was proposed in the late 1990s and has been under preliminary

South Korea's RQ-4s will conform to the U.S. Air Force's Block 30 standard, without signals-intelligence gear.



NORTHROP GRUMMAN

design for most of that time, with no assurance, even now, of being funded for full-scale development. Except insofar as it is obliged to help under the F-X Phase 3 deal, Lockheed Martin can have very little interest in promoting the KF-X as a viable fighter that would compete with F-35, even remotely. For example, Lockheed Martin backed the Alenia Aermacchi C-27J transport aircraft program until 2006, when it decided that by doing so it was supporting a competitor of its own C-130J, of about twice the size.

Further exemplifying its attitude, Lockheed Martin proposed during the F-X Phase 3 campaign that a single-seat version of the small Korea Aerospace Industries FA-50 light fighter be developed as the KF-X. Before that, the T-50, on which the FA-50 is based, was developed with support from Lockheed Martin only with the reported condition that the U.S. company could veto fighter variants that might compete with the F-16.

With the F-35s of F-X Phase 3 appearing later and in smaller numbers than first planned, South Korea is reportedly looking at acquiring 20-60 used Lockheed Martin F-16s from the U.S. as gap-fillers replacing worn-out F-4s and F-5s.

Leased F-16s could be brought into service within 2-3 years of a decision, an air force officer tells Yonhap. That timing fits well with what the South Korean air force judges to be a looming shortfall in its fighter force. Surplus U.S. F-16s also could be bought instead of leased, says another air force officer. South Korea expects U.S. budget cuts to make the F-16s available.

The air force has about as many fighters as it says it needs—400 or so—but it has forecast that the fleet will decline by about 20% by 2019, even on the assumption that F-X Phase 3 deliveries begin around 2015 rather than 2018. The F-4s and especially the F-5s already have little combat value.

Leasing or buying stopgap F-16s may not only serve to boost the air force's immediate firepower; they can eventually be declared in need of replacement, thereby helping the air force to maintain numbers next decade and later. Their replacements could be KF-Xs.

In 2013, South Korea had 58 Boeing F-15Ks, 174 F-16s, 64 F-4Es and 230 F-5s of various marks, plus 15 RF-4C reconnaissance aircraft, according to Aviation Week data. The air force's figures suggest that some of the aircraft—mainly F-4s and F-5s, presumably—are not operational.

South Korea has contracted BAE Systems to upgrade 134 F-16s built locally as KF-16s. ☼

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Fix It Or Else

Future F-35 buys linked to better performance

Bill Sweetman Washington

Increases in the production rate of the Lockheed Martin F-35 Joint Strike Fighter will be deferred if the contractors fail to correct problems with the aircraft and its support systems, JSF program office director Lt. Gen. Christopher Bogdan told the House Armed Services Committee on March 26.

"Additional progress must be demonstrated before awarding a contract for higher production rates," Bogdan says, in four areas: software development; reliability, "which is not growing at an acceptable rate"; the poorly performing Autonomic Logistics Information System (ALIS); and "closure of previously identified design issues." Lot 9 of low-rate initial production, for which an advance procurement contract has just been awarded, will include incentives based on "strong, event-based performance criteria."

Bogdan repeated a threat to strip Lockheed Martin and Pratt & Whitney of their status as "product support integrators" (PSI), responsible for the bulk of F-35 sustainment activities, describing them as "interim PSIs" and saying their

The JSF's Autonomic Logistics Information System, including a laptop-based portable maintenance aid, is proving troublesome.

performance on initial performance-based support contracts will determine whether they "assume this role on a more permanent basis."

These moves reflect concern about F-35 reliability, ALIS and operational costs. The Government Accountability Office's latest JSF report, also released last week, cites government estimates that F-35 operations and support (O&S) costs could "surpass the average cost of legacy aircraft by 40% or more, when original estimates indicated that the F-35 would cost less." The GAO adds that reliability improvements will be necessary to control O&S costs, which are "directly correlated to weapon system reliability," and that the picture is unlikely to improve "without a focused, aggressive and well-resourced effort."

At Aviation Week's Defense Technology & Requirements conference this month, Bogdan said JSF reliability was "woefully below the curve" compared with projected reliability at the current level of flight hours. "Parts we did not think were going to break are breaking quicker than we thought," he said, characterizing the problem as a "monumental fix—we are not going to see results quickly. But if we do not get it right, the availability will plummet and the O&S costs will skyrocket."

A "readiness cell" within the program is reviewing reliability problems, Bogdan said, in order to set priorities for remedial action. "We are looking at the 20 parts that fail most often, the Top 50 that take too long to fix and the 20 parts that cost the most when they come off." The goal is to increase F-35 availability to greater than 60% by 2015.

Another reliability-related issue concerns diagnostic and prognostic systems. "We assumed that the aircraft would be smart, and that ALIS would be smart, but neither is very

smart today," said Bogdan, describing the systems as "dumb and dumber . . . the aircraft tells you that things are wrong when they are not, and forgets to tell you about things that are wrong."

Bogdan expressed confidence that the problems would be fixed in time for service entry, but for now the program is developing workarounds that allow the aircraft to fly when ALIS gives erroneous error signals.

The JSF program office is more optimistic than the GAO or the Pentagon's director of operational test and evaluation DOT&E concerning the impact of software delays on initial operational capability (IOC) dates. By last January, the GAO states, the program had verified only half as much of the Block 2B software—the Marine Corps IOC standard—as planned, 13% versus 27%. The GAO endorses the DOT&E's estimate of up to 13 months' delay in delivering Block 2B.

However, Bogdan said there is "very little risk" to delivering 2B. "We are tracking 206 individual capabilities within the software. Today 80 percent have been verified as good to



go. We have 20 percent [remaining]," he said. "We have two more increments this summer before we finish flight-testing at the end of the year. My assessment is that we are within 30 days of completing Block 2B on time."

The process of modifying the Marine Corps' early-production F-35Bs to IOC configuration "is the long pole in the tent right now," Lt. Gen. Robert Schmidle, deputy commandant for Marine Corps aviation, told the committee. Vice Adm. Paul Grosklags, the Navy's top acquisition official, pointed out: "We need aircraft for flight-test and aircraft for pilot training, and the same aircraft have to be modified to the IOC configuration." It is a matter of prioritizing the work required, he added.

The GAO report also raises a longer-term concern about the ability of the service customers to sustain the program as planned. The projected cost has been stable since its 2012 restructuring, the GAO states, but it warns that the total acquisition cost—averaging \$12.6 billion per year through 2037, with several years above \$15 billion—"does not appear to be achievable in the current fiscal environment," consuming one-quarter of the Pentagon's major acquisition funds over its lifetime. ☞

USAF MAJ KAREN BOGDANOV

Panhandle Puzzle

Air Force stonewalls on Texas UFO

Bill Sweetman Washington

The identity of what appears to be a blended wing-body aircraft type photographed over Amarillo, Texas, on March 10 remains uncertain, with the U.S. Air Force declining any comment on the aircraft.

Three aircraft were observed flying in formation southwest of Amarillo around 4:20 p.m. CDT, by photographers on the fence line of the city's international airport. One of the aircraft could be a B-2, but the clearest color photos and monochrome images enhanced (for contrast and resolution) with commercial software suggest a

blended shape with a straight trailing edge. Steve Douglass, one of the photographers and an experienced aircraft observer, says the aircraft were "larger than fighter-size" and appeared similar in wingspan to commercial traffic.

The formation was not using Mode S transponders, according to a review of records at the Flightradar24 air-traffic-tracking site. Radio transmissions apparently associated with the flight were intercepted and recorded, possibly including the call sign "Sienna."

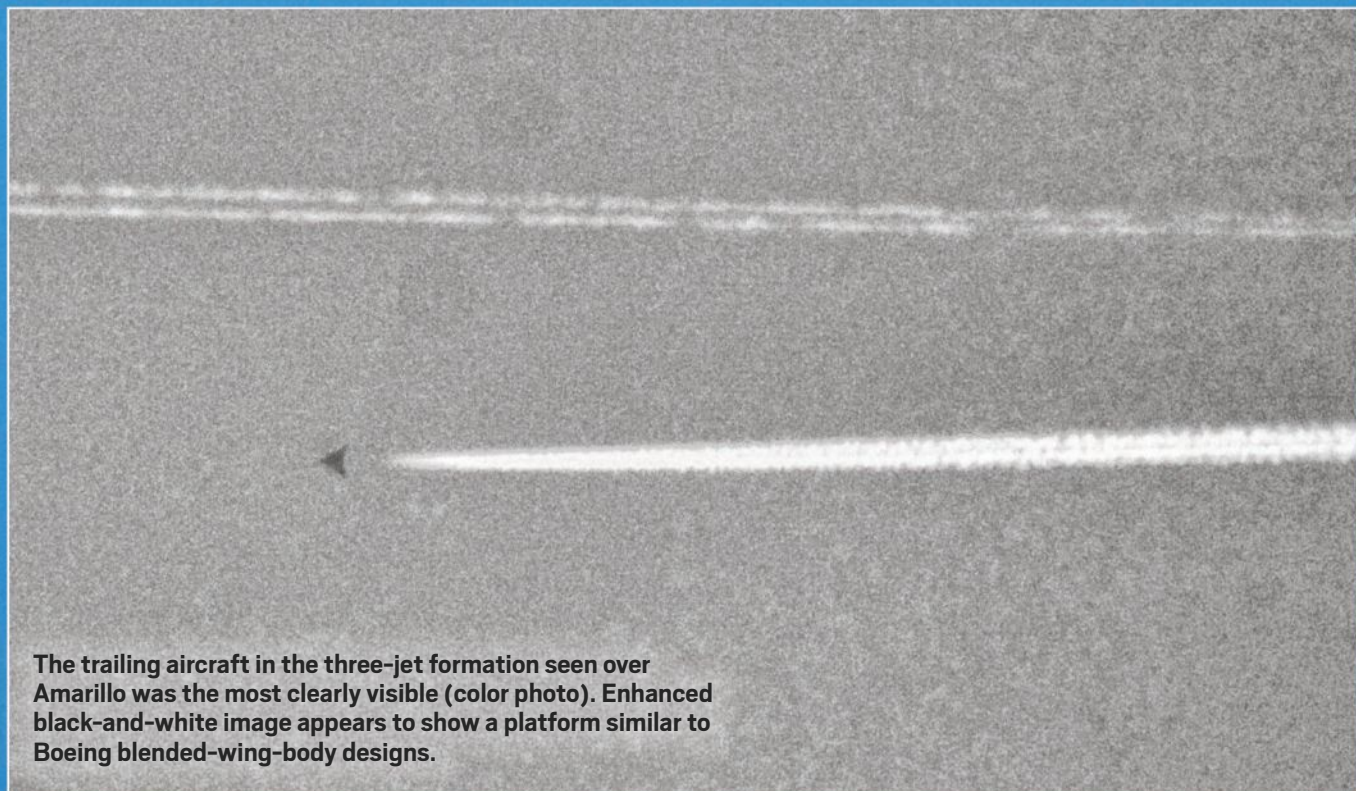
An Air Force representative in Washington responded to queries about the aircraft, and about flight ac-

tivities at that time and place, with the statement "I have nothing for you," a phrase long associated with responses to queries about classified programs and operations. The 509th Bomb Wing at Whiteman AFB, Mo., home of the Air Force's B-2 fleet, says that none of its aircraft were operating near Amarillo on March 10. However, test units have also flown B-2s.

The fact that three aircraft were in formation suggests an aircraft that is operational or close to reaching that status. The unidentified aircraft are not likely to have been examples of the Northrop Grumman stealth reconnaissance drone known as the RQ-180 (*AW&ST* Dec. 9, 2013, p. 20) because unmanned air systems are seldom flown in formation of any kind. Likewise, the Lockheed Martin demonstrator that is reportedly being built to support the Long Range Strike-Bomber program is likely to be a one-off product. ☒



For a closer look at the images and more about the photographing of these and other classified aircraft, check out Bill Sweetman's post on Ares at: ow.ly/v3Hvp



The trailing aircraft in the three-jet formation seen over Amarillo was the most clearly visible (color photo). Enhanced black-and-white image appears to show a platform similar to Boeing blended-wing-body designs.

New Tools

U.K. Defense Ministry and Raytheon U.K. collaborate to streamline weapons upgrades

Tony Osborne **Glenrothes, Scotland**

The Paveway IV is operational on the RAF's Panavia Tornado GR4 fleet and will be carried on the Eurofighter Typhoon next year.



TONY OSBORNE/AV&ST

Raytheon U.K. is developing a series of upgrades for its precision-guided bomb that could be introduced without the need for expensive integration onto types such as the Eurofighter Typhoon and Lockheed Martin F-35.

The often huge cost of software integration of new weapons onto types like the Typhoon can prove a stumbling block to introducing new capabilities into fleets. But by adding new developments without impacting weapon weight or aerodynamics, Raytheon believes it can add capabilities, particularly to the Typhoon, that might otherwise be lost as the Panavia Tornado GR4 retires at the end of the decade.

The Paveway IV has been selected to provide the first block of capability in the U.K. Defense Ministry's Selective Precision Effects at Range (Spear) program to deliver a new generation of air-launched weapons for future combat aircraft.

