

Russia's
Air Traffic Games

No Takers for
Airbus's A330 Regional

Litmus Test
for the F-35B

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ADVANCED MANUFACTURING

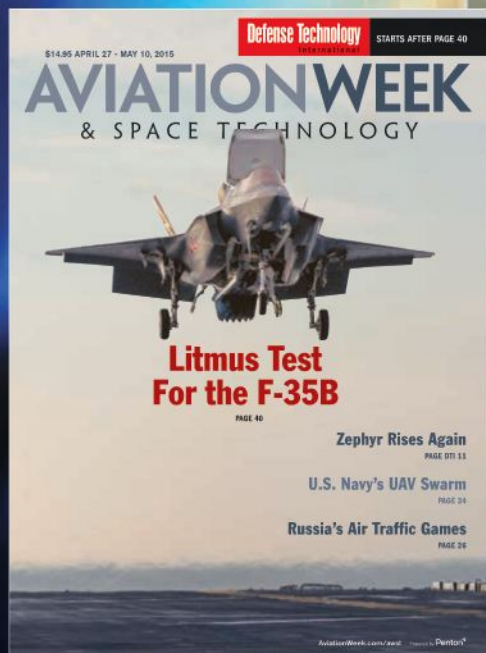
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COMPANIES



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The number of intercepts in international airspace prompted by Russian military aircraft, such as the turboprop Ilyushin Il-20, increased markedly during 2014. Alarm over the proximity of military aircraft to airliners flying in Europe's international airspace has prompted the European Aviation Safety Agency to examine how it can separate the two.

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ON THE COVERS



This week, Aviation Week publishes two editions. The far left cover features a special report on advanced manufacturing that examines whether the automotive industry's embrace of composites can be applied in the production of aircraft, which are built at much lower volumes (page 70). The cover's left photo shows composite structure BMW i3 electric cars being assembled in a highly automated plant in Leipzig, Germany, while the right photo features an Airbus A350 being assembled in Toulouse. More than 50% of the airliner's structure is carbon fiber. BMW and Airbus photos. In both editions are articles on how Europe is trying to cope with Russian military aircraft flying without transponders or radio contact (page 26), Airbus's failure to attract Chinese interest in a regional A330 (page 37), Aviation Week's annual Top-Performing Companies rankings and analysis (page 42) and the approach of crucial ship-based operational tests of the F-35B, a precursor to the Marine Corps declaring initial operational capability for the new fighter jet (page 40). An F-35B is featured on the cover of our Defense Technology International edition. Lockheed Martin photo. Aviation Week publishes a digital edition every week. Read it at AviationWeek.com/awst and on our app.



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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.

EFFECTIVE CAS IS ELUSIVE

In regard to "Danger Close" (AW&ST March-30-April 12, p. 54), in light of the air defense systems coming into service and their layering and density, note that when the F-35 becomes operational it will be forced to fly an attack profile similar to the A-10's. Given the new aircraft's lack of armor, single engine, general vulnerability, high cost and the very ad hoc nature of true close air support (CAS), the F-35 will never fly CAS against any peer or near-peer opponent.

It is fairly easy to design a CAS airplane to supplement and/or replace the A-10, but the real problem is the total absence of an effective, survivable manned-C4 intelligence, surveillance and reconnaissance (ISR) capability, which the Air Force has bitterly opposed developing.

As for other fighter aircraft, their use at such a tempo over so long a period literally guts any viable doctrine for fighting today's unconventional wars due to a total failure to grasp the proper use of asymmetry, or even recognize, much less understand, the asymmetries exploited by our foes.

Thomas J. Rath

PASADENA, CALIFORNIA

CONSPICUOUS ABSENCE

A table titled "U.S. Air Force Close Air Support Aircraft and Munitions" accompanied the recent article "Danger Close." The table was informative, but you left out an important category: Forward-Firing Precision Weapons.

Both the MQ-1 and MQ-9 can carry AGM-114 Hellfire missiles when in the armed ISR role or when expected to provide CAS support, and this is often a crucial difference between the support an MQ-9 can provide and (for example) what a B-1 might provide. The low-collateral-damage and small-danger-close numbers often make the difference in opting to employ or not.

The static and moving-target capabilities of the AGM-114 are hugely valued by ground troops in CAS situations, especially when the situation is dynamic or enemy forces are in close proximity to friendly forces. It is why the A-10 is so valued as well.

Name Withheld By Request

SAN DIEGO, CALIFORNIA

SIMPLE SOLUTION?

The A-10 Warthog solution seems too close to the noses of the parties locked in the argument.

Although it involves a major shift within the Pentagon, this dilemma could be solved by these actions:

- Mandate that air operations below 200-ft. altitude belong to the Marine air and Army air units.
- Transfer all A-10 assets, spares, and associated personnel and equipment to the Army and Marine Corps.
- Tie payment for A-10 operations to units that use and control them. Air cover would belong to the Air Force over land and Navair over the seas and waterways.

It all seems so logical. I am speaking based on a long career as a methods and standards engineer with the now-shuttered Naval Aviation Depot.

Richard Neveln

ALAMEDA, CALIFORNIA

BRAVING THE NEXT STEP

I am of a generation that empathizes with reader Col. Michael Gallagher (AW&ST April 13-26, p. 6) about retaining the A-10, but I sense we are wrong.

Analogies from the past include men charging at machine guns with bayonets, which were, after all, a great improvement on pikes, or the cavalry patiently standing by from 1914-17 waiting to pursue an enemy that refused to retreat, to name but two instances.

The military have always resisted embracing new weaponry. It is hard to like the F-35, but we must.

Lew Creedon

OCEANSIDE, CALIFORNIA

COCKPIT ACCESS VIABILITY

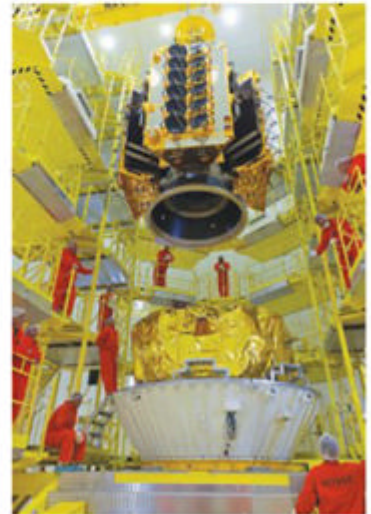
I applaud Jens Flottau's commentary "Flight 9525 Lessons" on the consequences of a rush to judgment in the aftermath of the Germanwings accident (AW&ST April 13-26, p. 17). But I have one quibble. He says the "possibility of pilot suicide was not considered" [in the aftermath of 9/11]. I disagree.

The aerospace community was well aware of the suicidal implications in the Egyptair and Silk Air events he cited, but no one could recommend an emergency override that did not conflict with the top priority—deny access to terrorists at all costs. And I haven't seen a convincing proposal since.

If we believe the terror threat has lessened or if it hasn't, that we can rely on passenger power, then do provide emergency access. But does anyone truly believe that?

Alex Fisher

BANBURY, ENGLAND



OSB NETWORKS

TOUTING TUGS FOR SPACE DEBRIS

The era of small satellites is nearly upon us as manufacturers position to provide vehicles and systems for an emerging market, as highlighted in "The Year of the Smallsat" (AW&ST March 30-April 12, p. 31).

As we start to fill up the prime low-Earth-orbit real estate with smallsats, we should not overlook a companion need in support of their proliferation—removal of the inevitable space junk that will be generated by failed smallsats and, even worse, orbital debris from smallsat collisions.

Yes there is still a lot of "space" in space, but cheap smallsats will bring a higher probability of failure compared with the more robust satellites currently in service. And the potential number of these less-expensive craft could be astronomical.

An enterprising company that can field a small maneuverable space tug with grappling capability to cope with the carcasses of spacecraft will be needed to clean up the remains and deposit them in a decaying orbit. The responsiveness of the tugs will have a significant impact on the balance sheet of the smallsat constellation owner/operator.

Tom Megna

LITTLETON, COLORADO

Who's Where



Gerry McRae



Robert McGahan



Patrick Coulter



Scott Politte



Jim Geary



Richard Bardellini



Dan Colbert

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

Brian Hunter has been named vice president-sales and marketing for *Ametek Singapore*. He was head of the Asia Pacific Comprehensive Accessory Repair and Exchange program of UTC Aerospace Systems.

Steve Hasker has been appointed to the board of directors of Los Angeles-based *Global Eagle Entertainment Inc.* He is global president at Nielsen N.V. and was its president for global products.

Sonny Stern has become vice president of sales for MRO Services at Atlanta-based *Delta TechOps*. He has been an executive at the International Lease Finance Corp. and AerCap.

Gerry McRae (see photo) has been promoted to executive director of business development from director of project management for *Flight-Safety International* of New York.

Robert McGahan (see photo) has been appointed director of business development for government training and simulation. He was manager of military business development for visual systems. **Patrick Coulter** (see photo) has been named director of business development for commercial training and simulation. He has been manager of FlightSafety's Learning Centers in Toronto and Tokyo. And **Scott Politte** (see photo) has become assistant manager of FlightSafety International's Wichita East Learning Center. He succeeds **Russ Axtell**, who has retired. Politte was the center's assistant director of training.

Erin Neal has been appointed an executive vice president at *McBee Strategic Consulting* in Washington. She was director of government relations for Orbital-ATK and had been manager for government relations at Ball Aerospace and Technologies Corp.

Ernest Waaser has become CEO of *NuSil Technology*, Carpinteria, California. He succeeds **Dick Compton**, who is retiring as CEO, but will continue as chairman. Waaser was an operating partner at Linden Capital Partners and had been CEO of Systagenix Wound Management.

Jim Geary (see photos) has been promoted to executive vice presi-

dent from vice president-sales of Peterborough-based *New Hampshire Ball Bearings (NHBB)*. **Richard Bardellini** has been promoted to executive vice president of R&S North America/general manager of the NHBB Astro Div. in Laconia from vice president-manufacturing and operations for NHBB's manufacturing divisions.

Philip Kiel has been appointed president of *Photo-Sonics Inc.*, Burbank, California. He was vice president-operations.

John R. Gawsyszawski has been named CEO of *Pacific Aerospace Resources & Technologies*, Victorville, California. He was chief operating officer and succeeds **David Green**, who is now chairman. Gawsyszawski has been vice president-business development at Air Services based in Cleveland.

Dan Colbert (see photo) has become president/CEO of *Aircraft Propeller Service*, Lake Zurich, Illinois. He succeeds **Mark Grant**, who will be chairman. Colbert was an operating partner for The Riverside Co. and was president of Crane Composites.

USAF Brig. Gen. Joseph T. Guastella has been nominated for promotion to major general and assignment as deputy chief of staff for operations, Supreme Headquarters Allied Powers Europe, Mons, Belgium. He has been deputy director for requirements for the Joint Staff at the Pentagon in Washington. Guastella will be succeeded by Brig. Gen. **Steven L. Basham**, who has been director of strategic plans, requirements and programs at Headquarters Pacific Air Forces, Joint Base Pearl Harbor-Hickam, Hawaii. He will be followed by Brig.

Gen. Gregory M. Guillot, who has been commander of the 55th Wing of Air Combat Command, Offutt AFB, Nebraska. Brig. Gen. **Ricky N. Rupp** has been appointed U.S. defense attache and senior defense official for

Israel at the U.S. Embassy in Tel Aviv. He has been special assistant to the commander of United Nations Command of Combined Forces Command, U.S. Forces Korea, Yongsan, South Korea. He succeeds Brig. Gen. **John S. Shapland**, who has been named director of air, space and information operations at Headquarters Air Force Materiel Command, Wright-Patterson AFB, Ohio.

Katherine A.W. McGrady has been appointed president/CEO of the *CNA Corp.*, Arlington, Virginia. She has been acting president of the Center for Naval Analyses. McGrady will succeed **Robert J. Murray**, who plans to retire.

Oliver Stratford has been named sales manager for Southern Africa for London-based *AJW Aviation*.

HONORS AND ELECTIONS

Capt. Lou Nemeth, who is chief safety officer at CAE Inc., has been named to the board of governors of the Washington-based *Air Charter Safety Foundation*.

Mark Roberts, who is a practice director within Bristol, England-based Atkins's aerospace, defense, security and technology business, has been appointed chairman of the executive committee of the *Air Power Association*. He is the first chairman who is not serving in the Royal Air Force.

Steve Townes, who is president/CEO of Ranger Aerospace, Greenville, South Carolina, has been named chairman of *SCAerospace*, a group organized by the South Carolina Council on Competitiveness and the Commerce Department. ☼

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DEFENSE

The U.S. Navy's Northrop Grumman X-47B accomplished the first autonomous aerial refueling of an unmanned aircraft on April 22. Flying behind an Omega Boeing K-707 tanker off the U.S. East Coast, the probe-equipped unmanned combat air system demonstrator autonomously engaged the deployed drogue and took on 4,000 lb. of fuel. The test concluded the planned X-47B demo program.

Poland has selected Airbus Helicopters' H225M as its future military utility helicopter, and Raytheon's Patriot as its next-generation air defense system, together valued at around \$8 billion. The defense ministry says helicopter bids from AgustaWestland and Sikorsky, which already have facilities in Poland, did not meet requirements (see page 28).

India may scrap its long-delayed Medium Multi-Role Combat Aircraft (MMRCA) deal with Dassault for 126 Rafales in favor of a government-to-government route, after negotiating the purchase of 36 Rafales from France in flyaway condition under a separate deal. MMRCA includes 18 aircraft from Dassault and the rest built locally by Hindustan Aeronautics Ltd., but negotiations have "gone into a loop," says India's defense minister (see page 29).

Dassault's Falcon 2000 Maritime Surveillance Aircraft has been selected by Japan's coast guard. The number of aircraft required was not disclosed. Dassault's partners in equipping the aircraft are L-3 Platform Integration and Thales. The coast guard already operates two Falcon 900s.

The due-regard radar required for the U.S. Navy's Northrop Grumman MQ-4C Triton to operate in international airspace will now be fitted to the "multi-intelligence" version of the unmanned aircraft, slated to become operational in 2020. The active-array radar was planned for the baseline version of Triton, which is to be operational in 2018, but hit development problems.

Antonov rolled out the An-178 transport aircraft on April 16 in Kiev,



ANTONOV

Ukraine. First flight is planned for early May. The airlifter is derived from the An-148 regional jet, with a rear cargo ramp, reinforced landing gear and uprated Ivchenko D-436 turbofans. In February, United Arab Emirates-based freight carrier Maximus Air signed a letter of intent for An-178s.

COMMERCIAL AVIATION

Citing Rolls-Royce's willingness to inject new technology into its engine, Emirates has switched suppliers and placed an order valued at \$9.26 billion for Trent 900s to power its next batch of 50 Airbus A380s. The deal potentially moves the airline closer to a reengined A380neo, which Emirates President Tim Clark says Airbus is still considering.

Forget inflight lounges, shopping and spas, Airbus is offering an 11-abreast economy configuration in the A380 main

deck. Operators will have the choice of 10-abreast standard economy seating or adding one seat per row. The seats are installed on the existing rails, so no extra floor work is needed. The configuration will be available in 2017 (see page 64).

Mitsubishi Aircraft will move a fourth aircraft to its planned U.S. flight-test effort to offset another delay in development of the MRJ regional jet. Ground tests revealed a software bug and the need to redesign some parts, delaying first flight to September-October from the second quarter. First delivery remains targeted for the second quarter of 2017 (see page 39).

Air Berlin and International Airlines Group (IAG) carriers British Airways and Iberia have withdrawn from the Association of European Airlines, citing disagreement over protectionist aviation policy. European airlines led by Air France-KLM and Lufthansa are calling for curbs on the growth of Gulf carriers. Qatar Airways is the biggest investor in IAG, and Etihad Airways in Air Berlin (see page 36).

Struggling with chronic airliner seat-delivery delays, Zodiac Aerospace has launched a major process reorganization. "We overloaded the production capacity," says CEO Olivier Zarrouati. "These delays are unacceptable, for the client and for us." He expects the delays, which have had an impact on Airbus and Boeing deliveries, to be resolved by August.

BUSINESS AVIATION

Piper Aircraft has revamped its high-performance single-engine line, introducing the turboprop M600 and Meridian M500 and the M350—an upgraded piston-engine Mirage. The M600 has Garmin G3000 touch-screen



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avionics and a new wing with more fuel capacity for a maximum range of 1,300 nm. Certification is expected in the fourth quarter. The M350 was certified on April 10.

Eclipse Aerospace and Kestrel Aircraft have merged to form One Aviation, with plans to develop a family of aircraft including the Eclipse 550 twin-engine light jet and Kestrel K350 single-engine turboprop. Kestrel's Alan Klapmeier, who co-founded Cirrus Aircraft, is CEO with Eclipse's Mason Holland as chairman. Kestrel development will now be funded from Eclipse sales.

ROTORCRAFT

Canada has ordered seven Bell 412EPi medium utility helicopters for its Coast Guard modernization. The C\$155 million (\$123 million) deal is the second helicopter contract placed by the Department of Fisheries & Oceans—umbrella agency for the Coast Guard—following a 2014 order for 15 Bell 429s. The 412s will be delivered starting in June 2016, replacing Bell 212s.

To ensure its Model 525 super-medium helicopter will not be missed when it makes its first flight, Bell has painted first prototype FTV1 bright orange. FTV1 is largely complete and awaiting installation of its five-blade main rotor system in preparation for ground runs and a first flight, likely to take place in the next couple of months.



BELL HELICOPTER

SPACE

Slower than expected throttle response is blamed for SpaceX's latest failure to demonstrate recovery of a Falcon 9 first stage by landing it on an unmanned landing platform, or "drone-ship," at sea. The stage toppled when it touched down with too much horizontal velocity after the April 14 launch of



SPACE EXPLORATION TECHNOLOGIES

SpaceX's sixth cargo resupply mission for NASA. The next landing attempt may be on land (see page 33).

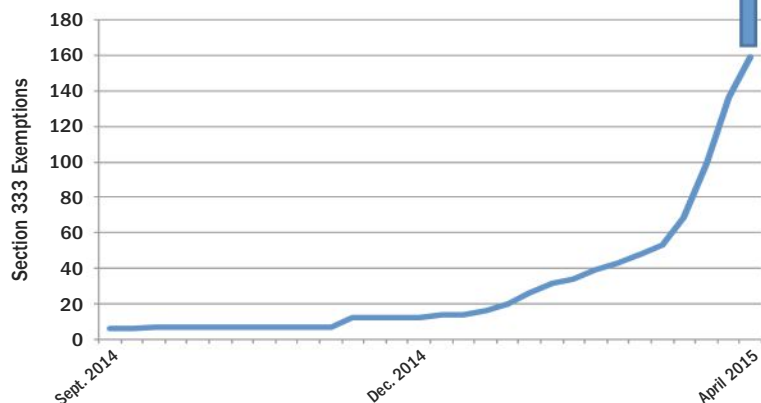
Wear in main-engine turbopump bearings is the "most probable" cause of the explosion that destroyed an Orbital ATK Antares launch vehicle on a resupply mission to the International Space Station in October. But engine supplier Aerojet Rocketdyne argues the source of wear was likely ingested debris in the propellant, which would shift responsibility to first-stage tank provider Yuzhmash and Orbital.

NovaWurks has agreed to build a 40-satellite constellation for a Canadian start-up using mass-produced "satlet" modular building blocks it is developing for Pentagon research agency Darpa. The company will provide the space segment for Montreal-based NorStar Space Data, which plans to provide hyperspectral Earth-observation and space-debris tracking services in low Earth orbit.

FAA's Accelerating Commercial UAS Approvals

1,672 operations approved in Canada¹

729 FAA petitions still pending²



¹As of Dec. 31, 2014

²As of April 20, 2015

Sources: FAA, Transport Canada



10 YEARS AGO IN AW&ST

The Airbus A380 made its maiden flight from Toulouse on April 27, 2005, in front of 50,000 onlookers. French President Jacques Chirac hailed the flight as "a milestone for Europe," but the program soon was bedeviled by wiring problems that would delay its entry into service with Singapore Airlines by about a year, to October 2007.