The 500-lb. weapon, which is fully integrated on the Tornado, has become one of the type's primary weapons, with no more than 1,000 operational drops on targets in Libya and Afghanistan. In recent months, work has been completed to integrate the Paveway IV on the Typhoon as part of the Phase 1 Enhancements (PIEb) program, which calls for the weapon to become operational on Royal Air Force (RAF) Typhoons in early 2015. Flight trials have

shown the weapon can withstand the Typhoon's wide-ranging flight envelope. The U.K. Defense Ministry also is considering integrating the weapon onto the MQ-9 Reaper unmanned air vehicle.

"The defense boards will sit imminently to bring these forward," says John Michel, weapons business director at Raytheon U.K. "Tornado is going out in 2019 . . . and key Spear decisions need to be made because the retirement of the Tornado will take a lot of capability out with it."

At the Defense Ministry's request, Raytheon also is developing a new low-collateral-damage warhead using a software technique called hydro-coding to simulate various warhead designs and how they will detonate. Engineers recently tested what simulation showed to be the most effective design, and then carried out a full-scale arena test at a range in West Freugh, Scotland, in February. The results, being collected in the coming weeks, will be used to calibrate and refine the hydro-coding simulations before deciding on the final design.

"Integration matters a lot," says T.J. Marsden, Raytheon U.K.'s chief weapons engineer. "By retaining the same mass, same form factor and the same aerodynamics of the vanilla weapon, we can reduce those integration costs but provide new capabilities."

The second sphere of work is to give the weapon the "punch

of a 2,000-pound penetrator in a 500-pound store," according to Marsden. The company has been testing a penetrator made out of steel compound that would be enveloped in a composite or aluminum shroud, which

retains the form factor of the bomb. The shroud would peel off as the bomb hits the target, allowing the penetrator to do its work.

A digital seeker, developed for use on the Enhanced Paveway II, is being ported over to the Paveway IV, potentially giving the weapon an improved ability to deal with moving targets, particularly those traveling at higher speeds and/or maneuvering.

Raytheon also has privately developed an anti-jam system that could be installed in a cavity in the weapon's tail cone, which would help it defeat both focused and broadband levels of GPS jamming. Trials are underway. All the options for Paveway IV development are due to be evaluated by the ministry's board in the coming weeks.

The Paveway IV is destined for the F-35 as well, and will be integrated under Block 3F as an internal and external store. Dropping from the bay requires one small modification: the addition of a slightly longer lanyard at the rear of weapon to allow its wings to pop out after they have cleared the bomb bay doors. Some trials have been completed.

The program has gotten a huge boost with the addition of its first export customer, reportedly Saudi Arabia. Saudi officials signed a deal for the Paveway IV at the end of 2013, and the first batch should be delivered in 2015. The order will sustain production for two years and follows the RAF's path of integration, with the Saudis expected to use the weapon on both the Tornado IDS—through the BAE Systems Tornado Sustainment Program—and on the PIEb update to the Typhoon.

Raytheon says it is working closely with BAE Systems to target other Typhoon operators to consider purchasing the weapon, including Oman, which ordered the type in late 2012. ☛

Slaps on the Wrist

For now, Western response to Russia in Crimea is not material to A&D industry

Michael Bruno **Washington**

U.S. and European sanctions on certain Russians have not impinged on Western aerospace and defense industrial bases to any great extent, but possible reactions down the road do have analysts and executives concerned.

To be sure, several stress points—starting with titanium supplies to manufacturers and some coproduction work—emerged quickly this month as President Barack Obama and European leaders announced travel and banking restrictions against a cadre of Russian and Ukrainian provocateurs of the former's annexation of the latter's Crimean Peninsula. What is more, an executive order Obama signed two weeks ago would allow U.S. agencies to stop current work, such as a contentious deal by the Pentagon to provide Russian Mi-17 helicopters to Afghan air forces or for space station crew transportation (see page 54).

But the Mi-17s and Russian launches of U.S. astronauts will continue for now, apparently due to their importance to U.S. national interests such as enabling withdrawal from Afghanistan or keeping an orbital destination for the U.S.'s budding commercial crew launches. Moreover, while Russian arms-exports, energy and finance sectors have been announced by U.S. officials as next-in-line for Western punitive action, it all depends on whether Moscow continues excursions into eastern Ukraine. Meantime, the sanctions that are in play are not targeted nor are they sufficient to disrupt the West's A&D industry yet because they are aimed at individuals.

"In severity of punishment, this has been fairly light," says Tom Captain, Global A&D Leader for Deloitte Touche Tohmatsu. "It looks a lot like window dressing."

Capital Alpha Partners Director Byron Callan, who heads A&D and industrial issues for that research firm, agrees, calling actions to date "symbolic" or even "irrelevant" for industry. "At the very least it should lead to reallocation of some U.S. intelligence focus toward Russia and, at the margin, may lead to minor changes in defense sales in some European countries, including those in East Europe," he says. Otherwise, "there is nothing financially material for the defense industry that comes out of this so far. For commercial aerospace, it is probably more interesting."

Indeed, titanium supply constrictions could become a sore point for companies such as Boeing if more sanctions are applied, several analysts note, meaning at least higher prices for the element. "That is going to be a key concern," says Richard Aboulafia, vice president for analysis at the Teal Group.

The aerospace industry is one of the top customers for titanium alloy products, with newer commercial aircraft using far more than previous generations due to its favorable strength-to-weight ratio. Boeing has forecast it would spend \$27 billion on Russian titanium supply, design engineering and services "over the next decades." In July 2009, Boeing and VSMPO-Avisma, Russia's largest titanium producer, started a 50/50 joint venture, Ural Boeing Manufacturing



Listen to Aviation Week editors discuss the Western response to Russia's actions in Ukraine on our latest Check 6 podcast. Download it from the iTunes store: ow.ly/uMUWe

(UBM) in Verkhnyaya Salda. Last November Boeing and Russia state-controlled Rostekhnologii (Rostec) agreed to expand their joint venture with a second UBM production facility in the so-called Titanium Valley there. Russian representatives reportedly said last week that the arrangement is proceeding with no disruptions.

More immediately affected, by comparison, is Montreal-based Bombardier's plan to locally build and sell up to 100 Q400 turboprops to Rostec, worth roughly \$3.4 billion based on the aircraft's list price. When announcing the deal last August, the Canadian company said a Q400 NextGen final assembly line in Russia would serve customers there and be "incremental" to Bombardier's operations in Toronto. The companies were working toward definitive pacts this year, they said at the time. But on the sidelines of an investors' conference March 20 in New York, CEO Pierre Beaudoin said final negotiations were delayed indefinitely as Bombardier honored Canada's call for sanctions.

In fact, with the exception of rare earths and elemental supplies, Russia is more of a growth opportunity for companies like Bombardier or GE Capital Aviation Services, the commercial aircraft leasing and financing unit of U.S.-giant General Electric that has provided new Airbus A320s to Aeroflot Russian Airlines. As to negative effects on manufacturing and business, Aboulafia and Callan believe that Russian industry—including Mi-17-provider Rosoboronexport—stands to lose more under current tensions.

Callan says that the Ukraine situation is a big event, but it is "still too murky to see what the ramifications will be." ☞

Bombardier has delayed its plans to build Q400s in Russia.



BRUCE DRUM/AIRLINERSGALLERY.COM

Russian Rockets

ISS is unaffected by Crimea sanctions and international saber-rattling

Frank Moring, Jr. **Washington**

The U.S.-Russian chill over Moscow's invasion of Ukraine's Crimean Peninsula so far has not extended to civil space operations, including last week's launch of another NASA astronaut to the International Space Station (ISS) on a Russian Soyuz rocket.

Steve Swanson lifted off on Soyuz TMA-12M alongside cosmonauts Alexander Skvortsov and Oleg Artemyev March 25 for the trip to the ISS (see photo), after autographing their doors in the crew quarters at Baikonur Cosmodrome and carrying out other Russian spaceflight rituals.

As Western leaders plot new ways to sanction their Russian counterparts over Crimea, U.S. companies that depend on Russia—and Ukraine—for space hardware are conducting business as usual. The U.S. government is as well, at least as represented by NASA. Swanson's ride and training cost the U.S. space agency \$70.6 million as part of a six-seat-per-year deal that runs through 2016. As it prepares to shift to U.S.-built commercial vehicles for transporting U.S. and non-Russian crew to the station, NASA is negotiating with Russian space agency Roscosmos for enough Soyuz seats to bridge the gap through 2017, including return and rescue flights into 2018.

"NASA and Roscosmos will continue to work with each other to maintain the space station, where humans have lived continuously for more than 13 years, and we are confident that our two space agencies will continue to work closely as they have throughout various ups and downs of the broader U.S.-Russia relationship," NASA says when asked if the geopolitical tensions have hampered its work with Russia.

The Soyuz docking with the ISS was delayed when a planned rendezvous maneuver failed to occur, and U.S. and Russian flight controllers tackled the problem together. As they worked, a classified National Reconnaissance Office payload was in final preparation for its launch from Cape Canaveral on a United Launch Alliance (ULA) Atlas V with a Russian-built RD-180 kerosene-fueled rocket engine as its main-stage propulsion system. The two-nozzle engine, a variant of the four-nozzle RD-170 built by NPO Energomash, has been powering Atlas launch vehicles since 2000, and ULA intends to keep using Energomash-built engines as long as possible.

Air Force Secretary Deborah Lee James says a review of RD-180 availability is underway, with results expected "by the end of May." A ULA spokeswoman notes the company and the RD Amross joint venture of United Technologies Corp. and Energomash that supplies the Atlas V engines "have a 20-year relationship for which all commitments have been honored." RD Amross maintains a two-year supply of RD-180s "to minimize potential supply disruptions," it says, and could acquire U.S.-produced versions of the engines if necessary (*AW&ST* March 24, p. 28). It also could launch "critical national security payloads" on its Delta IV rocket, ULA says.

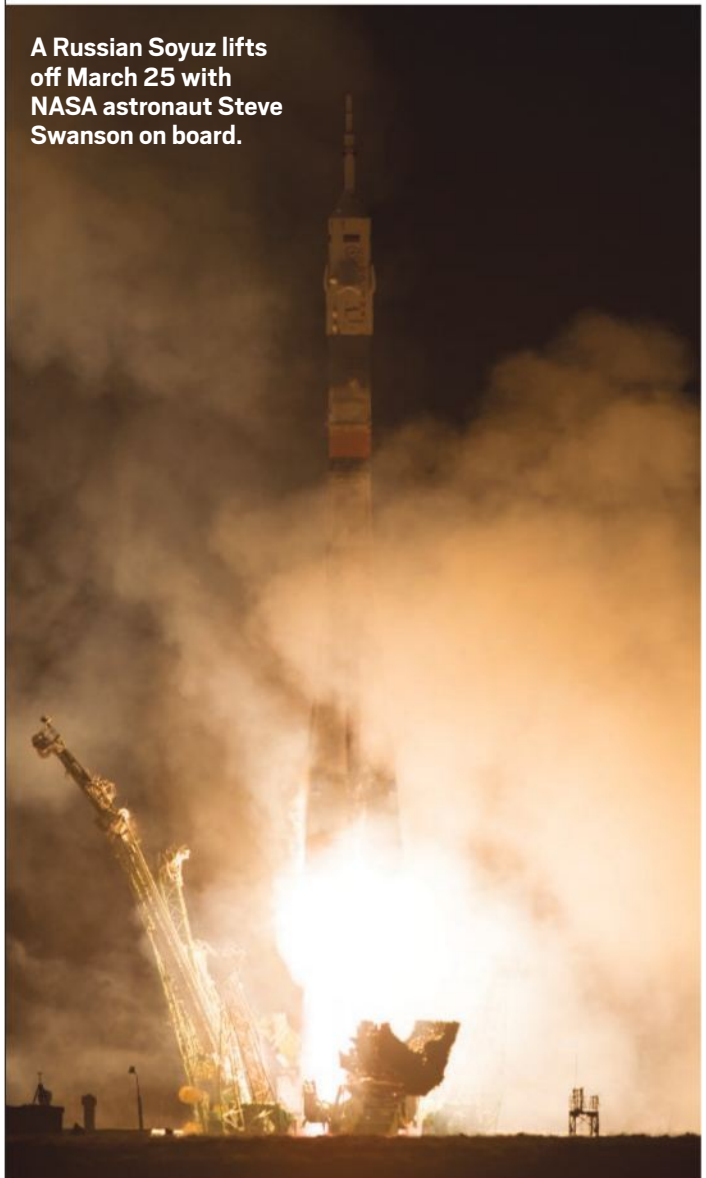
Orbital Sciences Corp. uses the AJ-26, a Russian-built, U.S.-modified, kerosene-fueled rocket engine as main-stage propulsion for its new Antares rocket, which flies with a first stage developed and built in eastern Ukraine under NASA's

Commercial Orbital Transportation Services development and Commercial Resupply Services ISS cargo-delivery efforts. Orbital says it has the necessary Russian and Ukrainian hardware on hand to fly cargo to the space station into early 2015 (*AW&ST* March 3, p. 12) and is looking for an alternative to the AJ-26, which is based on the out-of-production Russian NK-33.

Orbital reports it has enough AJ-26 engines to support launches through 2016, and David Thompson, Orbital chairman, president and CEO, says the "process of assessing alternatives is well underway." In a Feb. 13 conference call, Thompson told analysts he should have more to say on the search for alternatives to the AJ-26 subject in April. One of those alternatives is the RD-180, and Orbital has dropped an anti-trust lawsuit it filed against ULA and AD Amross over access to the engine.

"The parties will not undertake to negotiate a business resolution for Orbital's access to the RD-180 rocket engine, subject to all necessary approvals from the U.S. and Russian governments," Orbital says in a March 30 Securities and Exchange Commission filing. ☛

A Russian Soyuz lifts off March 25 with NASA astronaut Steve Swanson on board.



NASA/JOEL KOWSKY



Ready to Respond

Russia's encroachment on Crimea stirs Atlantic Alliance into action

Nicholas Fiorenza **Brussels**

Steps are being taken by NATO to bolster the credibility of its defense guarantee to Eastern European members, most visibly with airpower, in the wake of Russia's invasion and annexation of Crimea.

NATO Secretary General Anders Fogh Rasmussen said "Russia's military aggression in Ukraine is the most serious crisis in Europe since the fall of the Berlin Wall," which "follows a pattern of behavior of military pressure and frozen conflicts in our neighborhood: Transnistria, South Ossetia, Abkhazia and now Crimea." Russia fought a five-day war with Georgia over South Ossetia in August 2008, and Abkhazia split from Georgia—as did Transnistria from Moldova—following the collapse of the Soviet Union.

NATO's commitment under Article 5 to collective defense, is "not just words, but real assets and real actions: more planes to police the airspace over the Baltics, surveillance flights over Poland and Romania," Rasmussen told the German Marshall Fund of the United States' annual Brussels Forum conference March 21.

U.S. Air Force Gen. Philip Breedlove, NATO's Supreme Allied Commander Europe, told the Brussels Forum on March 23 that the U.S. has deployed F-16s from Aviano AB in Italy to Poland and F-15s from RAF Lakenheath in the U.K. to the Baltics. The four F-15Cs already policing the Baltic states from Siauliai AB in Lithuania since January have been reinforced by six more fighters. Naval assets have been redeployed to remain engaged in the Black Sea, he said. He noted that other measures are being considered, although he did not elaborate. France and the U.K. already have offered four fighters each for the next Baltic air policing rotation of four Polish aircraft starting in April. The NATO Airborne Early Warning and Control Force also has been conducting airborne-warning-and-control-system missions, including by an RAF

The U.K.'s E-3D AWACS aircraft will bolster NATO's effort to monitor Ukraine from Poland and Romania.

E-3D, to monitor Ukraine from Poland and Romania; France has offered to add an E-3F flying from its own territory.

Rasmussen also announced a plan to step up cooperation with Ukraine, which will include supporting the transformation of the Ukrainian armed forces, increasing their interoperability with NATO forces, and expanding Ukrainian participation in NATO exercises.

Ukraine has participated in all NATO-led military

operations and contributes to the NATO Response Force. The beset nation has been part of NATO's Implementation Force, Stabilization Force and Kosovo Force in the Balkans, has provided airlift and medical support to the International Security Assistance Force in Afghanistan, and sent warships to join the Operation Endeavour counterterrorism mission in the Mediterranean and the Operation Ocean Shield counterpiracy mission off the Horn of Africa.

Ukraine was the first non-NATO member to take part in the response force, starting with a nuclear, biological and chemical defense platoon in 2010. Ukraine also has a battalion of marines on operational standby.

"We can no longer do business as usual with Russia," Rasmussen said. And things are changing. NATO has suspended staff-level civilian and military meetings with Russia. The alliance has halted planning for what would have been the first NATO-Russia Council joint operation, a maritime escort mission for the destruction of Syria's chemical weapons. NATO foreign ministers will decide on further measures when they meet in Brussels April 1-2.

Breedlove expressed concern about a series of snap exercises conducted by Russia to bring large formations to readiness, drill them and then stand them down, with one of these exercises readying the move into Crimea. The incursion into Crimea went "like clockwork" compared to the 2008 war with Georgia, according to Breedlove, starting with the disconnection of Ukrainian forces in Crimea from their command-and-control network via cable cuts, jamming and cyberattacks, followed by the complete envelopment by Russian forces inside Crimea. Russia has sufficient forces on the eastern border of Ukraine to move into Transnistria, Breedlove said.

He sees implications for NATO force deployments and readiness: "How do we change our force structure [now so] that we can be ready in the future to respond to what we know is a tool to bring forces to high readiness, high preparedness, positioned correctly for rapid incursion across a border into a neighboring country?" NATO has the political will to invoke Article 5 if an ally is attacked and the forces ready to defend members like the Baltics, Breedlove points out. ☛

New Math

Unorthodox analysis of satellite data offered investigators best hope of finding MH370

Amy Svitak Paris

Almost immediately after Malaysia Airlines Flight 370 (MH370) vanished March 8 enroute from Kuala Lumpur to Beijing, London-based satellite-fleet operator Inmarsat began analyzing a dozen electronic transmissions between the missing aircraft and its Inmarsat 3-F1 satellite.

Inmarsat says these transmissions were routine—a combination of Aircraft Communications and Reporting System (Acars) messages and periodic satellite “pings,” also known as “handshakes,” that ensured MH370’s idle aircraft terminal remained logged onto the network after routine communications ceased between 1:07 and 1:37 a.m. local time.

But the company’s unprecedented analysis of the squawks and pings—correlating range, speed and the impact of Doppler shift on signal frequency—has given search-and-rescue investigators their best hope of locating the missing aircraft.

“It certainly was a new approach,” says Tim Farrar, an analyst with satellite-indus-

Burst frequency offset is the difference (due to Doppler shift) between the expected received frequency and that actually measured.

try consultancy TMF Associates, based in Menlo Park, Calif. “But remember, locating a cell phone from seeing where it last pinged the cellular network was also new 20 years ago. The point is, it’s something that’s never had to be done before, because the primary systems would normally give you all the relevant information.”

Built by Honeywell Aerospace, MH370’s L-band satcom terminal uses position, speed, direction, pitch, roll and yaw data from the aircraft to steer its antenna and maintain a lock on Inmarsat 3-F1. But while the terminal is continually pinging the spacecraft, this data is only used to orient the antenna and offset transmitted frequency due to Doppler shift. It is not transmitted off the aircraft.

In the absence of information, Inmarsat’s initial analysis used the time it took for the aircraft’s pings to reach Inmarsat 3-F1 to estimate a range for its possible location at 8:11 a.m., the last confirmed communication between the aircraft and satellite. Eight days after MH370’s disappearance, these early calculations gave investigators two corridors to search on opposite sides of the equator along northern and southern arcs.

Analysts note that this initial reasoning, details of which were released by the Malaysian government March 15, may have been flawed in part because it relied on an assumption about the aircraft’s cruise speed, and thus how far it would have traveled based on “ping arcs” derived from six hourly

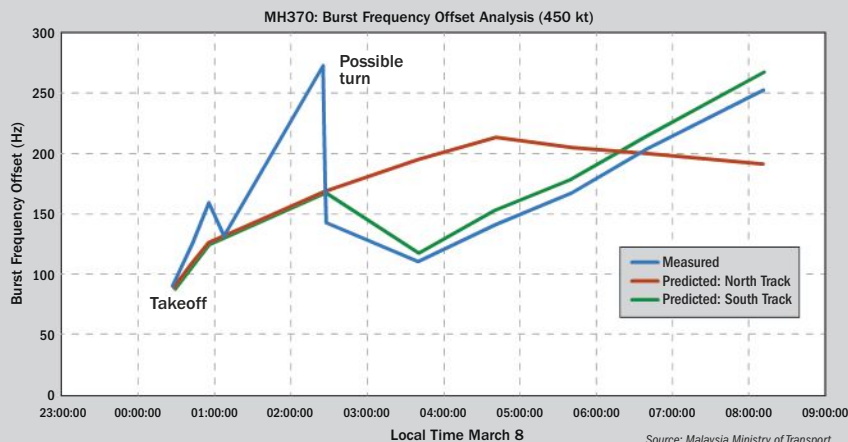
“handshakes” exchanged between the Boeing 777 and Inmarsat’s gateway Earth station between 2:30 a.m. and 8:11 a.m.

In addition, the analysis assumed Inmarsat 3-F1 was flying directly over the equator at an altitude of 35,800 km (22,245 mi.) at 64.5 deg. E. when MH370 sent its final ping at 8:11 a.m.—although in fact the spacecraft, which moves in an inclined geosynchronous orbit that causes it to drift slightly north and south of the equator, was located just north of the Equator at that time, according to calculations by physicist and space scientist Duncan Steel, based in Wellington, Australia.

On March 24, Malaysia’s transport ministry said Inmarsat and the U.K. Air Accidents Investigation Branch had refined the analysis, factoring in the satellite’s location, velocity of the aircraft relative to it and the resulting Doppler shift.

Inmarsat then compared flight-path predictions with six other 777s flying in various directions on the same day. As a result, investigators dramatically narrowed the search area to the southern Indian Ocean west of Perth, Australia. Despite the more detailed calculations, analysts continue to question the aircraft’s final position, based on unexplained data released by the Malaysian government March 25. For example, a 78-min. gap between the last Acars message at 1:07 a.m. and a message at 2:25 a.m. appears inconsistent with the hourly

MH370 Measured Data Against Predicted Tracks



handshake protocol. Doppler-shift data suggests the aircraft made a sharp left turn at 2:25, as it dropped off primary radar, coinciding with three pings in rapid succession that occurred just before 2:30 a.m. “That would imply the terminal on the plane potentially tried to reacquire the signal after it lost the satellite signal during a sharp maneuver,” Farrar says.

Four hourly “handshakes” followed—at 3:40 a.m., 4:40 a.m., 5:40 a.m., 6:40 a.m.—at which point a second gap in communication of more than an hour occurred before the aircraft’s sixth handshake at 8:11 a.m. A final, partial ping recorded at 8:19 a.m. is likewise unexplained. Malaysian officials say a subsequent ping was slated to occur at 9:15 a.m., but “no response was received from the aircraft,” indicating it was no longer logged onto the network. Farrar says the incomplete ping suggests the transmission may have occurred when the terminal’s battery lost power, which means it could have continued pinging the satellite even if the aircraft had crashed.

“One might conclude tentatively that the plane crash was at or close to that time,” Farrar says. ☼

Congestion Control



SAN FRANCISCO INTERNATIONAL AIRPORT

An aircraft taxis on Runway 1R at San Francisco International Airport, facing construction work that has begun on an adjacent taxiway.

This will reduce queues at runway thresholds to desired levels. Shorter taxi queues mean reduced fuel burn and, for passengers, less time sitting in the aircraft waiting to take off. Retaining a small queue is important to maintain pressure on the runway and ensure no takeoff opportunities are missed, says London.

The system considers wake vortex separation requirements as it sequences flights to minimize time intervals between aircraft without compromising safety levels. During peak times, 1-2 extra departures an hour can be achieved, in addition to the benefits from reduced taxiing, Saab says.

Airport personnel have estimated the runway closures will increase operator costs by more than \$15 million—\$8 million of this caused by longer taxiing distances and \$7 million from increased queuing. Saab predicts Aerobahn will reduce this cost by \$3.5 million.

At JFK, Saab says, Aerobahn is enabling significant taxi-time reductions and dramatic cost savings. Independent analysis by the Massachusetts Institute of Technology's Lincoln Laboratory confirmed that airlines collectively are saving an average of \$15.6 million a year in fuel costs due to Aerobahn, with a reduction of 32,000 tons of CO₂ emissions.

Of the 26 airports that use Aerobahn, 20 are in the U.S. The version that includes the departure manager has so far only been introduced in New York and San Francisco.

Another relatively new program at San Francisco will help relieve congestion at the airport during the runway closure. In fall 2013, the FAA introduced the closely spaced parallel runways (CSPR) initiative. This has improved arrival rates during low visibility, which can be a problem in San Francisco due to low cloud and fog. CSPR has boosted the airport's arrival rate, from about 30 per hr. in such conditions to 33-34.

San Francisco also will be the initial site for a surveillance system being deployed by Saab under the FAA's airport surface surveillance capability (ASSC) program. Saab is contracted to deploy ASSC at eight more airports in the U.S. ☛

Sequencing departures helps airports avoid gridlock during runway shutdowns

Adrian Schofield **Auckland**

Closing half the runways at one of the busiest West Coast airports for four months could be a recipe for chaos, but San Francisco International Airport is hoping that a new traffic-flow system will prevent taxiway bottlenecks and keep flight delays to a minimum.

Two of the airport's four runways will be closed from May 17 through September so major construction work can be carried out to meet FAA runway safety mandates. Saab Sensis has been contracted to deploy a departure manager (DMAN) system during this period to coordinate the increased load on the other two runways.

The DMAN system, part of an advanced version of Saab's Aerobahn product, was introduced at New York John F. Kennedy International Airport during a similar runway closure in 2010. It proved to be so successful in streamlining airline operations that it was retained and is still in use.

The runways being closed at San Francisco are the parallel 1L and 1R, which will have an engineered material arresting system (EMAS) installed at the runway ends. Parallel runways 28L and 28R had their thresholds extended last year, although they were closed only intermittently and mainly on weekends. Extending 1L and 1R was not an option, but airports can install EMAS to meet the new FAA requirements.