Read our original coverage of the first A380 flight and other momentous events at:
AviationWeek.com/100





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COMMENTARY

Defense Offset Strategy Needs a Big Idea

It seems clear what is foremost for Deputy Defense Secretary Robert Work these days. At the Pentagon's April 9 press conference endorsing "Better Buying Power 3.0," Work said the impetus for his new "offset strategy" is an urgent concern about "a steady erosion of our technological superiority that we have relied upon for so long in all our defense strategies."

The day before, he had implored students and staff at the Army War College in Carlisle, Pennsylvania to join the initiative's modernization campaign "to identify the technologies, identify the operational and organizational constructs . . . to fight our future adversaries."

The time is surely right for the Pentagon to focus its attention on retooling military capabilities. The counterinsurgency wars in Iraq and Afghanistan have, of necessity, imbalanced our forces' readiness for other kinds of conflict. And the flat outlook for U.S. defense spending will continue to impose trade-offs that test priorities. But the occasion for this initiative also arises from historical changes within the arenas of economics and technology. And while there is plainly an appreciation of how the distribution of economic power and diffusion of technologic know-how is transforming the threat, too little is being said about how these factors also will shape the particular leverage the U.S. and the West can employ to offset adversaries' comparative advantages. Simply put, I believe our reflex to gain that leverage from yet another technological revolution is misguided.

By invoking the term "offset strategy," Work is harkening to two historical precedents. In 1954, President Dwight D. Eisenhower (left photo) announced the results of a "New Look" at U.S. force posture in Europe, where the Warsaw Pact enjoyed an overwhelming advantage of conventional forces. To counter Soviet



U.S. INSTITUTE OF PEACE

U.S. DEFENSE DEPARTMENT

superiority without bankrupting the West, the New Look traded manpower for nuclear warheads and their delivery systems, in which the U.S. enjoyed a decisive technological advantage.

By the mid-1970s, when the Soviets' development of nuclear weapons and adaptation of conventional forces again called into question the credibility of European defenses, then-Defense Secretary Harold Brown initiated what came to be regarded as the second offset strategy. The result—clearly expressed in the Long-Range Research and Development Planning Program (LRRDP) run from William Perry's (center photo) directorate for research and engineering—set out to achieve decisive military advantage by using precision-guided weapons orchestrated through a network of command, control, communications and intelligence.

New Look marked a lethality revolution in U.S. defense planning, and the LRRDP is credited with instigating a precision revolution that has differentiated U.S. military capabilities from the Persian Gulf war in 1991 through today. So what kind of revolution in U.S. military capabilities will Bob Work's (right photo) turn of the offset strategy produce? To answer that, the Pentagon

will need to discern the most problematic military challenges adversaries present and, in turn, the comparative advantages from which our society can gain leverage.

At Carlisle, Work proffered a three-pronged challenge confronting U.S. military forces: The proliferation of precision munitions amplified via an "informationalized" operating concept and employed by a diversity of fighting formations. Sharpening that formulation into a problem statement as compelling as the ones "Ike" and Bill Perry had would go a long way toward focusing the work of the initiative, which today seems diffused across a too-broad range of objectives. Unhelpfully, Work now speaks of not one but several offset strategies encompassing a multitude of potential competitors, each of which is "probably going to require a different approach and a different strategy."

More important, realizing an effective new offset strategy also will require a new understanding of the sources of America's comparative advantage in the 21st century. The initiative seems to assume that decisive advantages in the two strategies to offset Soviet military power—superior economic and technological resources—can be relied upon again. They cannot: Economic power is today broadly distributed and most advanced technologies are accessible around the globe.

If the U.S.'s economic and technological resources are no longer truly discriminating, where will we find the leverage needed to fuel the strategy? Will the third offset strategy mark a revolution in military adaptation that leverages our society's nearly unique capacity to absorb and prosper from change? Will it harness our dominant media and entertainment industries to overmatch adversaries' attempts to command the narrative of conflict? Or will the third offset strategy be remembered as a revolution in operating and organizational constructs that exploits the American propensity for business-model innovations that build "blue oceans" of uncontested market space?

These are the big ideas at the heart of the problem facing the Pentagon's offset strategists; let us hope they are addressed before simply trying again to invent our way to sustaining U.S. military dominance into the 21st century. ☛



By Michael Bruno

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COMMENTARY

Do Your Research

In Pentagon's push for industry R&D, 'I don't know' risks becoming 'I told you so'

U.S. department store pioneer John Wanamaker allegedly once lamented that half the money he spent on advertising was wasted, the problem was he didn't know which half.

For years now in aerospace and defense, industry seemed to be saying the same thing when it came to its own independent research and development (IRAD) spending. The solution, unfortunately, has been simply to cut back on it and to focus most of its internal R&D eyed for government contracts on merely cutting the prices of their products to win awards (see Top-Performing Companies articles on pages 42-50).

Companies might have been able to get by in this fashion since the end of the Cold War, but analysts and observers are increasingly seeing the potential for a major change to industry later in this decade, and those who know are talking about where to look for clues. A big one stems from the Pentagon's recently finalized Better Buying Power 3.0 acquisition policy and outreach to nontraditional providers, as well as the consequences it may—or may not—bring.

“From our Washington perspective, we have not believed that consensus appreciates how shifting Defense Department concerns could impact defense contractor valuation and financials in 2016-18,” says TPC adviser Byron Callan, a director at Capital Alpha Partners.

With apologies to Ernest Hemingway, one reason the “consensus” may not be appreciating it yet is that change can come “gradually, then suddenly.” The Pentagon has openly expressed concern about losing U.S. military technological superiority to the likes of China, Russia and others since at least late 2013. At the time, America was still caught up in getting to know “sequestration” and the political gridlock that shut down the government. Complaints about R&D spending might have been lost in noise.

Also, the first two iterations of Better Buying Power had little to do with



U.S. DEFENSE DEPARTMENT

technology and more to do with fixing the widely described broken defense acquisition system. Now comes BBP 3.0, along with the so-called Third Offset strategy and a soon-to-be-revealed Long-range R&D Plan. While officials like Defense Secretary Ashton Carter and defense acquisition czar Frank Kendall have only just begun their road trips to explain what they hope to achieve, the new policies appear to have the potential to be felt.

For instance, under BBP 3.0 defense contractors will have to notify and seek the endorsement of a Defense Department official regarding some of their IRAD. Kendall told reporters this month that the requirement will be “minimum,” and essentially involves finding someone in the department to agree to a company's plan. But it nevertheless reflects a desire by Pentagon officials to reassert influence over industry's IRAD after acquisition reforms in the early 1990s loosened reins, with many companies focusing their spending on ways to stay competitive or dominant, and not on technological advances for the military.

The Pentagon will use powers already on the books to do this. Contractor IRAD—separate from government-funded research—can be expensed to the department as a reimbursable cost to a degree. Around \$4 billion in IRAD

conducted by defense companies as an allowable overhead expense is spent every year, according to the department.

While such new requirements might seem onerous, remember that the whole technology push represents an opportunity to industry. The Third Offset strategy looks to develop robotics, autonomous systems, big data and advanced manufacturing, and other “next-generation” technologies. The question becomes who takes advantage of this opening: “disruptive” companies like Amazon and Google, heritage primes like Boeing and Lockheed Martin, or international companies to be named?

For the primes, at least, a course

Frank Kendall, the undersecretary of defense for acquisition, technology and logistics, wants your R&D.

correction is necessary first—and the Pentagon is not immune either.

“It is expected that the defense industry would have business opportunities to research, develop and field these technologies should there be a business case and projected return on investment,” consulting firm Deloitte—a TPC participant—says in its global A&D forecast this month. “However, with both the Pentagon, as well as company funded R&D in a long-term decline, the investments and funding required for development may slow down this well-intended strategy.”

For sure, other issues such as intellectual property rights and ownership also will have to be worked out, according to several analysts. And above all, the customer must become dramatically quicker in sourcing and applying new technology and using other innovations.

“The focus on technology is welcomed by many in industry, but there are also a number of firms working on technologies, such as robotics, that are currently not particularly interested in working with the Defense Department,” says Andrew Hunter, director of the Defense-Industrial Initiatives Group at the Center for Strategic and International Studies.

“If the Pentagon wants to sustain U.S. technological superiority in the 21st century,” he adds, “it will need to invest in building a culture of innovation and experimentation and [to] deploy new technologies faster.” ☛



By William Garvey

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COMMENTARY

Eagle Arising

Pioneer for the sad and the successful that followed

When the subject turns to all-composite production airplanes, several makes and models come to the fore: Boeing's 787 Dreamliner; the Cirrus SR20/22, Cessna's sporty TTx, Austria's Diamond Aircraft line, the ill-starred Beech Starship and Bombardier's \$1.4 billion balk, the Learjet 85. What rarely enters that discussion is the very first of the kind, the Windecker Eagle 1. Until now.

The Eagle can trace its genesis to the 1950s and the Lake Jackson, Texas, dental chair of Leo "Doc" Windecker, whose patients included workers from the local Dow Chemical plant. Through casual discussions with them he learned that Dow was developing glass fiber material that was lightweight but strong, flexible and didn't corrode. A pilot and irrepressible tinkerer, Windecker thought those properties would be ideal for airplane construction.

In 1958, together with his dentist-wife, Fairfax, he began researching fiberglass-reinforced plastic structures and soon had enlisted the support of Dow. Ultimately, they won a patent for a flexible, non-woven epoxy glass fiber they christened "Fibalay." Encouraged by further experimentation, the couple formed Windecker Research in Midland, with the express purpose of building and certifying an airplane.

What evolved was a sleek, four-place, low-wing monoplane powered by a single 285-hp Continental engine, which began flight-testing in early 1969. Since the FAA had no experience with composite airframes and engines, the agency imposed an overdesign requirement of 20% on it. And when the aircraft went into a flat spin due to improper weight distribution and crashed during its final spin test—the pilot bailed out successfully—the agency then insisted the subsequently modified design undergo exhaustive spin testing. Finally satisfied with the design and construction, in December 1969 the agency awarded the Eagle I a type certificate, the first under FAR23.