Runways 1L and 1R handle the major-

ity of departing flights at the airport, with the exception of some widebody flights that need a longer takeoff roll.

The capacity with all runways open is about 100 arrivals and departures per hour, a San Francisco International spokesman says. During the runway closure, capacity will be down about 15% to 85 flights per hour. Airlines have agreed to help by curtailing planned growth in their summer schedules. Although there still will be a "modest increase" in operations, additional flights will be scheduled during off-peak hours.

The introduction of the Saab system promises to be the most effective measure during the closure. The \$2 million contract with Saab includes the on-site staff who will help run the system, the airport's spokesman says. There are no plans to retain the departure manager when the runways reopen.

Deployment of Aerobahn at San Francisco has already begun, says Dan London, Saab Sensis's director for airline and airport automation. A 10-day operational test of the system is scheduled to begin in April. Airlines are also being trained in the system's use, as it involves collaborative decision-making.

Aerobahn will assist the airport, airlines and controllers in sequencing movements more precisely. The system will generate recommended gate departure times, shifting some delays from the taxiway to the gate and ramp to optimize airport flows.

Turkish Delight

Pegasus proves there is a market for low-cost air travel in Turkey

Cathy Buyck **Brussels**

When Turkey's Esas Holding, a private equity firm set up by the powerful Sabanci family, bought Istanbul-based charter carrier Pegasus Airlines in 2005 and relaunched it as a domestic low-cost carrier, few paid attention to the venture. Those that did doubted its success.

But Esas, which also has a 12.2% share in Air Berlin (which it is reportedly trying to sell to Etihad Airways), is proving that its analysis was spot-on. In less than 10 years, Pegasus Airlines has successfully introduced the no-frills concept to Turkey and become the largest privately owned scheduled airline in the country, carrying 16.8 million passengers on a network spanning 31 domestic destinations and 45 international gateways in 30 countries last year. Its market share in the scheduled market has grown to 27% on domestic routes, second only to Turkish Airlines.

The dominant position of Turkish Airlines in the domestic market was one of the main reasons Esas acquired Pegasus and repositioned it as a low-cost carrier (LCC), but regulatory changes in the early 2000s and Turkey's strong economy paved the way for the growth.

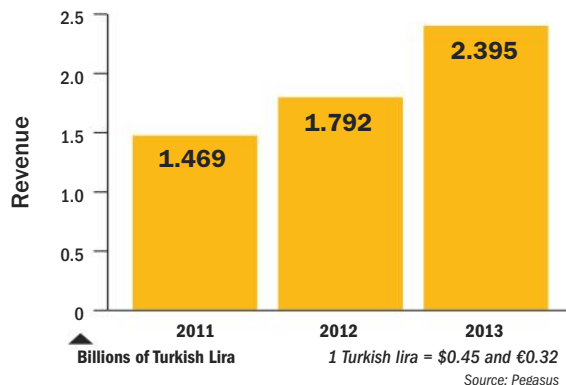
Turkey is one of the fastest-growing aviation markets in Europe, and Pegasus has consistently outperformed the overall growth rate. The budget operator enjoyed a cumulative annual growth rate in scheduled passenger numbers of 31% in 2007-13, versus 13% for Turkey, according to data from the General Directorate of State Airports Authority of Turkey (DHMI).

Pegasus increased international passenger numbers last year by 24.8%, to 6.6 million, compared to 2012, and domestic passengers rose 23.3%, to 10.2 million. Its system-wide enplanements grew 21.8%, and Pegasus management is confident it will meet its target of boosting passenger numbers by about 20% this year, with gains in both domestic and international markets.

"There is still room for solid growth in passenger numbers and market share," Chief Commercial Officer Guliz Ozturk says, noting that despite strong growth, both the domestic and international markets remain underpenetrated on a trips-per-capita basis. "Turkey has a population of about 77 million, a lot of young people that want to travel, and it is a very large mountainous country with few motorways and limited high-speed rail. We see considerable upside," she adds.

Competition in the domestic market is still limited. Besides Turkish Airlines, which accounts for about 55% of all seats

Pegasus Airlines Revenue



within Turkey, Pegasus competes with a handful of smaller players such as Atlasjet, OnurAir and Corendon Airlines.

Pegasus launched flights to 13 new destinations in 2013, including seven domestic and six international routes. It will add a few destinations within Turkey this year, but most of the growth there will come from increased frequencies. The LCC plans to continue adding new international routes at a rate of 6-7 per year.



Pegasus Airlines blends a point-to-point LCC structure with network feed primarily through Istanbul's Sabiha Gokcen airport.

KEITH GASKELL

The airline's international growth initially focused on Europe, as bilateral air services agreements with European Union countries tend to be liberal, but Pegasus sees increasing opportunities in the Middle East, North Africa and Russia/Commonwealth of Independent States. The Turkish civil aviation authority is "actively working to making agreements less restrictive," Ozturk notes. "We're now flying to destinations like Dubai, Beirut, Doha and Moscow. These were a dream for us five years ago."

Pegasus recently obtained flight rights from Istanbul Sabiha Gokcen International Airport to Madrid, Frankfurt, Kuwait and Simferopol in Crimea. The carrier has just be-

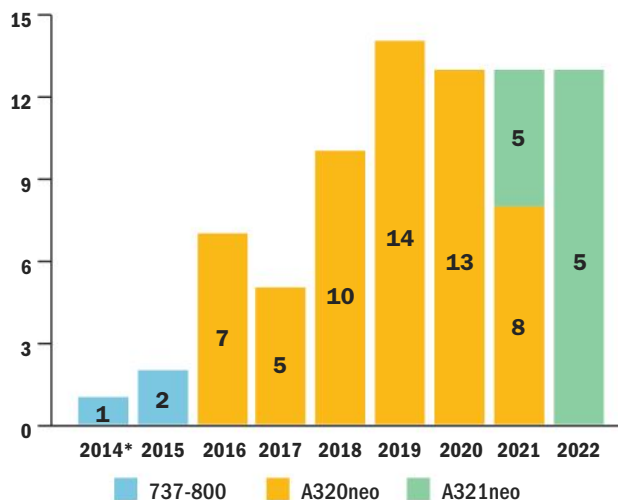
gun flying this month to all but Simferopol, due to the crisis in Ukraine, Pegasus Chairman Ali Sabanci says. Its current Ukraine routes accounted for 1.5% of total revenues last year.

Ozturk says the airline's main hub at Sabiha Gokcen and the 6-hr. range of its narrowbodies give it an excellent base for growth. Unlike Istanbul Ataturk International Airport, there are no capacity constraints at Sabiha Gokcen, and its owners are planning a second runway to accommodate future growth.

Turkish Airlines is establishing a secondary hub at Sabiha Gokcen and expanding the operations of its low-cost sub-brand AnadoluJet at the airport, but the LCC is not afraid of intensifying competition from its much larger rival because "our cost per available seat kilometer is much lower," Ozturk says. The airline will remain at Sabiha Gokcen when Istanbul's new airport opens.

Pegasus positions itself as a "low-cost network carrier," combining the low-cost, no-frills model with connecting traffic to make full use of its strategic geographic location. "We live in a dynamic environment. We have to permanently adapt and change. There is not one model; models are blending," Ozturk says. International tickets are available through a number of global distribution systems, such as Amadeus and

Planned Aircraft Deliveries to Pegasus by Year



Deliveries from manufacturers * One new Boeing 737-800 delivered March 3, 2014

Source: Pegasus

Route Revamp

Hawaiian Airlines using contrasting approaches to tweak long-haul and domestic operations

Adrian Schofield Auckland

For Hawaiian Airlines, subtraction is as important as addition, as it strives for the right formula to strengthen its diverse and far-flung network.

The carrier is making major moves in all three of its core markets. It is culling underperforming routes that were part of its rapid international ramp-up, while this summer it will increase domestic services to the U.S. West Coast. This month the airline was finally able to launch its turboprop subsidiary in the interisland market, and it stands to benefit from the demise of a smaller competitor.

Expanding to new international destinations has been one of the cornerstones of the carrier's strategy, and it has added a slew of new routes since 2010. However, it has recently announced the suspension of flights from Honolulu to Taipei and to the Japanese city of Fukuoka.

CEO Mark Dunkerley tells Aviation Week that the route cuts are not indicative of any wider problems with its international network or with the

carrier's overseas growth strategy.

Dunkerley says the two routes had "very specific circumstances that are not broadly applicable to other international routes." The "vast majority" of the new international services are "performing extremely well," and many of them count among the airline's most successful, he says. Next month Hawaiian will launch flights to Beijing, a market for which it has high hopes.

The problems with the two suspended routes were serious enough to discontinue them, but that does not change the airline's focus on overseas expansion and establishing an international network that can be "a new leg to the stool," Dunkerley says. The general aim has been to reduce the airline's reliance on domestic flights to the U.S. mainland.

The Taipei flights, which were launched in July 2013, have proven "disappointing," Dunkerley says. The carrier had expected that Taiwan's entry into the U.S. visa waiver program would stimulate the market, but that did not occur to the extent predicted.

Other markets have experienced demand jumps of 50-100% following their inclusion in the U.S. visa waiver program, says Dunkerley. Hawaiian saw this occur in the Seoul market in 2009, where the visa waiver prompted a 100% rise in demand despite the near-global financial crisis.

"We anticipated similar [demand growth] in Taiwan, [but] it did not materialize," Dunkerley says. The service will be cut on April 7.

Likewise, the Fukuoka route has not produced the necessary growth to justify its continuation. It was introduced in April 2012, and will be suspended on June 30. Japan has been a focus of Hawaiian's international growth; the carrier also flies to Tokyo, Osaka, Sendai and Sapporo.

Besides the two route cuts, Hawaiian is reducing the frequency of its Seoul flights. This is partly because its new direct Beijing service, which



Sabre, helping sales in markets where the Pegasus brand is not well established.

The airline is open to codeshares—it has one with KLM—as long as the arrangement delivers feed to its network, the codeshare partner accepts Pegasus's no-frill business model and the partnership does not add costs. The carrier also will consider commercial deals that can provide market access in case of restrictive bilaterals. For instance, Pegasus adds its "PC" code on Azerbaijan Airlines' twice-daily service from Baku to Sabiha Gokcen.

Like its low-cost peers, Pegasus has a relentless focus on cost control, and "cost per available seat kilometer is what really matters," says Sabanci. Pegasus operates only short- and medium-haul flights with a modern, fuel-efficient fleet. Averaging four years of age, the aircraft have a single class cabin configuration and aircraft utilization is high (12.6 block-hour per day in 2013). Dynamic pricing and low, promotional fares are used to stimulate demand and push up load factors, which reached 80.2% last year.

Despite its high growth rate, Pegasus continues to deliver profits. Operating profit increased by 28%, to 258 million Turkish lira (\$115 million) in 2013, and group revenue rose 34%,

to \$1 billion, with ancillary revenue up 47.9%, to \$152 million.

The carrier has not yet decided if it will move toward a single aircraft-type fleet or a mix of Boeing and Airbus narrowbodies after it starts taking delivery of its A320neo family aircraft. Pegasus will start receiving A320neos from 2016 and A321neos as of 2021. "We have a very flexible fleet development plan, with an upside case option and a downside case option. The decision will depend on our growth in the next couple of years, and how many new destinations and markets we will add to our network," Ozturk says.

The downside scenario foresees a single fleet of 75 A320neo family aircraft in 2022 and leasing out its fleet of 737-800s, while the upside case anticipates a dual fleet of up to 127 737-800s and A320/A321neos.

Pegasus was the first Turkish airline to order the A320neo, signing a commitment in December 2012 for up to 100 A320neo family aircraft, 75 of them firm orders. The LCC also considered the Boeing 737 MAX to complement its existing 737s: Pegasus and consolidated subsidiaries IzAir and Air Manas operate a fleet of 47 Boeing 737-800s and one -400, along with three A320-200s on lease from Avolon. It is scheduled to receive one more A320 this year. ☼

begins April 16, will diminish the need for connections to China via Seoul, says Dunkerley. Beginning on April 23, it will operate Airbus A330-200s five days a week to Seoul instead of smaller Boeing 767-300ERs seven days a week.

Routes from Hawaii to the U.S. mainland remain a large part of the carrier's business, despite its new focus on the western edge of the Pacific Rim. Its recent strategy has been to hold mainland capacity relatively flat, although it is proving that it will still jump in if opportunities arise. While tough competition has long been a hallmark of this market, Dunkerley notes that Hawaiian understands its dynamics better than any other airline.

Hawaiian will expand its presence in key West Coast markets this summer. It is set to reintroduce a daily Honolulu-San Jose, Calif., service on May 16, a route it cut in January 2013.

It will also upgauge its Honolulu-Oakland, Calif., flights, from 767s to A330s.

The carrier is planning to make its seasonal Los Angeles-Maui flight a year-round service, and will complement it with a second daily flight during summer months. This summer it also will launch seasonal flights from both Los Angeles and Oakland to Kona and Lihue.

Some of the upgauging decisions are spurred by the carrier's fleet modernization. During a 13-month span from December 2013 to January 2015, the airline is due to receive five A330s, and will retire four 767s.