COMMUNICATION RESOURCES, INC.



Eagle 1 with new engine and prop.

But just as the Windeckers began manufacturing the aircraft, a recession hit and the light airplane business went into lockdown. Having already spent \$20 million and unable to secure further financing, Windecker closed its doors after building just nine airplanes, including the two prototypes and one delivered to the U.S. Air Force, which wanted to test its stealth characteristics.

Only two airframes, both unflyable, remained in private hands—those of Windecker's son, Ted. Not long ago he transferred ownership to Wei Hang, a Chinese entrepreneur determined to see the Eagle soar again. At the moment, a restoration team in Mooresville, North Carolina, is using elements from the two aircraft plus a new engine, avionics package, interior and prop to create a single flyable one, albeit with an Experimental license. The goal is to have it ready for this summer's AirVenture in Oshkosh, Wisconsin.

After that, Hang will have the Eagle shipped to China, where he intends to learn to fly. While the airframes' acquisition, together with the restoration and upgrade, represent a formidable investment in a failed machine, project chief Don Atchison says because of the

aircraft's "historical significance, rarity, style and performance," Hang "will own a truly unique aircraft when it's finished and flying again." ☺

HIGHLIGHTING HAZARDS

What's the most common type of accident in business aviation? According to the National Business Aviation Association's (NBAA) Safety Committee, it's the "runway excursion," a term for an aircraft running off the runway end or side and into uncharted territory.

These sometimes deadly events occur during takeoff or landing and can involve any number of factors, from an unstable approach to ice or snow on the runway to a mechanical fault. In May 2014, a Gulfstream IV overran the runway end at Hanscom Field near Boston during a rejected takeoff, and in the subsequent crash, both pilots, a flight attendant and four passengers were killed and the aircraft destroyed.

Despite efforts to reduce the rate, the committee says the frequency of runway excursion accidents has changed little over the past decade, noting the rate has hovered around 3.6 per million flights. That's 60% higher than the corresponding commercial aviation rate.

Runway excursions are often survivable and preventable, based on well-identified risk factors, aircraft performance considerations and recommended defenses, which makes the mishaps a logical target of a focused risk-reduction effort, the NBAA says.

Consequently, the committee has identified runway excursions as one of its two primary safety issues for the year. The other is loss of control in flight, cited as a possible factor in over 40% of fixed-wing general aviation accidents from 2001-11, many involving non-professional, single-pilot operations.

Safety Committee Chairman Steve Charbonneau says today's congested airspace, complex procedures and the intensity of voice communications invite task saturation and distractions in single- and two-pilot cockpits. ☹



Steve Charbonneau

S CHARBONNEAU



By Jens Flottau

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COMMENTARY

Caution Warranted

The higher value of the U.S. dollar is reemerging as a major factor in air transport

A decade ago and before the big round of mergers, “international” used to be the magic word for U.S. airlines. It seemed to open up an opportunity for growth despite the mature domestic market, and the weak dollar was seen as a plus. But times have changed. The capacity reductions across its international network announced by Delta Air Lines as it presented first-quarter earnings are pretty substantial: Up to 20% fewer seats to Japan, 15% less to Brazil and up to 25% fewer to the Middle East, Africa and India.

Delta's decision may have been radical, since its profits are still healthy. If Delta is hurting on its international routes, then so are United and American, the other two U.S. airlines that have significant international exposure. Southwest, JetBlue and Alaska have less to fear in that regard.

The move illustrates that the ongoing debate about the recent boom in aircraft orders, the growth in capacity and the still relatively slow pace of retirements has not gone far enough. The discussion about the huge demand for aircraft and whether or not an order bubble has built up has emerged only because interest rates have plunged and the price of fuel had been high. Interest rates are still low, making borrowing affordable even for airlines with weaker balance sheets. But after the recent drop in oil prices, the rise of the dollar back to where it was 15 years ago is the second major underlying factor for the air transport industry that has changed substantially in recent months.

The impact of a stronger dollar will differ greatly from carrier to carrier and region to region. Like lower oil prices, it will only be felt over time, as previous currency hedges expire, and will only have a structural influence on the industry if the dollar remains stronger vis-a-vis other leading currencies, like the euro or the Japanese yen.

For example, a large U.S. airline only benefits fully from the low price



Delta is retiring a further six Boeing 747-400s this year as it reduces capacity in several international markets.

of fuel because it is priced in U.S. dollars. But for European airlines, the more expensive dollar eats up a lot of the cost savings they could in theory have expected from the oil price drop. Delta sees an impact internationally because revenues generated in foreign currencies are worth less at home, but it still has a huge domestic network that is unaffected.

European airlines see the opposite effect wherever they generate U.S.-dollar revenues, but the impact will still be mixed, because travel to the U.S. is now a lot more expensive for Europeans and fewer will be able to afford it. Carriers in the United Arab Emirates (UAE) will see the fuel price

benefit—since the UAE dirham is tied to the dollar—but are also hit by weaker Asian currencies and the weaker euro. And neither Emirates nor Etihad has a domestic network that will be able to balance out what is changing internationally. And so on.

But let's not forget what a persistently higher-value dollar could mean for the two big aircraft manufacturers, Boeing and Airbus. Once Airbus Group's currency hedges expire in the next one to two years, the company will benefit. It is selling most of its aircraft in dollars, yet in spite of efforts over several years to put more manufacturing into dollar-based economies (assuming that currency's continued weakness), a huge part of its production remains in Europe. The revenues generated in dollars through aircraft

sales will therefore be worth more, even when higher dollar-based payments to international suppliers are taken into account.

The question is how Airbus will use this future advantage. It could be tempted to buy more market share, because it can now more easily afford to offer discounts in key campaigns that it does not want Boeing to

win and those discounts will hurt its bottom line much less. Therein lies a risk for Boeing that should not be underestimated, but there is a risk to the industry as a whole as well.

Many analysts have been warning for a long time that the numbers of aircraft that airlines have been ordering for several years—based on the assumptions of ongoing low interest rates, high fuel prices and a weak dollar—have simply been too high. It is probably too soon to tell how exactly these dynamics will change, but with two major parameters driving industry performance having swung so dramatically in a short period of time, the industry would do well to exercise caution, as Delta has done. ☛



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COMMENTARY

Sea State of the Art

From overwhelming defenses to following submarines, autonomy could reshape naval ops

The U.S. Navy may be struggling to get its signature carrier-launched surveillance and strike unmanned-aircraft program off the ground, but it has more than one autonomous card in its maritime deck. From long-endurance air vehicles flying from warships and swarming small UAVs overwhelming adversaries, to long-duration unmanned undersea and surface vessels, the Office of Naval Research (ONR) is pushing to prepare autonomous technologies for the fleet.



DARPA CONCEPT

The Low-Cost UAV Swarming Technology (Locust) program will demonstrate the rapid launch of 30 disposable small air vehicles to autonomously come together and perform a mission. The goal is to show that swarming UAVs can defeat an adversary more cost-effectively than other weapon systems. The demos, using Raytheon's Coyote tube-launched small UAV, will take place from ONR's Sea Fighter technology-demonstrator vessel off the Florida coast in fiscal 2016-17.

Last August, in a demo on the James River in Virginia, ONR showed that swarming small unmanned surface vessels could overwhelm a hostile vessel. The technology involves a transportable kit that can be installed on almost any boat. Locust is part of an effort to demonstrate autonomy technologies that can be applied across surface, undersea and air domains, says Rear Adm. Mat Winter, chief of naval research.

ONR also has partnered with Darpa on the Tern program to demonstrate a Predator-class medium-altitude, long-endurance UAV able to operate from the small flight decks of destroyers

and other warships. Now in Phase 2, AeroVironment and Northrop Grumman are each designing vertical-lift unmanned aircraft (pictured). One is to be selected for Phase 3 to build a full-scale demonstrator for land-based and at-sea testing.

In the undersea domain, ONR has completed missions exceeding 30 days with its Large Displacement Unmanned Undersea Vehicle (Lduuv) prototype. An open-ocean demo is planned for May 2016 in which the autonomous submersible will sail from San Francisco to San Diego, says Winter. In an early example of ONR unmanned technology transitioning to the Navy, a program of record is to be started in fiscal 2016, with a production Lduuv planned to become operational by 2020.

A new program, the Medium Displacement Unmanned Surface Vehicle (Mdusv), "will be to autonomous surface vessels what Lduuv will be to undersea autonomy," says ONR. Mdusv is planned to operate with the Anti-Submarine Warfare Continuous Trail Unmanned Vessel (Actuv) being developed with Darpa. Actuv

is demonstrating "a relatively cheap unmanned surface vessel to track their expensive submarines," says Steve Walker, Darpa deputy director. "We are in Phase 3 and will test a 130-ft.-long system in the next year. The Navy will do sea trials in the fall." Leidos is prime contractor.

Darpa, meanwhile, is working to exploit autonomous technology to add flexibility and resilience to maritime systems in other ways. One of those is the Upward Falling Payloads (UFP) program to develop a globally distributed undersea payload-dispensing architecture on the deep ocean floor. "Today the Navy puts capability on the ocean floor with submarines, but we would like to preposition capabilities that are available to be triggered when needed," says Walker.

The UFP concept involves a distributed system of deployable unmanned and nonlethal nodes that would lie on the ocean floor in special containers for years at time. When remotely activated, the nodes would rise to the surface to deploy their payloads, which could include unmanned aircraft. "We are in Phase 2. This year, we will take the technologies into the water. In Phase 3, we will integrate them into a capability and also show what is possible with a distributed architecture," he says.

To support the emergence of these new autonomous and persistent capabilities, Winter says ONR plans to start a new prototype program in fiscal 2016, the Forward Deployed Energy and Communications Outpost. This will be an undersea constellation to provide communications, resupply, recharging and other services to support submarines and unmanned surface, undersea and air vehicles, and that will be able to operate when space assets and airspace are denied.