Meanwhile, the Hawaii interisland market is losing one of the handful of small carriers that competes with Hawaiian Airlines; regional jet operator Go! is planning to cease operations on April 1.

Go! is owned by Mesa Air Group,

and the parent company announced that it is withdrawing the Hawaii service so it can redeploy aircraft to support its growing operations on the U.S. mainland. Go! began operating in 2006 as a low-cost carrier, when it challenged incumbents Hawaiian and Aloha Airlines. Aloha subsequently ceased operations.

The Go! fleet has shrunk to two Bombardier CRJ200s, which it operates to four island destinations beyond its Honolulu base. These include Kona and Hilo on the island of Hawaii, as well as Lihue on Kauai and Kahului on Maui. All are also served by Hawaiian Airlines.

The interisland market is dominated by Hawaiian Airlines, which for the most part uses Boeing 717s on these routes. The carrier's other competitors are Island Air and Mokulele Airlines, which in many cases operate to airports too small for the 717s.

Island Air, which was bought by billionaire Larry Ellison in 2013, flies ATR 72-200s. Mokulele operates Cessna Grand Caravans. Go! and Mokulele merged in 2009 then split in 2011, although they continued to be codeshare partners.

Hawaiian Airlines this month launched its own turboprop subsidiary named Ohana, which will compete with Mokulele and Island Air on the Molokai and Lanai routes. Island Air has announced that it will discontinue its Molokai route on April 1. ☼



The arrival of more new Airbus A330s is helping Hawaiian to boost some services.



Print to Build

Aerospace comes to grips with the challenges and opportunities of additive manufacturing

Graham Warwick **Washington**

In an industry where a technology can take 20 years to go from laboratory to flight line, excitement about additive manufacturing (AM) might seem premature. But as production parts built layer by layer move into engines and aircraft, aerospace is not immune to the 3-D-printing fever that grips manufacturing.

“The excitement is quite appropriate,” says Hamid Mughal, director of manufacturing for Rolls-Royce. “The potential of additive-layer manufacturing is definitely limitless. In time it will be game-changing, but there is a lot of hard work to be done to achieve that potential.”

While many expect 3-D printing to usher in a new industrial revolution, aerospace is taking a cautious, step-wise approach to understanding the new materials and processes and exploiting the design freedom that AM enables. The aerospace industry is embracing the technology

at an accelerating pace, nonetheless. The reason: reductions of up to 75% in material usage and 50% in production time and cost.

Boeing has used 3-D-printed plastic air ducts in several of its aircraft for more than a decade. Now General Electric is additively manufacturing metal fuel nozzles for the CFM Leap-1 and GE9X engines. Small replacement plastic parts, 3-D printed because the original tooling no longer exists, are in service on the Airbus A310 and BAe 146. Additively manufactured plastic and metal brackets are flying on the A350, and Lockheed Martin is qualify-

ing reinforced polymer and titanium components for the F-35.

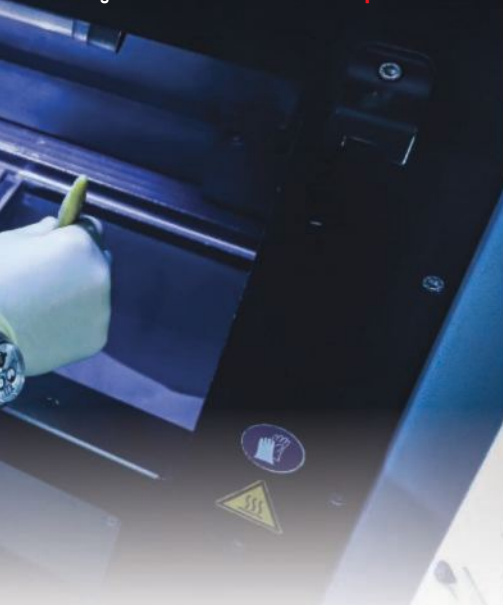
For airframe and engine manufacturers, the attraction of AM is the ability to make lighter, higher-performing parts while dramatically reducing the buy-to-fly ratio for expensive metal alloys. With conventional subtractive manufacturing—machining from solid billet—the ratio of raw-material to finished-part weight can be as high as 10:1 for complex components such as the titanium fuselage bulkheads in a combat aircraft.

Using AM, complex assemblies can be replaced with a single component and parts of a design that cannot be produced by any conventional means, in highly optimized structures where material is placed only where needed to carry loads or direct flows. “There is an amazing opportunity to reduce buy-to-fly, but you have to design for additive, to open up the gamut for new designs,” says David Hills, Airbus director for research and technology.

Medical implant makers were quick to embrace AM. The automotive industry is using the technology for rapid prototyping, enabling many design iterations, but high-volume production remains out of reach. “Instead of three tries at a design, we can do 60 or 100,” says Paul Susalla, section supervisor



Tap the icon in the digital edition of **AW&ST** to see more applications of additive manufacturing in aerospace, or go to **AviationWeek.com/aerospaceAM**



for rapid powertrain manufacturing at Ford. "Producing one part every 17-18 seconds is hard to do today. It will be easier in aerospace because of the lower rates."

In principle, additive manufacturing is simple: Take the 3-D digital model of a part, cut it into slices like a CT scan and use them to program a machine that melts and deposits material layer by layer to build up the part. The specifics are more complex, and they depend on the raw material and feed-stock form, energy source and working environment as well as part geometry, complexity and size, among many other variables.

For aerospace, the raw material can vary from a low-temperature polymer to high-temperature superalloy, in the form of a powder bed or wire feed; the energy source can be a laser in an inert atmosphere or electron beam in a vacuum; and the part can range from a simple plastic duct to a load-bearing metal structure. To use AM cost effectively, the industry must understand the matrix of how all those variables affect part performance.

Traditionally high-strength parts are machined from forged alloy billets so the final part has the same known properties as the original material. "With additive manufacturing, you

create the material as you create the part. That's what makes it complex," says Rob Sharman, head of metallic technology at GKN Aerospace.

"When we went from forgings to carbon fiber, we increased the variables. Now two separate materials are combined to get the end bulk properties," he says. "With additive manufacturing, there is much greater variability: the strength of the laser and size of its beam; powder particle size and flow; how you scan the beam to create the part, whether you spiral in from the outside or zig-zag from one side to the other. All these parameters change

Avio Aero has opened a production facility dedicated to additive manufacturing of propulsion components.

the heat flow into the material, which impacts the end properties."

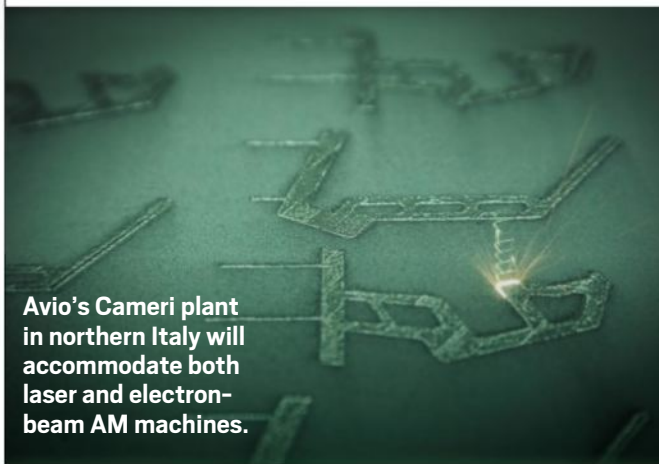
An example is residual stress from heating the part during build, a problem particularly with laser deposition. "Managing residual stresses and distortions is critical," says Mughal. "Di-

are lightweight lattices that replace the solid webs used to carry loads. "The problem with optimized structures today is there is no way to cost-effectively remove so much material. The extra machining costs so much that the benefit is not worth it," Sharman says. "But with AM, you pay for what you put in, so there is a cost benefit to putting less material into a part. Now optimized designs cost less than non-optimized. You can improve performance, take out weight, use less machining and take less time to make a part."

Because of AM's complexity, aerospace is using it first for design visualization and rapid prototyping, to make limited-life parts for ground and flight tests and create tooling for production of conventional components. The next step is to use AM to produce parts without changing the design geometry. "It's about building confidence by making sure [the part] will still perform with new material and process specifications," Sharman says.

"First you have to understand the matrix and be able to repeatably and

reproducibly create a material microstructure similar enough to the existing part," he says. "Once you get that confidence, you can change one variable at a time: Keep the design and material the same, but change the process. Then keep the material the same, but vary the design. And, finally, vary



AVIO AERO PHOTOS

Avio's Cameri plant in northern Italy will accommodate both laser and electron-beam AM machines.

rect laser deposition parts can crack open before you have time to anneal them to reduce the stresses. We need to be able to understand, predict and optimize the processes."

To fully understand the matrix of variables requires a huge amount of testing, Sharman says. "The flip side is, once you understand the matrix, the reverse is true. It is no longer about generating a bulk material property like a billet. It's about what's required where. You can start to put material only where it is needed, to create optimized structures and totally new cost-effective designs," he says.

"Bird-bone" structures, for example,

everything."

AM is changing how companies organize themselves. Until last year, Lockheed Martin's five business sectors were working independently. "They were off doing their own things, so we formed the corporate production council to focus on how quickly we could leverage work in 3-D printing in three areas: tooling and ground equipment; engineering development and rapid prototyping; and flight articles," says Dennis Little, chair of the council. "With every new technology, qualification is too slow and difficult. By leveraging five business areas with the same quality systems and machines,

we can bring a lot to bear on qualification. It is still a tall hurdle, but we can get there more quickly," he says.

Ford's Susalla encourages aerospace companies to use AM to do more prototyping. "Fail early and fail quick. Do a lot of prototyping upfront, inexpensively and quickly," he says. While software is developed in iterative spirals, hardware is not. "Now we can do quick builds and throwaway parts," says William Flite, senior manager for hardware engineering and additive manufacturing at Lockheed Martin. "Traditionally, we measure maturity by drawing release. Now we can use AM as risk mitigation, to visualize the design, prove out the prototype, retire risk and bring design reviews earlier," he says.

Sharman expects the adoption of additive manufacturing to follow the same profile as composites. "Carbon fiber was invented in the 1940s and is now in primary structure. It went from tertiary to secondary to primary structure, military to civil. And carbon fiber is still not optimized for the material, it is still on a journey of adoption in structures. Additive manufacturing will be no different," he says.

adoption pattern will be similar to any other technology, but the time will be compressed."

Adoption will be paced by the opportunities for insertion in new products. While 3-D-printed polymer components are being fielded as spares for out-of-production parts, additively manufactured metal parts are appearing in new engines such as the Leap-1 and Pratt & Whitney PW1000G and aircraft like the A350. "The cost of requalifying a part suggests the insertion point is new products," Sharman says.

A major driver of the adoption rate will be the increased use of titanium that comes with the move to carbon-fiber primary structures. "Titanium

Airbus is developing part designs optimized for additive manufacture, such as this hinge bracket.

Producing net-shape preforms that require less titanium and machining does not use the full

potential of AM, "but producing a complex prismatic titanium part for tertiary or secondary structure drives that first confidence step industry needs," Sharman says. Airbus has designed an additively manufactured A320 nacelle hinge, while Bombardier is working on a door stop for the CSeries, relatively simple titanium parts that can be both lighter and less costly with AM.

Beyond understanding the matrix of variables that determine part performance, the challenges facing aerospace in deploying AM cover the supply chain, machine capability, design tools and engineering skills. "We can produce parts in an R&D environment, but the real challenge is not making one part but many, in a reliable, repeatable fashion," says Sharman.

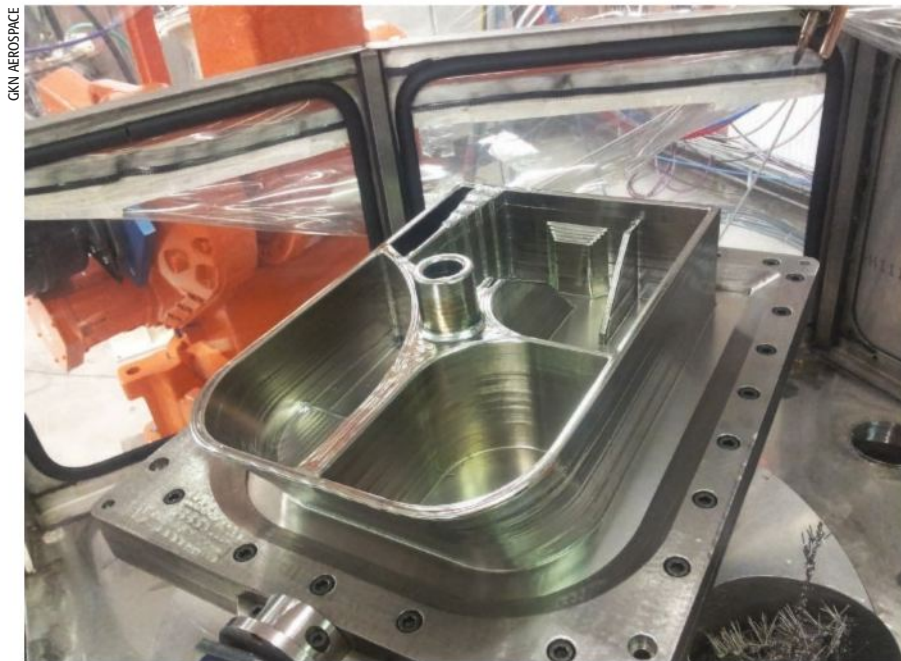
The supply chain from powder material to part finishing needs to be robust, with assured quality. "How do you look after and recycle the powder, which will age?" asks Mughal. More powder-metal development work is needed, he says, to understand "what variability is acceptable and what causes poor builds."