"We are working to develop an autonomous environment, not just a vehicle or a system," he says. "Autonomy brings in the technology of algorithms, software and processing, but also the humanistic side. We need to understand how humans make decisions so that in 20-30 years we can have an autonomous environment in which the human is in a Barcalounger and the unmanned system is providing persistent capabilities." ☛



By Bill Sweetman

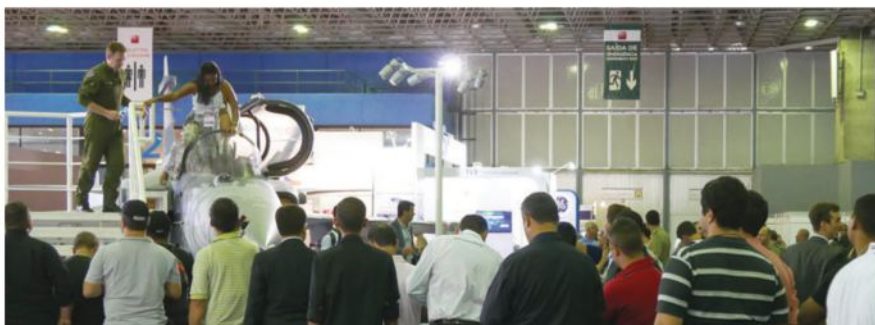
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COMMENTARY

How To Build Fighters

As India stumbles, Brazil moves forward

Being a ground-floor partner in the development of a fighter aircraft is a very big deal for Brazil. This was clear at the LAAD defense show in Rio de Janeiro earlier this month, from the long lines of showgoers waiting for a chance to pose in the cockpit of Saab's Gripen mock-up (photo), next to the all- or part-indigenous weapons under its wings or at the many "we're-on-Gripen" exhibits around the hall.



BILL SWEETMAN/AW&ST

Together with the equally ambitious Prosub submarine project, Gripen is swallowing much of Brazil's acquisition budget, delaying other projects. But the first 36 aircraft are expected to be followed by about 70 more JAS 39E/Fs for the air force and Sea Gripens for two planned new aircraft carriers in the late 2020s. Brazil is leading development of the JAS 39F two-seater and would do the same for the carrier jet.

No other South American neighbor builds fighters or submarines; they are the first target export markets, making the projects a symbol of Brazil's leadership.

The Gripen project is proceeding methodically because neither side has infinite money or manpower. It will be the 2020s before a Gripen makes its maiden flight in Brazil. But the program is on schedule, which is more than can be said for the Franco-Indian Medium Multi-Role Combat Aircraft (MMRCA).

Following a source selection almost two years ahead of Brazil's, the plan to deliver 126 Rafales to the Indian air force, with the Indian line delivering aircraft four years after contract

signature, is sunk well past the axles in a swamp of bureaucracy and mistrust, and is on hold while Dassault delivers 36 jets from its own factory.

This difference is not a fluke. The Gripen is a simpler aircraft than the Rafale that pulls parts from a global supply chain. But a lot of Rafale hardware is unique; it is France-sourced in order to be free from foreign control. Brazil's Embraer has been competing in the world market for decades, unlike state-owned Hindustan Aeronautics Ltd., which is the designated national leader on MMRCA. Dassault's initial Indian plan may have been to build an all-new factory with its preferred partner, Reliance Industries, but that was politically unacceptable.

The longer schedule on the Gripen project reduces risk, and nobody is thinking yet about co-producing complex subsystems like the radar and engine. Brazil has an ambition to install a new big-screen cockpit—from Elbit's local subsidiary, AEL Sistemas—but otherwise the configurations are similar.

South Africa's Denel was at LAAD with its new Marlin medium-range air-to-air missile, possibly looking for

another partnership (Denel and Brazil's Odebrecht are building the A-Darter short-range AAM) but neither Saab nor Odebrecht seems in a hurry to bite on an expensive option. It's not the AAM that's expensive, but the integration and testing.

Underlying these programmatic differences are divergent Indian and Brazilian attitudes to the "defense trilemma"—a pick-any-two of autonomous national development, affordability and military capability, where no solution is optimal for all three goals.

The cheapest way to equip forces is often direct import, softened with offsets or industrial participation. This is where the U.S. traditionally has pitched products. If you want autonomy, you either have to spend more (Japan is a good example, with its low-volume, high-tech weapons) or under-fulfill equipment needs, constrain operational requirements or accept some risk over time.

Brazil has taken a pragmatic approach to the trilemma, exploiting a potentially large but risky loophole: the ability to recoup some of the cost of autonomy via exports. Both the Gripen and the Brazilian-built version of the Scorpene submarine are seen as potential export earners in the long run, including aftermarket upgrades and support. Where there is little export potential, Brazil favors outright buys.

But "Made in India" has become doctrine in New Delhi, accompanied by laws restricting foreign investment in defense companies. (AEL Sistemas could not exist in India.) This has delayed the most straightforward deals—Pilatus, for instance, has had trouble finding an indigenous company to build PC-7 trainers—and has consumed time and money while failing to deliver capability to the armed forces.

One reason for India's problems is a worldwide one: A program's benefits are measured in jobs today, and strategy be damned. Brazil's priority, conversely, is to acquire know-how when its transplanted engineers (or at least those who survive the Swedish winter) return.

The Brazilian approach is not risk-free. Surface warships and other weapons will grow older until the Gripen and Prosub are out of the development stage, and it's early to talk about export sales. But so far, it's Advantage Brazil. ☼



By Pierre Sparaco

*Former Paris Bureau Chief
Pierre Sparaco has covered
aviation and aerospace
since the 1960s.*

COMMENTARY

Too Little, Too Late?

Airbus clings to idea of a souped-up A330 but the marketplace seems to say otherwise

Airbus is aggressively pressing its case for the revamped A330. The European manufacturer is pitching the aircraft as the most utilitarian and competitive long-range twin available, although most industry observers believe it can only be a stopgap. The true question is whether the time has come for an all-new aircraft that incorporates the latest advances in engines instead of relaunching the long-range, aging twin.

BRUSSELS AIRLINES



Brussels Airlines uses its A330-200s and -300s to service its African and American destinations.

More than 1,500 A330s have now been sold and are expected to be succeeded by the neo version. But the going has been slow.

Despite an apparently strong debut backed by so-called launch customers, new clients are rare: 135 firm orders, including AirAsia (55) and Delta Air Lines (25). The list price is an attractive \$275 million and fuel consumption reportedly is as much as 14% below its predecessor's. But the A330neo could well be a niche product; various sources have projected sales of no more than 500-550 aircraft over the next 20 years. Range has been increased by 740 km (460 mi.), but does the market require such an improvement? After all, we are talking about the middle of the market.

Today almost all airlines are opting to install more seats in existing air-

frames to remain profitable in the face of increasingly low fares, including on the medium-haul route system. A recent neologism—"fifth class"—could apply to high-density cabin arrangements. The traveling public is already dissatisfied with seat comfort and will certainly dislike the idea of further constraint, although the airlines are touting the difference in comfort as "negligible."

At this point, no "superneo" is in sight and Airbus is clearly not ready to invest \$10-15 billion in an all-new long-range commercial transport. The European manufacturer's top priority is obviously to increase its profitability well above its current level, making the best possible use of its record 6,386-aircraft backlog, an industry record. Revenue last year increased to \$174.6 billion, and its shareholders

received a €1.2 (\$1.29) dividend, a 60% increase over 2013.

Given the robustness in the rest of Airbus's portfolio, time and circumstances render the idea of an all-new aircraft nonviable. Moreover, traffic is expected to further grow an average of 5% per year over the next two decades, reinforcing predictions of a brilliant future. Last year, Airbus secured 1,456 net orders and delivered 629. In other words, it sells twice as many aircraft than it produces. Most probably, no other industry segment is performing as well.

Actually, the issue is significantly broader and sheds light on Airbus Group's targets. Is enhanced profitability the ultimate goal, in contrast with previous years? It has not been stated clearly before. The Airbus-Boeing duopoly continues to thrive; each of the rivals boasts a 50% share. However, the European manufacturer does have problems. The A380 megatransport has not sold well, or reached its financial breakeven point nearly 15 years after its go-ahead (317 orders, 192 deliveries). The backlog stands at no more than 165, and the production rate remains a disappointing 2-3 aircraft per month. Early predictions did not take shape. In the late 1990s, Airbus was convinced the number of mega-cities would increase to 71 in 2023 and to 91 in 2033, confirming the need for a greater-capacity aircraft. This is not today's demographic reality; although cities are becoming larger, this has not translated into more demand for the A380.

In contrast with the A380's semi-failure—it has few new sales prospects in sight—the A350XWB has done well, posting 780 orders secured by 40 customer airlines. The program launched late and was able to benefit from lessons learned from the multiple technical difficulties that beset Boeing's 787. Ironically, an improved A330—originally proposed as a response to the 787 years ago and long superseded by the A350—was close to today's A330neo.

The battle, more than ever, remains between Airbus's A320-series range and Boeing's MAX. Their combined production rate is nearly 50 aircraft per month, a formidable challenge for the aerospace community, especially the American-European supply chain. ☛



Senior Editor Frank Moring, Jr., blogs at: AviationWeek.com/onspace
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COMMENTARY

Additive Affordability

Space industry pushes manufacturing innovation to hold down costs

COLORADO SPRINGS—Peter Beck flew here from New Zealand with a rocket engine in his luggage. The tiny powerplant, dubbed Rutherford, drew a lot of interest at the annual Space Symposium with its battery-powered turbomachinery. More to the point was the low launch cost—less than \$5 million to orbit—that Beck's Rocket Lab company promised for the Electron smallsat launcher it will power with the Rutherford (see p. 51).

One key feature of the tiny engine was almost a throwaway. The regeneratively cooled Rutherford was built using additive manufacturing (AM), essentially 3-D-printed in Inconel and titanium. As the traditional government customers for space vehicles see their budgets flatten or shrink, industry is taking a deep dive into AM to keep its products competitive in an increasingly commercial marketplace.

That includes companies that have traditionally counted governments as their only customers as well as more-entrepreneurial startups like Rocket Lab and Space Exploration Technologies (SpaceX).