Additive manufacture of this component reduced material waste and energy use, says GKN.

AM machines must be more robust and reliable, with higher yields and the ability to work faster and make larger parts. "Deposition rates determine cost-effectiveness. Today, they are not fast enough," says Mughal.

"All the OEMs are working on getting more production-friendly machines. This is a fast-growing market, but still small. We will see the type, scale and number of machines increase," says Sharman.

Factory designs may have to change, Mughal says. "If you have 10 to 15 machines together in a factory, the electromagnetic fields could interact with their performance. What is the



But because AM is a rapid, tool-less technology, the rate of adoption could be faster. "You can print a part overnight, test it, change it and print another one the next night. With carbon fiber, you can wait six months for a tool," Sharman says. "I believe the

use has gone up rapidly, and it is a far more expensive material, more challenging to produce and harder to machine," he says. Across industry, this is driving the move to net-shape manufacturing to minimize machining and material waste.

minimum distance between machines? What are the work practices?" he asks.

"We need finishing processes tailored to additive-layer manufacturing, to remove adhered powder and improve surface finish," Sharman says. "How to avoid finishing or develop cost-effective finishing capabilities, requires some thinking." New inspection methods are needed, including in-process monitoring methods to ensure component integrity.

Another challenge is training engineers to design for additive manufacture. "There is a growing belief that if we don't get this in front of our engineers the benefits will not come our way," says Mughal. Little says Lockheed has deployed design engineers to the factory floor to work with manufacturing engineers and learn what AM machines can do, so they will stop thinking two-dimensionally. "The biggest challenge is the shift in skillset required to make the most of AM," says Sharman.

New design rules and tools are needed, too. "The design tools today are quite limited," says Dan Johns, chief technologist for additive manufacturing at GKN. "We have only just got composites modules into our design tools, and that took 60 years. We need to get AM knowledge bases into our toolsets, and to look out of our sector to gain that knowledge," Mughal says.

"This is not a single technology," says Sharman. "It is a whole suite of different processes that offer huge potential to revolutionize manufacturing in the long term. AM is no different than casting; it is a huge range of technologies with different uses, each with pros and cons, involving different levels of maturity and adoption . . . We believe the different processes are not competitive with each other. Each sits in its own niche, although some may come out slightly stronger."

Despite its caution, aerospace is moving resolutely into AM. "In the medium term, we will see small, complex, lightly loaded parts in titanium and nickel-based alloys," says Mughal. "Longer term, we will see very high-performance, highly integrated parts in critical load-bearing applications. We will see graded and hybrid materials, tailored and multifunction parts with embedded devices. We will put intelligence into components so we can understand them in make and in service." ☛



ROLLS-ROYCE

Rolls-Royce produced this hub demonstrator in a European research program via laser deposition of nickel alloy.

Adding Power

The propulsion industry is leading the transition of additive manufacturing into production

Graham Warwick *Washington*

General Electric scored a media coup when it announced the new CFM Leap-1 and GE9X engines would incorporate additively manufactured fuel nozzles. But these parts in the heart of the engine are just the tip of a surfacing iceberg of additive-manufacturing applications in aerospace propulsion.

Italy's Avio Aero—now owned by GE Aviation but also a supplier to Pratt & Whitney, Rolls-Royce and Snecma—is a leader in Europe in transitioning additive manufacturing to production.

In December, the company opened a 2,400-sq.-meter (25,800 -sq.-ft.) facility in Cameri, northern Italy, dedicated to additive manufacturing.

The facility can accommodate up to 60 electron-beam-melting (EBM) and direct metal laser-sintering (DMLS) machines, two gas atomizers for producing titanium aluminide (TiAl) powder and heat treatment equipment. Among the components Avio will produce are TiAl low-pressure turbine blades up to 350 mm (14 in.) long, manufactured using EBM.

Other parts the company has produced using EBM include lattice structures in titanium for centrifugal oil separators and in stainless steel for acoustic liners. Using DMLS, Avio has produced combustor liners, swirlers and afterburner injectors in cobalt chromium, and rocket-motor



Tap the icon in the digital edition of *AW&ST* for an interactive look at the aerospace engine-makers' applications of additive manufacturing techniques, or go to AviationWeek.com/aeroengineAM

turbopump impellers in Inconel 718 and volutes in stainless steel.

Germany's MTU Aero Engines is to incorporate additively manufactured components in the next-generation geared-turbofan demonstrator it will build under the Sustainable And Green Engines (SAGE) project within Europe's Clean Sky public-private research program.

MTU is leading the SAGE 4 demonstrator, based on a Pratt & Whitney PW1524G donor engine, which is scheduled to run in 2015 and fo-

GE is producing fuel nozzles for the CFM Leap-1 via selecting laser sintering of cobalt chromium.

cused on improving the efficiency of the high-pressure (HP) compressor and low-pressure turbine modules, says Joachim Wulf, SAGE 4 program manager.

Included in the technologies to be tested are additively manufactured HP compressor inner air-seal carriers. Found in the later compressor stages and usually made of steel or nickel alloy, seal carriers currently consist of a machined ring onto which two metal honeycomb strips are brazed.

For the SAGE 4 engine, the ring segment and honeycomb structure is additively manufactured in one step using selective laser melting (SLM) of Inconel 718. Multiple segments are grown from a base plate in a single operation, with minimum machining required after manufacture to separate them from the base and finish the end faces.

"We can generate a lot of parts in a short time," says Wulf, who adds that making conventional seal carriers involves much "logistic movement" to produce the honeycomb, machine the ring and braze them together. "Now we can make them in one step, including the honeycomb," he says.

But despite its apparent simplicity, additive manufacture of the seal carriers "is far from economic at the moment," Wulf says. "Additive manufacture is still in an experimental state. There are concerns about the quality of the material, which introduces lots of quality measures that are rather costly." A "huge amount" of testing, mainly for high-cycle fatigue, will be required to prove the process, he says, noting that "there is still a poor surface quality from the additive manufacturing process."



Keeping as many of the functional surfaces of the SLM parts as possible in their as-manufactured condition is a particular challenge, he says, but it is necessary to benefit from the economic advantages of additive manufacturing by eliminating machining. Assembly experiments with different combinations of tolerance zones have been conducted to establish the proper clearances for trouble-free assembly of "SLM-to-size" components, he says.

Pratt & Whitney, meanwhile, says it has made "hundreds" of additively manufactured prototype parts, including tooling and engine hardware, to support development of its PurePower geared-turbofan family. "We have flight tested and are in the process of certifying some of the unique components for our PurePower engine," the company says, adding that the components were flown in its PW1500G test engine. "Some of the additively manufactured parts for the PurePower engine that we've identified publicly include airfoils and brackets."

Rolls-Royce is coy about the status of its additive manufacturing efforts but says it is "advanced" in the development of components and processes. "We have a very structured program of work," says Hamid Mughal, director

of manufacturing. This includes developing materials property databases, integrating additive-manufacturing modeling into product life-cycle management toolsets and developing cost-effective finishing capabilities.

The company has used additive manufacturing to produce components for design visualization and test rigs, large parts using wire-feed material addition methods, and small high-temperature parts to replace complex assemblies in engines. Rolls is involved in the four-year Merlin European Union research program to increase deposition rates for SLM and powder- and wire-feed laser metal deposition.

The manufacturer is a founding industrial partner in the university-led Manufacturing Technology Center (MTC) in Ansty Park, England. In January, the U.K. government committed £30 million (\$50 million)—to be matched by industry—to create the National Netshape and Additive Manufacture Center at the MTC, which will focus on developing processes to produce components for aero-engines and landing gear. Mughal says Rolls-Royce Germany will perform research under that country's Industry 4.0 future manufacturing initiative. ☐

Instituting Additive

U.S. initiates a \$600 million drive to revitalize manufacturing; aerospace is a key component

Graham Warwick **Washington**

Aerospace companies are prominent partners in new public-private advanced manufacturing institutes launched by the Obama administration. Participation will enable manufacturers to leverage internal R&D by pooling resources with academia, competitors, suppliers and other industries on government-sponsored research projects.

"We will get dollars of value back for nickels and dimes in investment,"

The Defense Department will provide \$70 million over five years for the Almmii, matched by at least \$78 million from industry, universities and state and local governments. The Pentagon will provide another \$70 million to the Digital Lab, with industry, academia, government and other partners committing to add another \$250 million.

The new entities were announced in February, following January's creation of the Next Generation Power

bers. So far, \$13.5 million in government and \$15.3 in consortium funding have been awarded to 22 projects, ranging from process control, through rapidly producing complex composite tooling, to manufacturing multifunction parts with embedded wires, meshes and components. Aerojet Rocketdyne, GE Aviation, Honeywell, Lockheed, Northrop Grumman, UTC and others are involved.

Education is featured. "Each institute is tasked with the workforce development and training mission," Betza says. "We will have a laser focus on the education coming out of each institute, and how quickly [it can be imported]."

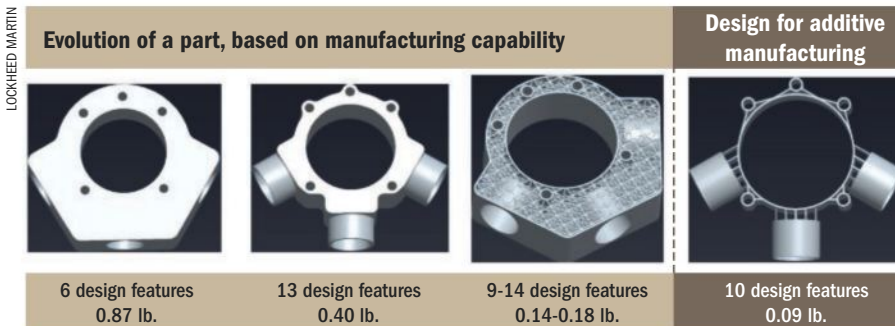
Almmii will concentrate on removing technological barriers to manufacturing new lightweight high-performing metals and alloys, accelerating the transition from laboratory to production and training the workforce. All forms of metals and alloys will be looked at, including nano-enhanced, Betza says.

Many of the materials exist, but "the challenge is in optimizing component designs and developing the advanced processes to manufacture them robustly on a large scale [affordably]," says Alan Taub, Almmii chief technology officer and professor of material science at the University of Michigan.

The Digital Lab will unite manufacturing experts with software companies to integrate the 3-D design "digital thread" across the supply chain. "It is about bringing model-based engineering to the factory floor; paperless assembly using 3-D models; virtual environments; mobile computing; simulation, analysis and optimization—it is a wide swim lane," says Betza.

Challenges include establishing true interoperability, managing intellectual property, network security and developing new organization cultures. The Digital Lab will use an open-source online software platform—the Digital Manufacturing Commons—to create networks of people, manufacturing machines and factories to enable real-time collaboration and "big data" analysis to reduce the time/cost of design and manufacturing, states UI Labs. ☛

Traditional Design vs. Design for Additive



Fully exploiting the design flexibility that additive manufacturing allows could dramatically reduce materials use, as well as part weight and cost.

says Steve Betza, director of advanced manufacturing for Lockheed Martin. The company is a Tier 1 partner in America Makes, the National Additive Manufacturing Innovation Institute in Youngstown, Ohio, which is the pilot for up to 16 institutes planned under the National Network of Manufacturing Innovation.

Lockheed is also a partner in the American Lightweight Materials Manufacturing Innovation Institute (Almmii)—led by EWI and headquartered in Detroit—and is part of a 60-member consortium that includes Boeing, General Electric and United Technologies.

Boeing, Lockheed and GE will also participate in the Digital Manufacturing and Design Innovation Institute, or Digital Lab, led by UI Labs and headquartered in Chicago. Among the 73 partners are Dassault Systemes, General Dynamics, Honeywell, Rockwell Collins and Rolls-Royce.

Electronics Manufacturing Innovation Institute in Raleigh, N.C., which is focused on wideband-gap semiconductors. It received \$70 million in funding from the Energy Department. The government has launched a competition for the Advanced Composites Manufacturing Innovation Institute with another \$70 million, which is also supplied by the Energy Department.

America Makes was established in August 2012 with \$30 million promised over an initial three years from the Pentagon, plus \$40 million from industry, academia and other partners. Lockheed has committed \$2.5 million over five years for Tier 1 status, which ensures them maximum access to intellectual property developed under research projects, says Betza.

The Youngstown institute is becoming a showcase lab for additive manufacturing. Its role is to sponsor calls for projects proposed by consortium mem-

Taming Composites

NASA will lead effort to speed the development and certification of carbon-fiber structures

Graham Warwick **Washington**

Boeing's 787 and Airbus's A350 are reaping the performance rewards of pushing composites to 50% of structure weight, but getting there has not been easy. Now NASA is teaming with industry to cut the cost and time required to develop and certify the new materials.

Light, stiff carbon-fiber structures are enabling new levels of fuel efficiency, but compared with well-established metals many more iterations of testing, failure and redesign are required before manufacturers and regulators are confident that the designs are safe. This adds cost and time, made worse by each manufacturer—in the absence of industry standards—developing its own material systems and manufacturing processes that must be demonstrated to the regulators' satisfaction.