Aerojet Rocketdyne (AJR) is using the technology to speed development of the AR-1 engine it is proposing as a replacement for the Russian RD-180 on the Atlas V. Lockheed Martin has been studying large-scale AM for the F-35 warplane for about a decade, and is moving the technology into spacecraft with a new \$6 million AM center near Denver.

Of that sum, more than \$4 million went to buy a "Direct Manufacturing" system from Sciaky Inc., the Chicago-based aerospace supplier that turned its expertise in electron-beam welding into large-scale AM tools. Using the Sciaky system to build spacecraft-propellant tanks from titanium wire, as well as laser-sintering techniques that



FRANK MORRING, JR./AW&ST

turn metal powders into brackets and other parts, Lockheed Martin Space Systems Co. hopes to cut the time to manufacture a satellite from as long as 48 months to 18, according to Dennis Little, vice president for production.

"If you're going to build a titanium tank for a satellite that we currently build, you have to buy a billet of forged titanium, and the latent time is 14 to 18 months to get it from the supplier, and then you have to machine it down to its final geometry," Little says. "This machine, the Sciaky, lays it up bead by bead, and then you machine it to the final thickness, and you have two spheres and probably a barrel section for the final tank geometry. So you get a tank for a small satellite, machined in three pieces, and within a week's time."

Lockheed Martin engineers worked with Sciaky to design the satellite-tank AM tool, which uses an electron beam in vacuum to melt the titanium wire and lay it up onto the spinning article (photo). It already has produced 35-in. tanks, and is moving on to 40-in. and ultimately 48-in. tanks. The hardware will go into the company's A2100 satellite-bus "technology refresh" already underway, and perhaps the planned Jupiter space tug in contention for NASA's next International Space Station cargo resupply service contract (CRS-2).

To date, tanks produced in the in-

dependent research and development effort have scored "in the high 90s" in tests to failure, compared to tanks machined from forged billets, which Little terms "pretty darned good, and probably good enough." Any shortfall can be covered by adding thickness to the tank walls, he says.

SpaceX uses laser-sintering AM to make impellers and other parts for the Merlin engines that drive its Falcon 9 launch vehicle, which is now in the process of being certificated for human spaceflight under a NASA Commercial Crew Transportation Capability contract. Aerojet Rocketdyne (AJR) is using the same technique, applying some "engineering rigor" to ensure the resulting engine parts have performance comparable to parts produced with the traditional subtractive machining.

"In general, we're using it across the board on traditional products to bring the cost down for those types of geometries that lend themselves to it, and then we're also exploring what type of new products you can build, because it is a very different way of building and thinking about things," says Julie Van Kleek, the company's vice president of advanced space and launch systems.

Given the high speeds and pressures and low temperatures that rocket engine parts must withstand, materials properties of parts produced with AM are particularly important. An engineer may be able to design a part for additive production that would be impossible to create with traditional machining, but it still must meet fatigue and hydrogen-embrittlement specifications before it can fly.

The results are starting to pay off, according to Linda Cova, executive director of hydrocarbon engine programs at AJR. Some of the AM-generated parts have enough fidelity to their designs that they can be hot fired without additional finishing, she says.

"We've learned a lot about the properties that you can actually get, and what influences the properties," Cova says. "Is it the size of the powder? There are so many different elements that go into it, so we spend a lot of time understanding that, so we know when we're done we have a part that's reliable, repeatable and clearly [has] the benefit of shorter schedule." ☛



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COMMENTARY

Give and Take

House panel recommends adding dollars for F-35B JSF and F/A-18F Super Hornet

The first draft of a defense policy bill working its way through Congress is likely to include additional money for F-35B and F/A-18F combat aircraft. The question is how much. The House Armed Services Committee, which considers the legislation April 29, will decide on a subcommittee request to address at least some of the Navy and Marine Corps requests for “unfunded requirements.” The draft does not specify how many aircraft

the legislation would include. The Chief of Naval Operations has asked for an additional 12 Super Hornets and eight F-35Cs, plus another six F-35Bs for the Marines, if Congress could fund the overall budget request put forward in February. Along with the authority to buy additional fighters, Rep. Michael Turner (R-Ohio), who leads the subcommittee in charge of tactical aircraft, is staying true to his pledge to maintain oversight of the Pentagon’s most costly weapons program. The bill will ask for an independent report on details of the F135 engine problem that grounded the F-35 fleet last summer. But Turner says there are no plans to revive a second engine scuttled in 2011.

“It is not an attempt to bring back the alternate engine,” he avers. The bill also asks for another independent report on the progress of the F-35’s Automated Logistics Information System, which lawmakers recently learned produces a false positive reading 80% of the time. ☛

PERSISTENT SURVEILLANCE

As the X-47B unmanned aerial vehicle, the first UAV to take off and land from an aircraft carrier, wraps up its final planned demonstrations (see page 12), the follow-on Unmanned Carrier-Launched Airborne Surveillance and Strike (Uclass) program will remain under review at the Pentagon until this summer. It is also being closely watched by Congress. Last year, lawmakers directed the Defense Department to deliver a report on an acquisi-



‘It is not an attempt to bring back the alternate engine.’

—REP. MICHAEL TURNER

tion strategy for Uclass along with its fiscal 2017 budget request. Not content to wait, the House Armed Services seapower subcommittee is asking for quicker feedback from the Pentagon. If the draft of the panel’s addition to the fiscal 2016 defense policy bill becomes law, the Defense Department would have to provide cost and schedule estimates for Uclass to Congress during the peak of the Pentagon’s budget planning season—Sept. 1, 2015. Rep. Randy Forbes (R-Va.), the panel’s chairman, and others in Congress are advocating for Uclass to have a deep-penetrating-strike capability and emphasize that it cannot be just a sophisticated intelligence, surveillance and reconnaissance platform. “If we make the wrong decision on Uclass, I am confident we will regret this decision for many years,” Forbes says. ☛

CONTROLLED SUPPORT

The leader of the union representing air traffic controllers (ATC) has joined a chorus of support for moving air traffic operations out of the FAA’s purview—with some conditions. Any new system must be spared the kind of stop-and-start funding provided by Congress and should not make a profit, National Air Traffic Controllers Association President Paul Rinaldi recently told the Aero Club in Washington. And while many point to Canada’s private ATC system as a model, Rinaldi cautions that the U.S.’s neighbor has far less air traffic to control. “I don’t know if it’s scalable,” he says. “I’m willing to roll up my sleeves and see.” Congress is already pursuing a revamped FAA as it begins building a reauthorization bill to set policy for the flight safety agency to replace legislation that expires in September. Rep. John Mica (R-Fla.), former chairman of the House Transportation and Infrastructure Committee, has a proposal that would establish an employee stock ownership corporation for air traffic controllers that would take over the nation’s ATC operations and implement NextGen ATM. ☛

PRIMING THE PUMP

Since 2009, large aerospace companies worldwide have been working with spacefaring governments on collaborative road maps for exploring space beyond low Earth orbit. While the approach ultimately followed by an international partnership patterned on today’s space station is far from clear, the collaboration is proving beneficial to all, according to one participant. “It’s an interesting dynamic because all of the companies are in some sense competitors, but we also recognized that it’s in the best interest of everybody if we can create [opportunity],” says Josh Hopkins, Lockheed Martin’s space exploration architect. “If nothing gets built, there’s nothing for us to compete for.” Other companies working on the project include Boeing; Airbus Defense and Space and Thales Alenia Space from Europe; Canada’s MacDonald, Dettwiler and Associates; Mitsubishi Heavy Industries of Japan, and Russia’s RSC Energia. “There’s enough specialization that we can each see a niche or a role for our companies,” Hopkins says. ☛

Baltic Encounters

Non-contactable military aircraft are posing a high risk to air safety in Europe's busy skies

Tony Osborne **London**

Concerns about Russian aggression at Europe's easternmost frontiers are usually a matter primarily for defense planners. But worries about the proximity of military aircraft to airliners flying along air routes in Europe's busy international airspace has prompted the European Aviation Safety Agency (EASA) to examine how it can keep the two apart to prevent both a potentially serious accident and an escalation in an already tense geopolitical situation.

Over the last year, NATO has tried to deter what it sees as Russian belligerence and to allay the fears of its allies by moving military forces—including fighter aircraft—further east. But this has brought NATO and Russian aircraft often into close proximity, especially over the Baltic, a region of airspace used by hundreds of flights each day, and made more complex because of the way air traffic management (ATM) is shared by the countries that border it.

EASA began investigating the issue late last year after a request from the European Commission on behalf of European Union (EU) member states that had reported foreign aircraft operating near their borders over the sea without transponders activated or filed flight plans. The countries were also unable to make radio contact with the aircraft, EASA says.

The problem came to international attention after Swedish authorities confirmed that in March last year a Scandinavian Airlines Boeing 737 carrying 132 passengers came within close proximity to a Russian reconnaissance aircraft, believed to be an Ilyushin Il-20 “Coot” over the Baltic Sea.

The European Leadership Network, a defense think tank, later classified that incident as high-risk, stating that it could have caused casualties and led to a direct military confrontation between Russia and Western states.

Although it does not name Russia as the source of these flights in its investigation of the activity, EASA's report,

published on April 15, says it has identified 15 additional instances in 2014, 13 of which were air-proximity incidents involving aircraft coming within 0.5 nm of one another horizontally or 300 ft. vertically. Three of the occurrences were airspace infringements.

Data suggest the number of non-cooperative military flights over the Baltic has at least tripled since 2012

EASA says 13 of the 16 incidents involved uncooperative military traffic. It recorded six more incidents in January and February of this year, compared with just six such incidents in 2013.

The agency says that calculating the number of non-cooperative military flights over the Baltic is a challenge because of the potential to count more than once flights that pass through different information regions. However, the data suggest the number of non-cooperative military flights over the Baltic has at least tripled since 2012, EASA says.

NATO fighters based in Lithuania and Estonia performed 150 interceptions during 2014, four times more than in 2013. These figures apply solely to the Baltic and do not include redirections of air traffic undertaken tactically by air

traffic control (ATC) in other parts of Europe responding to uncooperative traffic in their airspace.