"There is a movement to change the way we develop and certify composite structures," says Richard Young, manager of NASA's new Advanced Composites Project. "It is not that it can't be done—we are currently able to build and certify composites—but it is time-consuming and labor-intensive. Our development and certification methodology is not very efficient."

Beginning this year, the five-year project will be funded at \$25 million annually, matched by money from industry partners Bell Helicopter, Boeing, GE Aviation, Lockheed Martin, Northrop Grumman, United Technologies and its Pratt & Whitney unit. NASA and the companies are forming a consortium for the program, with the FAA involved to provide guidance and feedback.

The companies will work together to establish an improved baseline for composites development and certification, including standardized design tools and validated simulation methods. An overall goal of the project is to reduce the time required to develop and certify carbon-fiber structures by a minimum of 30%. "As time goes on, we can achieve significantly higher [reductions]," he says.

"Today this work is done on an individual-company basis. It has not achieved the required level of acceptance and confidence from the regulators, so manufacturers have to test everything to establish a design's safety," says Young. The result is a lot of trial-and-error cycles to reach a safe design. "The goal of the project is to use standardized tools with limited testing to achieve the same result."

One of the biggest challenges with composites "is that the structural material does not exist before you make the part. It is not rolled aluminum, already tempered, for which you know the properties," he says. "With carbon-fiber, you buy raw material, and properties can vary from part to part depending on how it is made. That makes it difficult to establish a material specification."

Many more types of damage must be addressed, including delamination, disbonds, cracking and wrinkling. Carbon-fiber is sensitive to defects, which can create variations in the performance of a part depending on where the damage occurs. This creates a scatter in test results, "so you need

Composites introduce many more design variables that must be tested and verified.

more testing to establish a level of comfort," Young says.

"At a subcomponent level, composites can require up to 100 times more tests than traditional metals. And large specimens—where the largest increase is required—are the most expensive," he says. "Large panels can make up 10% of the specimens tested, but 50% of the development cost."

The project will attack the issue from several directions. "We will look at the certification requirements, at what is the definition of success. There may be alternative ways of achieving compliance," Young says. Current processes at partner companies will be examined to identify the largest number of reworks and the greatest opportunities for improvement. And available tools will be assessed against baseline cases established by the consortium to see which work best for which problems.

"In the end this is a tool-and-process development project," says Young. "We will develop standard tools, establish a user base and exercise the tools on pilot projects to develop standard cases industry can use as guidance for developing and certifying new products." These projects will involve generic structures relevant to the companies involved: a multi-stringer-stiffened panel for airframes; a full fan case for turbofan engines; and a highly loaded joint for airframe and rotorcraft applications.

The program also will develop rapid inspection methods. "Standard tools show defects as a change in color, but it is hard to translate this into what the effect is of that type of damage in that area of a component," he says. "We will develop automated inspection tools to speed the process and connect them to analysis tools to characterize the defect, understand the implication for part performance and tell us if it is good enough."

The project output will be documentation on standard tools, processes and use cases to be incorporated into FAA advisory circulars and the government-industry CMH-17 composites materials handbook, which provides design and fabrication guidance. The effort is expected to reduce costs and accelerate innovation. "When a new material comes along, we will be able to hit the button knowing it will not take the time and money it did previously," Young says. ☐



QUICKSTEP

All Bets Are On

With nations and companies in a new global game, A&D research is again a discriminator

Michael Bruno Washington

Textron Systems closely adheres to the philosophy “build it and they will come.” For Exelis, its credo is akin to “show me the money.”

But with the Pentagon saying “just do it,” these and the rest of the Western aerospace and defense industry’s myriad approaches to independent research and development (IRAD) are experiencing a renewed level of business interest as the sector heads into the latest once-in-a-generation revamp.

“Capital deployment favoring shareholders worked just dandy in 2013, but a theme to watch in 2014 is whether R&D and new product development prove to be more important stock-price-performance discriminators,” Capital Alpha Partners analyst Byron Callan has told investor clients.

Callan’s comments come as U.S. defense spending flattens in the near term, while long-term sequestration-level limits have been declared wholly inadequate by government officials. In turn, leaders such as Pentagon acquisition czar Frank Kendall have been asking industry to protect and even boost IRAD because even though officials are moving money within their own budget plans to favor pursuit of advance technology, Defense Department R&D is falling nonetheless and they are afraid of losing technological superiority globally (*AW&ST* Feb. 17, p. 52).

In fact, budget expert Todd Harrison of the Center for Strategic and Budgetary Assessments think tank says the Pentagon’s total annual R&D test-and-evaluation spending already has dropped 25% from its fiscal 2010 peak through 2013. This roughly mirrors the prior downturns, but the amount could drop even further under sequestration-level restraints as R&D and procurement serve as some of the few bill-payers for military personnel and force-structure spending.

Yet the challenge for industry, especially prime contractors and incumbents, ranges far beyond the Washington Beltway. Advances overseas such as Russian and Chinese stealth fighters and air defenses, or the latter country’s purported hypersonics, antisatellite and antiship missiles, could eventually undermine U.S. and allied programs by bypassing their decades-long development and fielding. “We see China’s advances in military technology as potentially disruptive,” Callan notes specifically.

And that is not all, says Steven Grundman of the Atlantic Council. “I would add to this list of factors forming the

markets’ inflection the advance of commercial technologies in, most especially, computing, sensing, communications and biotechnology, to name just four disciplines that are rapidly advancing on the commercial side of the world and not on the defense side of the world.” Indeed, the pace of technological change has led to a “reverse of the orientation of spin-on and spin-off that we variously enjoyed or endured during the Cold War,” he says.

The changing landscape has many like Callan and Grundman looking for signals from companies. “Just as Harris disrupted the radio market, we would continue to watch for instances where firms challenge segments or programs dominated by primes based on their own risk-taking and investment,” Callan says. He also cites more recent examples such as Raytheon’s wins on the Navy’s Next-Generation Jammer and Air-Missile Defense Radar competitions, which “were both attributed to technology investments it made years ago.”

But for companies facing existential falloffs in federal funding, the question of what to do remains. Not surprisingly, as shown by the \$2 billion Textron subsidiary and the \$5.5 billion

ITT-spinoff Exelis, the answer appears to be rooted in where you come from as a business.

“I have a hypothesis,” says Textron Systems CEO Ellen Lord. “In this current environment, the U.S. will gain the most benefit from having multi-industry companies applying commercial best practices.” Among other actions, those include moving and sharing engineers, proprietary technology and business relationships across units like Bell Helicopter, Beechcraft and Cessna, all while the defense sector is slumping.

Lord cites Textron’s offerings like the Scorpion light-attack jet and Shadow M-2 tactical UAV, neither of which was launched with a government customer securely in place. For the Scorpion, “they took a composite airframe and commercially available parts that were already being used on other Cessna aircraft, and they designed toward a low total-ownership cost and came up with a system that can be immediately exported,” she says. “This jet was designed to be operated at less than \$3,000 per flight hour, making it very interesting for a whole variety of missions,” she adds, citing the F-16 as a comparison.

“[The] second example of leveraging our IRAD in a down cycle: We, on our own dollars, have developed the Shadow M-2 tactical aircraft,” Lord continues. “Taking the wings from the current Shadow and multiple other parts [and] designing a new fuselage, we have come up with a system that we demonstrated multiple times now has the ability to carry the payloads that strategic aircraft are flying today. We are going to be in a position to be able to deliver a capability to the warfighter at much lower cost.”

Ultimately, however, it was the commercial mind-set that drove it all. “We went out, we looked at the marketplace, we looked at the needs, we looked at the future, we identified



Textron states that its business approach allows it to develop and market the Scorpion light-attack jet, even though it has not yet secured any customers.

TEXTRON

what the gaps are and we took our own money,” says Lord, a chemist by training whose career at Textron started in the automotive industry. “We made a bet on what is needed and we developed the capability and we went and flew. And we think the customers will follow.”

By contrast, stand-alone A&D provider Exelis follows its customers, explains CEO David Melcher. The retired Army three-star general, who joined former parent ITT five years ago, cites “the needs of the company and shareholders” when asked about IRAD and says his company tries to benchmark its R&D against industry peers, especially those of mid-size.

“We certainly have to focus our investments because we do not have the same deep pockets that the big primes have,” he says. “Now each of our businesses has a number of ideas, and they’ll come tell you, ‘this’ is the best use of IRAD spending. We want to make sure that is validated with our customers so they agree this is the place to put the dollars.”

But even that more conservative approach does not guarantee the company’s position in the future. “I worry about whether we have enough, and I know the government side of it is going to be going down,” Melcher acknowledges. “My sense has been we are close to underinvesting. And so a lot

Economy Class

Saab plans to contain JAS 39E costs

Bill Sweetman [Linköping, Sweden](#)

Saab is using a mixture of new technology, state-of-the-art tools and an innovative approach to development as it tries to reverse the worldwide trend in defense acquisition costs and deliver the JAS 39E fighter at lower development, procurement and operating costs than its predecessor, the JAS 39C/D.

Costs emerged as a major challenge at the program’s earliest definition stages. According to air force chief of staff Maj. Gen. Michael Byden, the service assessed an avionics-only upgrade, an all-new aircraft and a “new but known technology” version with a new engine, before selecting the third option.

As work on the Gripen Demo proceeded, it became clear that the development of the JAS 39E would cost more than the C/D, which had retained the engine, airframe and radar of the JAS 39A/B. But Lars Ydreskog, head of aeronautical operations and JAS 39 chief engineer, says that “the Swedish

air force could not afford to do this in the traditional way.” The company set a goal of keeping development costs to 60% of the C/D figure. Saab’s fixed-price development contract is valued at 13.1 billion Swedish kronors (\$2.1 billion) over five years, about \$155 million less than the JAS 39C/D.

Acquisition costs are expected to be lower, although the JAS 39E is larger than the C/D and costs on the latter have been reduced. “A few years ago, we made 28 Gripens a year,” Saab CEO Hakan Bushke said at the Paris air show last year. “Now we make 8 to 12 per year, and the cost per unit is lower.”

New tools and processes have been applied on the Gripen Demo and the Neuron unmanned combat air system prototype, says Ydreskog. The Demo, he says, cost 40% of the original estimate.

The most important tools are grouped under the term “model-based systems engineering,” Ydreskog says. Saab uses industry-standard Dassault Systemes

Catia design software but says it applies it in unique ways. For example, there are no 2-D drawings in the JAS 39E program. Every part and manufacturing operation is defined by a 3-D model, from requirements and standards through design, manufacture and assembly and into the maintenance stage.

The same model is used by all the groups involved in the design process—weight and balance, aerodynamics, weapon integration and so on. The result is that 70% of defects are discovered in the simulation stage and all groups can contribute to the solution and confirm that it will work. With earlier program tools, the design would be in flight-test by the time 70% of problems were identified.

Catia is also used for weight and stress analysis—the aircraft weight can be monitored once a month by a single engineer—and for “zonal review,” the process of checking for any physical conflicts between parts. Using third-party viewers (rather than costly workstation licenses), Catia data can inform producibility and maintainability simulations as well as interactive publications for support. Saab is working with Dassault on this process and expects to see such techniques in future Catia releases.

The definition of the Gripen C/D configuration includes 70,000 written documents, Ydreskog says. There are none in the JAS 39E database: Specifications and requirements (for example, resistance to bird-strike, corrosion and electromagnetic interference) are built into the models.

Other features of the new aircraft involve redesign to take advantage of technology that was not mature when the JAS 39A/B was developed. Many sheet-metal assemblies have been replaced by high-speed machining and the new wing-body frames are forged from aluminum-lithium. “When we de-

Saab’s Gripen Demo is testing the full suite of JAS 39E sensors. The latest is the Skyward-G infrared search-and-track system, located ahead of the windshield.



of the cost-reduction measures we did within our company were explicitly designed to create more headroom to invest more in IRAD, which we intend to do over the next several years. So [it is sort of] our way of trying to counter what we see as a little bit less government funding for research and development in our own way. But you know we are struggling with exactly where to put it.”

Whether the self-described commercial approach taken by Textron Systems is the key for the West’s A&D industry or the more disciplined tack by Exelis proves prescient remains to be seen. Regardless, Callan predicts that they and other

legacy companies will be facing increased competition from new entrants that hew to different business models.

“Google’s investment in robotics, Amazon’s interest in small UAVs and Facebook’s deal to buy Titan Aerospace (which makes solar-powered long-endurance drones) all point to non-traditional competitors in markets that also are of keen interest to defense,” he notes. And “some competitors, notably SpaceX, bring entirely different business models and investment behavior compared to public companies.”

The landscape may be shifting for years, Callan and others portend. ☼

signed the system, we looked at Legos,” Ydreskog says, as the goal is to make assembly simple and repeatable.

One of Saab’s objectives is to make the learning curve steeper than usual. The industry standard is to reach a near-optimal time for manufacture at the 180th aircraft produced. Saab wants to reach that stage by the 30th aircraft—halving the number of work hours taken on the first 100 aircraft.