On several occasions, controllers working the airspace around the U.K. have been forced to divert traffic around the expected flightpaths of Russian Tu-95 Bear bombers flying over the North Sea or around Ireland into the U.K.'s southwestern approaches. NATO fighters escorted the Tu-95s during their probing missions.

At the same time, Russia accuses the NATO powers of flying intelligence-gathering missions in the Baltic with transponders switched off. According to recent statements from Russia's mission to NATO, the alliance is flying as many as 8-12 missions in the immediate vicinity of Russia's borders each week. The mission also characterizes the accusations of Russian military aircraft creating risks for civil aviation as part of a “tendentious information campaign.”

“It is necessary to note that NATO states' military aircraft always make their flights near Russian borders with transponders turned off,” Russian officials said in January. “However, it does not mean that they are invisible to airspace control means.”

Most recently, Russia has stated that a U.S. Air Force Boeing RC-135U Combat Sent it intercepted near the Kaliningrad Oblast had its transponder switched off. The U.S. State Department denied this and accused the Russian Su-27 pilot who intercepted the RC-135 of flying in an “unsafe and unprofessional manner.”

EASA says it would not be sensible to take dramatic measures, such as making the skies around the Baltic a no-fly zone for European civil airlines, as this would have “enormous economic consequences.”

But the presence of these military flights is considered highly hazardous to civil traffic because civil ATC authorities are often unaware of them. The situation could worsen, EASA notes, as forecasts suggest air traffic to the Baltic States could increase by 50% between now and 2035, adding greater risk if the geopolitical environment has not improved.

“It needs to be recognized that it is difficult to predict the evolution of the geopolitical situation and that this is beyond the control of civil aviation regulators,” the report states.

Currently, the airspace above the Baltic—at least above flight level 195 (19,500 ft.)—is classified as Class C airspace, which means that aircraft accessing it should file a flight plan, use two-way communications and have their transponders switched on, allowing civilian ATC to see them. But with non-cooperative military aircraft not following these rules, EASA says mitigating measures are needed to bring risk to an acceptable level.

The task is complicated, however, by the complex nature of the airspace around the Baltic, which is shared by several EU member states and has

implemented at the tactical level between air defense and ATC units when scrambled aircraft become airborne for interceptions.”

The report states that primary surveillance radar detects only the rough horizontal location of a target but not necessarily its height. Passing this data on to surrounding aircraft as traffic information in their proximity would im-

prove situational awareness for flight crews, EASA notes.

In several EU member states, permanent measures to reduce the risks are being discussed, the report states, including the technical feasibility for civilian ATC to view primary surveillance radar data. EASA says this data should be provided to civil ATC agencies to the “maximum possible extent.”

four functional airspace blocks.

The Baltic features a significant number of northern-to-southern traffic flows, as well as eastern-to-western ones, EASA says. These issues make the situation more complex, as traffic information about military aircraft cannot always be provided in a timely fashion to civil aircraft flying in the same narrow parts of the airspace.

EASA advises member states to follow the International Civil Aviation Organization's recommendations in its Circular 330 document, which suggest enhanced cooperation or interoperability between the ATM systems used by military and civilian agencies. This includes making the primary surveillance data from military radars accessible to civilian ATC units, something presently done only in a handful of EU states.

“The Agency recommends that member states work closely together to further develop and harmonize concrete civil/military coordination procedures for ATM [at the EU] level,” the report states. It adds that the information should be disseminated when non-cooperative traffic is likely to be flying into different area control centers.

“Similar coordination has to be



The number of intercepts prompted by Russian military aircraft in international airspace increased markedly during 2014. Here a Russian air force Ilyushin Il-20 “Coot” is escorted by a Royal Norwegian Air Force F-16 over the Norwegian Sea.

ROYAL NORWEGIAN AIR FORCE

Warsaw's New Pact

Poland looks to Europe for helicopters and the U.S. for missile defense, but broader implications loom

Tony Osborne **London**

Poland has taken the next step toward modernizing its armed forces, but its selection of Airbus for its helicopters and Raytheon for its Patriot missile defense system may have wider effects.

The Patriot choice may cast a shadow over Lockheed Martin's Medium Extended Air Defense System (Meads), which was eliminated from the Wisla (Vistula) project last June, but is now being offered for the medium-range Narew contest. The key goal for Lockheed Martin is selection of Meads in Germany's Tactical Air Defense System contest to replace

tenance capability.

Warsaw's selection of the Airbus Helicopters H225M Caracal from France raised eyebrows because the company did not have a significant presence in Poland, unlike competitors AgustaWestland and Sikorsky. But the French offer was a potent one. With the backing of the Airbus Group, the helicopter subsidiary will help the parent company's growth by making Poland Airbus's fifth European market, potentially attracting billions of dollars of new money over that offered by the competitors.

France's decision to suspend the sale

a later phase of modernization that also includes plans for a new attack helicopter under Project Kruk (Raven) and potentially a fleet of heavy-lift helicopters. Polish officials say the Kruk project has been accelerated as a result of the current security situation with Russia.

Poland's decision has dismayed Sikorsky, which currently builds and exports the S-70i International Black Hawk from its Mielec facility. The company says its \$3.3 billion offer—which also included S-70B Seahawks for the ASW mission—included having aircraft ready for delivery in 12 months.

But Sikorsky has said it had concerns about the program and was close to abandoning its bid late last year. Company officials also have said Poland asked Sikorsky to offer the S-92, which the company declined to do and continued to submit the S-70i. It remains unclear what the company

could do next, but former Sikorsky President Mick Maurer told Aviation Week in March: "If you don't have the host-country stamp approval on your product, it's a tougher sell."

Poland selected the Airbus Helicopters H225M over Sikorsky's International Black Hawk and the AgustaWestland AW149.

"We aren't going to do something that's spiteful, we could assemble [Black Hawks] almost anywhere."

In a statement on PZL-Mielec's website, Sikorsky urged the Polish defense ministry to "reexamine" its decision.

For AgustaWestland, the Polish purchase represents the second major failure to sell the AW149, having come in second in Turkey to Sikorsky. AgustaWestland said it was assessing the decision of the Polish defense ministry and determining its next steps.

Poland will now carry out what it calls verification checks on the Caracal with testing in-country in May and June. If successful, deliveries of H225Ms into Poland could begin in 2017, likely from the company's production line in France. Deliveries from an assembly line to be established at Lodz-based Polish Military Aviation Works No. 1—known as WZL 1—would likely follow. ☞



or upgrade its Patriots. Analysts suggest Poland's decision could well prompt Germany to decide to upgrade its Patriots.

Poland now plans to begin negotiations with the U.S. government to buy eight Patriot batteries, with all the systems in service by 2025, although Warsaw says it wants a temporary defense capability with two batteries in operation within three years of signing the contract.

Raytheon already has contracts with Polish industry. Alongside inter-governmental negotiations on delivery conditions, a series of offsets will be discussed including technology transfer, production work and main-

of two Mistral amphibious assault ships to Russia also may have played a part in the Airbus selection, as Warsaw was concerned about that deal.

However, the program now may look less attractive to Airbus. Poland's initial plan was to buy 70 helicopters to replace Russian-built rotorcraft currently performing the troop transport, search-and-rescue and antisubmarine-warfare (ASW) missions. But Warsaw may buy only 50 aircraft, which could increase the in-country cost of assembly. Poland now plans to retain some of its Russian-built Mil Mi-17s into the next decade.

It is unclear whether purchase of the other 20 aircraft will reemerge in

Make in India

Despite problems, Airbus says India is willing to take 'modern' approach to coproduction



The Indian market is a strategic priority for Airbus, with an estimated order potential of 1,290 new aircraft through 2032, including 913 single-aisle jets.

due to Dassault's refusal to accept liability for jets made by HAL.

On April 13 Indian Defense Minister Manohar Parrikar categorically stated that "if India goes in for additional Rafale fighters, it will also be through government-to-government deals." The 36

Amy Svitak Paris

New Delhi's order of 36 Rafale combat jets stole the limelight during a recent Franco-Indian summit in Paris, but a less high-profile event has proved equally noteworthy—Indian Prime Minister Narendra Modi's visit to Airbus facilities in Toulouse, where the aerospace giant said it is ready to develop production and final assembly lines in the south Asian nation as part of New Delhi's "Make in India" push.

"India is a very complicated market, but a very important market for Airbus," says the company's chief strategist, Marwan Lahoud.

"In commercial aviation, Indian companies are good customers to Airbus already, particularly the private Indian airlines; in military, we have a tender for MRTT tanker aircraft, transport aircraft and several hundred light helicopters," Lahoud told France's BFM Radio in an interview following Modi's April 11 visit to Toulouse.

Airbus touts its leading position in India's civil aviation market, where nearly 800 aircraft have been ordered for delivery over the next 10 years. He said 200 are already flying, owing to an order of A320neo passenger jets from low-cost operator IndiGo, helping to give Airbus a 70% market share.

Airbus gave Modi a tour of the A380 final assembly line and a presentation on the company's supply chain in India, from which it purchased about \$400 million in goods last year from 40 Indian companies that combined employ more than 5,000 people.

Airbus currently operates two engineering centers in India for civil and defense activities, plus a research and technology center that employs more than 400. The company said all of these centers could be expanded.

Modi, who visited France April 9-12, said a key objective of his visit was to foster Franco-Indian industrial cooperation, particularly in defense.

However, the Indian premier gave Paris only partial satisfaction during the visit with an order for 36 Rafale combat jets agreed to April 10, leaving in limbo a three-year-old negotiation between Dassault Aviation and Hindustan Aeronautics Ltd. (HAL) to purchase 126 of the fighter aircraft, 108 of which were to have been made in India under the nation's Medium Multirole Combat Aircraft (MMRCA) tender. The deal has been deadlocked for more than a year

Rafales could be inducted into the Indian air force in as little as 18 months, he told the *Hindustan Times*.

With the future of the MMRCA deal unclear, Lahoud says Airbus is confident Modi has every intention of adopting a more modern approach to co-production. "We are an international company capable of producing anywhere," Lahoud says, adding that Airbus Group's primary concerns include the control it has over the value chain of the products it builds there. "On this point, Modi assured us that India has the intention to adopt a modern approach to this issue."