The JAS 39E system includes millions of lines of code, but the plan is to complete basic testing in 1,200 sorties versus 3,700 flights for the JAS 39C/D. Although this goal may seem risky, in light of problems with the Joint Strike Fighter (JSF) (where managers reduced the planned number of sorties, relying on modeling and simulation, but later had to restore them), Saab argues that the JAS 39E program is different.

Much of the software is ported from the C/D—the initial Mission System 21 package is the latest in the Gripen series. The C/D and JAS 39C are similar enough that weapons clearances can be simplified. Saab will test a subset of complex and demanding weapon loads, thereby clearing simpler combinations.

One of the biggest changes is the new avionics architecture, which is already flying on the Gripen Demo. Using certified Arinc 653 partition standards, the system represents a change “from the 1980s and 1990s, where we made all the computers talk to each other all the time,” says Mats Lundberg, head of flight test and verification. The aims are to guarantee that mission-system software cannot endanger the aircraft and to go “from finding a problem to fixing it and flying, in hours,” he says.

That is expected to reduce the volume and criticality of regression testing—the process of ensuring that software changes do not have unpredicted effects elsewhere—which has been a major issue with the JSF. ☼

‘Just as Good’

A single-engine design would meet South Korean air force requirements for KF-X

Bradley Perrett **Beijing**

Bigger is not always better, argues Korea Aerospace Industries (KAI), urging Seoul to back the medium-sized aircraft it has proposed for the KF-X indigenous fighter program. Indeed, the aircraft will perform a good deal better in key areas than the larger rival design of the Agency for Defense Development (ADD), according to KAI’s calculations.

In some parts of the government, the message must be falling on receptive ears. Senior executives in KAI were known to prefer a single-engine design before their proposal was revealed last year; they doubted that the country would pay for a big fighter or had the engineering resources to develop one. But local media report that a more influential force was involved: The finance ministry had directed the company to work on a cheaper alternative to ADD’s twin-engine fighter.

The ministry’s involvement reinforces an argument that the long-running program, which faces serious political opposition, is more likely to move to full-scale development if KAI’s concept is chosen. With some members of parliament doubting that the country should try to develop its own fighter, the legislature is imposing tight conditions on the limited funding it is making available for the KF-X (AW&ST Jan. 20, p. 29).

Boeing, Lockheed Martin and Airbus Defense and Space have reviewed the KAI and ADD designs and found that both meet the air force’s specification, KAI says in the March issue

of its company magazine, adding that the two designs are equal for combat effectiveness. Lockheed Martin is expected to support the development of the KF-X if, as is highly likely, the F-35 is finally ordered for the separate F-X Phase 3 program, although the U.S. government would forbid transfer of sensitive technology.

KAI’s concept is called KFX-E, with a baseline single-fin design known as C501, while ADD’s most likely concept is the C103. According to KAI, both types can fly farther than the 310-nm combat radius required for air-to-air and strike missions. They also outperform the F-16C in that regard, although that Lockheed Martin aircraft exceeds the specification in air-to-air mode and almost meets it for ground attack.

But KAI says its smaller aircraft will fly farther than the C103 in both cases. Although no figures are given, a chart suggests that the C501’s advantage is almost 10% for the air-to-air mission and 20% for strike. In both cases, the C501’s radius is more than 400 nm.

KAI does not explain any of its performance estimates, except to say that its aircraft has high fuel efficiency. Moreover, its design is unlikely to have been worked out to the level of detail of ADD’s, so estimates of its characteristics should not be as reliable. The comparison assumes that the C501 would be powered by a General Electric F110-GE-132 engine of about 32,000 lb. thrust and the C103 by two GE F414s of 22,000 lb. thrust.

Engine suppliers have not actually been chosen, however.

With the benefit of two engines, the C103 has the edge in acceleration and thrust loading, but KAI claims advantages in speed, ceiling, climb and sustained turn performance. Notably,

Korea Aerospace Industries' single-engine design for the KF-X would be a little larger than the F-16.

its figures assume the very light armament of only two short-range air-to-air missiles. A larger and more powerful aircraft would normally suffer less penalty as loads increase.

In a second production version, the C103 could carry some of its load internally, reducing drag and radar reflections, whereas KAI's concept has no room for a weapons bay. KAI has two answers, not previously revealed. One is to equip the aircraft with an external pod shaped for stealth, like the one Boeing has proposed for the F/A-18E/F Super Hornet. Drag from KAI's pod would presumably eliminate much or all of the C501's performance advantages.

The second idea, which has been proposed in other projects elsewhere, is to cover each of the two semi-recessed air-to-air missiles with a "conformal weapons fairing." A drawing indicates that the fairings would be hinged to the lower fuselage, in effect turning the missile stations into little weapons bays. A challenge would be to design an installation, including the actuation mechanism, that is not significantly heavier than permanent bays built into a slightly enlarged fuselage. An alternative would be to make the fairings expendable, ejecting each just before its missile is launched, but then an issue would be ensuring that the discarded fairings do not fly back into the aircraft.

However the fairings are fitted, KAI's design has room for only two missile recesses. So a more normal load of four medium-range air-to-air missiles could be stealthily taken into action only by carrying the pod as well, assuming that the pod does not obstruct ejection of the body-mounted weapons.

ADD has been the leader and chief advocate of the KF-X program since about the time a proposal to build an indigenous fighter emerged in 1999. KAI, having developed and built the T-50 supersonic trainer and combat



KF-X Contenders

Performance as percentage of F-16 with F110-GE-229

		KAI C501	ADD C103
Engines		1 F110-GE-132	2 F404-GE
Max. Speed		98%	93%
Ceiling		104%	99%
Climb (with max. fuel)		101%	99%
Sustained Turn	10,000 ft. alt.	102%	95%
	(at optimal speed with	15,000 ft. alt.	106%
	two short-range AAMs)	25,000 ft. alt.	105%
Acceleration, Mach 0.8-1.2		110%	118%
	(with two short-range AAMs at 30,000 ft.)		
Thrust/Weight		100%	109%
	(at optimal speed with 50% internal fuel)		

Source: Korea Aerospace Industries

derivatives with help from Lockheed Martin, has been supporting ADD in design studies. The two appear to have parted ways in the past two years when they studied alternative designs with one or two engines. KAI evidently liked a single-engine design called C102E, from which the C501 has been developed. The company's concept and ADD's are 90% similar, KAI says, without explaining how that is measured. The shapes are similar.

The air force wants two engines, for redundancy and therefore safety, which would more or less ensure that the aircraft would be at least as big as the Eurofighter Typhoon. ADD's concept is that big, with an empty weight of about 11 metric tons. KAI saw a smaller aircraft as less taxing on the country's economic and technical resources; its concept would weigh 9.3

tons empty, about 4% more than in-production Lockheed Martin F-16s.

Parliament is not sure it wants either. It voted 20 billion won (\$19 million) in funding for the program for 2014, only enough to keep the seemingly endless design studies underway. Moreover, by imposing tough conditions on the program, parliament ensured it will keep tight control, with an implied threat to kill it if it goes off the rails. Development cannot cost more than 8.4 trillion won and must be completed by 2025, according to the conditions on the funding. A foreign partner, presumably a fighter builder, must take a 15% share of the program.

A single-engine KF-X would cost 6 trillion won to develop, a member of parliament has said. ☛

With Bill Sweetman in Washington.

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April 9—MRO Military, Phoenix Convention Center.

**June 10-11—MRO Baltics, Eastern Europe & Russia (BEERs),
Sheraton Warsaw (Poland).**

**July 16—Farnborough Civil Manufacturing Briefings, Farnborough
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Oct. 7-9—MRO Europe, Madrid.

Nov. 4-6—MRO Asia, Singapore.

Nov. 19-20—A&D Programs, Litchfield Park, Ariz.

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April 14-16, 2015—MRO Americas, Miami.

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MRO Military. Both at Phoenix Convention
Center. [events.aviationweek.com/current/
mro/index.htm](http://events.aviationweek.com/current/mro/index.htm)

**April 11—Society of Experimental Test
Pilots' East Coast Section Symposium.**
NAS Patuxent River, Md. [www.setp.org/
table/east-coast](http://www.setp.org/table/east-coast)

**April 14-17—Asian Business Aviation
Conference and Exhibition.** Shanghai.
www.abace.aero/2012/

**April 30—American Institute of
Aeronautics and Astronautics' (AIAA)
2014 Aerospace Spotlight Awards Gala.**
Washington. www.aiaa.org/gala2014

**April 30-May 1—Speednews 12th
Aerospace & Defense Industry Suppliers
Conference.** Jonathan Club. Los Angeles.
[speednews.com/aerospace-and-defense-
industry-suppliers-conference](http://speednews.com/aerospace-and-defense-industry-suppliers-conference)

**May 5-9—AIAA's SpaceOps 2014 13th
International Conference on Space
Operations.** Pasadena (Calif.) Convention
Center. www.aiaa.org/spaceops2014

**May 12-15—Association for Unmanned
Vehicle Systems International's Unmanned
Systems 2014.** Orange County (Fla.)
Convention Center.

[www.auvsishow.org/auvsi2014/public/
Content.aspx?ID=1394&sortMenu=102000](http://www.auvsishow.org/auvsi2014/public/Content.aspx?ID=1394&sortMenu=102000)

May 19-22—National Space Symposium.
Berlin. www.nationalspacesymposium.org/

May 20-25—ILA Berlin Air Show.
www.ila-berlin.com

**May 22—Aerospace States Association's
Annual Meeting.** Space Foundation office,
Colorado Springs. www.aerostates.org

**May 22—The Society of Experimental Test
Pilots.** Wright Patterson AFB, Ohio. www.setp.org/table/great-lakes/

May 24-25—Rotortech 2014. Novotel Twin
Waters Resort. Queensland, Australia.
www.austhia.com

**June 16-20—20th AIAA/CEAS
Aeroacoustics Conference.** Hyatt Regency
Atlanta. [www.aiaa.org/
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Reinventing A&D, Who Will Lead?



Lynn is the CEO of Finmeccanica North America and DRS Technologies and a former U.S. deputy secretary of defense.

Declining post-war defense budgets, the increased pace of technological change and globalization are combining to reshape the defense industry. The question is whether we can reinvent ourselves or be dragged through impending change involuntarily.

Today more than one-third of all platform and service dollars spent by the Pentagon are with nontraditional commercial and international companies, according to a recent study by Booz & Co. (see page 47). Combined with the sharp drop in defense spending, U.S. defense companies are chasing a declining share of a declining market with fewer funds allocated for the development of next-generation technology.

Such change will become a growing problem if not properly managed. For generations the Pentagon has been a technology exporter to the commercial sector of transformational capabilities such as GPS and the initial Internet developments. Today it is increasingly becoming an importer of the technological ad-

“The focus on keeping stock prices high has deferred deeper consolidation or increased investment in next-generation, disruptive technologies.”

vances taking place all around us. For example, given the role of information technology in everything from commerce to national security, we are increasingly relying on commercial industry for software and tools. Companies like Google and SpaceX are moving into defense. Soldiers can use smartphones to obtain real-time surveillance from drones or coordinate with fellow troops via text-messaging.

Unfortunately, there are no defense companies among the top 20 industrial research and development spenders worldwide. In fact, the company-funded R&D budgets of the top five U.S. defense contractors combined still would not put defense on the list. Next-generation commercial technology speeds ahead in areas such as 3-D printing, renewable energy, nanotechnology, autonomous vehicles and the Cloud.

Meanwhile, globalization is altering the defense industry in much the same way it has revamped other businesses. We live in a borderless world. China makes iPhones. Ohio builds Hondas. India produces

generic drugs. No U.S. weapons system today is made without foreign parts and suppliers. In fact, the biggest U.S. military acquisition in history—the Joint Strike Fighter—has nine partner countries participating in its development.

How can the Pentagon and industry benefit the most from today's changing landscape? I would suggest three steps:

- For starters, the U.S. government should allow further consolidation where necessary, so industry can streamline operations and focus resources on the technology development that maintains U.S. pre-eminence globally. With a greater than 20% drop in defense spending in recent years, it is not possible or desirable to retain the current industry structure in these circumstances.

- Second, government and industry should more fully embrace globalization to benefit from the investments made by key U.S. allies and partners.

- Third, the Pentagon should pursue genuine acquisition reform, not just for the conventional reasons of lowering costs and reducing schedules. The goals of reform should include lowering the barriers to entry in the defense market to allow better access to commercial technology.

Taken together, competition would *increase* despite further consolidation if the U.S. concurrently made it easier for all companies to vie openly and fairly. This could only happen if the Pentagon overhauled its Byzantine acquisition process.

So far, the defense industry is moving slowly to adjust to this emerging environment. The largely financial focus on keeping stock prices high through share repurchases and increasing dividends has thus far deferred deeper consolidation or increased investments in next-generation, disruptive technology.

Short-term actions like this cannot go on indefinitely in a declining market. For real change to occur, U.S. defense companies must increase spending on research and development and leverage the world's best technology, especially from nations that purchase our defense systems and train and fight alongside our armed forces.

Ultimately, the Pentagon and our industry must let global free-market instincts prevail. That is the best and only way to harness the benefits of change and maintain U.S. technological superiority in the wake of this next evolution in the defense industry.

When it comes to our defense, today the U.S. has a unique opportunity to look beyond its borders, both physical and mental, and turn the tide of global and technological change to its advantage. ☛



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