Following the visit, Airbus stated it is "willing to set up final assembly lines and establish supply chains and related infrastructure for military transport aircraft and helicopters" in India, in full compliance with procurement policies and foreign direct investment requirements.

Airbus Defense and Space said it has submitted a joint proposal with Tata to produce C295 aircraft in India to replace the aging Avro 748 transports of the Indian air force and is pitching the C295 for an Indian coast guard requirement for transport aircraft.

The division also plans to develop and manufacture electronic sensors with Indian partners and "has advanced discussions to support Hindustan Aeronautics' combat aircraft programs."

Airbus Helicopters is in discussions with Indian companies on teaming arrangements for the Naval Utility Helicopter, the Reconnaissance and Surveillance Helicopter and the Naval Multi-Role Helicopter competitions.

In addition, Airbus said it stands ready to build large telecommunications satellites with Indian partners. Both sides use each other's launchers to put satellites in orbit.

Although no contracts were announced during the visit, Lahoud expects to see billions in contracts announced in the coming months. "We are going to build military equipment in India, that's indisputable," he says.

In the meantime, as head of France's GIFAS aerospace equipment supplier group, Lahoud said he welcomed Modi's request for 36 made-in-France Rafales, though said he was disappointed that India has thus far shunned the Eurofighter Typhoon, a rival combat jet built by a European consortium that includes Airbus. But he asserts the Rafale deal is not the death knell for the Typhoon. "It is used by four European air forces, and two export air forces, so we have 40 years of activity in front of us," he says. ☼

JOERIKS/AVIATION.NET

Living Space

Private sector helping NASA study ways to stretch Orion

Frank Morring, Jr. **Washington**

The Orion multi-purpose crew vehicle is designed to take humans to Mars, but with less than 20 cubic meters of pressurized volume for a crew of four it could get more than a little cozy en route. Commercial cargo vehicles designed to supply the International Space Station (ISS) may add some elbow-room for the long haul to the Red Planet.

Boeing, Lockheed Martin and Orbital ATK all have won small NASA contracts to study how their commercial cargo vehicles could be modified as habitats for Orion crews in the exploration “proving ground” near the Moon. Bigelow Aerospace, which has orbited two “expandable” habitat testbeds, and is scheduled to berth another one at the ISS this fall, is also running a study, and three other companies are studying advanced environmental control and life-support systems (Eclss) for future habs.

As part of NASA’s Next Space Technologies for Exploration Partnerships (NextSTEP) project, the companies are matching space-agency funds with their own resources in 50-50 cost-sharing arrangements to make work they are doing on NASA’s current needs “extensible” to exploration beyond the ISS and low Earth orbit.

“What we’re trying to do is maximize commercial applications of these technologies while getting an impact for our requirements as well,” says Jason Crusan, director of advanced exploration systems in the Human Exploration and Operations (HEO) directorate at NASA headquarters. “There may be commercial applications for habitation in low Earth orbit at some point. We’d like to understand what industry thinks

about that. At the same time we have real requirements for habitation in deep space, and there have been some commonalities in that.”

To meet NASA’s stated goal of exploring Mars with humans in the 2030s, planners envision spending the decade of the 2020s exploring cislunar space, “evolving” the systems it would take for astronauts to operate there for a few months into the spacecraft that would enable 1,000-day missions to the planet and perhaps its moons.

The planned Asteroid Redirect Mission (ARM) to move a boulder from the surface of a near-Earth asteroid into a stable distant retrograde orbit (DRO) at the Moon would not require a separate habitat. An early crew would live in their Orion for three weeks while studying the sample in DRO. Instead, NASA foresees using DRO or one of the Earth-Moon Lagrangian points as a place to practice human operations for as long as 60 days, and to push development of the hardware that would be needed for Mars.

“We’re looking at a modular approach where you have commonality of the elements to minimize the number of unique new elements that need to be built,” Crusan told the NASA Advisory Council (NAC) on April 8. “If you actually do this development up front, we don’t need to develop a surface-specific hab or a transit-specific hab or a taxi-specific hab or an initial short-duration hab.”

Bigelow has based its habitat developments on inflatable-structures work started at NASA’s Johnson Space Center. It has two unmanned habitats in orbit, and in September is scheduled to launch its Bigelow Expandable Activities Module (Beam) to the ISS for testing with humans inside. Boeing, Orbital ATK and Lockheed Martin are competing for second-round Commercial Resupply Services (CRS-2) contracts to support the station, and the latter two are basing the habitat work on their cargo vehicles in keeping with the principle Crusan describes.

Boeing’s CRS-2 proposal essentially pulls the seats, abort engines, Eclss and other human gear from the CST-100

Full-scale mock-up of Lockheed Martin’s proposed pressurized cargo carrier for deliveries to the space station. The company also will use the structure as it develops a crew-habitat version of the module under its NextSTEP study contract with NASA.



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Commercial Aviation

commercial-crew vehicle it is developing for NASA, and replaces it with cargo accommodation. For its NextSTEP habitat study, Boeing is developing a separate vehicle that is intended to be simple and affordable early on, and evolvable for later long-duration missions, according to Crusan's presentation to the NAC.

Orbital ATK plans to adapt the Cygnus cargo carrier that already has delivered cargo to the space station under a CRS-1 contract into a habitat for cislunar space that can be expanded by linking its pressurized modules. Lockheed Martin is using the same pressurized module it has proposed for CRS-2 as the basis of a habitat for the NextSTEP study, and is already building a full-scale mockup for the cargo-carrier proposal that also can be used for the habitat study (see photo).

Josh Hopkins, the space exploration architect at Lockheed Martin Space Systems, is managing the NextSTEP work internally. In addition to the 40-cubic-meter pressure vessel—built at the same Thales Alenia Space factory in Turin, Italy, that builds the Cygnus—the Lockheed Martin habitat would

advanced Eclss and other developmental exploration hardware, Hopkins says. While Lockheed Martin plans to add electric propulsion (EP) to its Jupiter tug for operations in geostationary orbit, the Jupiter spacecraft is based on the company's planetary spacecraft and would not need it for cislunar operations.

"We could fly the same propulsion system, the same hardware, that we're designing for the ISS mission," Hopkins says. "That was part of the decision process of basing that on an interplanetary bus rather than a low-Earth-orbit bus. The electronics are designed to handle the radiation. It's designed so it doesn't need 24-hour-a-day babysitting, and essentially the delta-V is low enough that we can get there with that propulsion system on existing rockets."

Three other companies won NextSTEP partnerships to conduct advanced Eclss work aimed at extending the range of habitats toward Mars. Dynetics Inc. of Huntsville, Alabama, will study miniature systems to scrub carbon dioxide and other gases from cabin air; Hamilton Sundstrand of Windsor Locks,

Connecticut, will work on modular Eclss subsystems designed to use common components, and Orbitec of Madison, Wisconsin, will study "hybrid" systems that merge chemical and biological processes to help close the life-support loop.

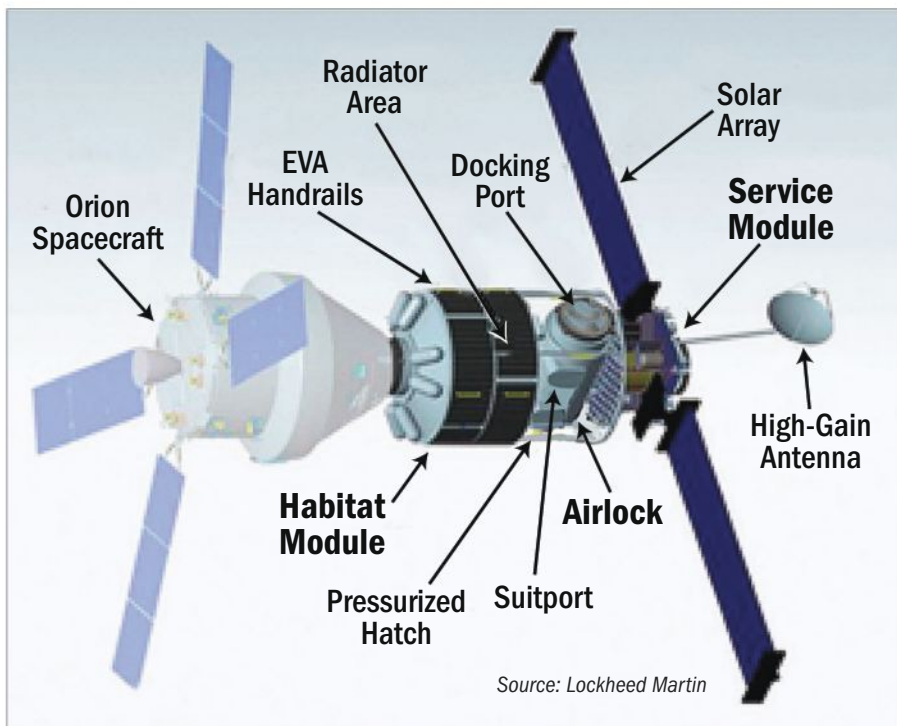
While the Lockheed Martin habitat won't need electric propulsion to reach cislunar space, EP remains a major enabler for prepositioning supplies and

The cargo carrier and the habitat would use the same planetary bus under Lockheed Martin's 'Jupiter' concept.

habitats at Mars for human explorers. NASA picked three NextSTEP partners to advance their ongoing work in the field—Ad Astra Rocket Co., Webster, Texas, for long-duration tests of its Variable Specific Impulse Magnetoplasma Rocket prototype; Aerojet Rocketdyne, Redmond, Washington, for an operational demonstration of a 250-kw nested Hall thruster, and MSNW, also of Redmond, to advance the 100-Joule Electrodeless Lorentz Force Thruster it has been de-

veloping with U.S. Defense Department funds.

Rounding out the NextSTEP partnerships are two 6U-cube-sat resource scouts designed to ride piggyback on the first flight test of the heavy-lift Space Launch System on a swing around the Moon in 2018. Lockheed Martin Space systems will receive \$1.4 million for "Skyfire," which will collect surface spectroscopy and thermography. Morehead State University in Kentucky will get \$7.9 million for the "Lunar IceCube," which will use an infrared spectrometer to seek ice, liquid water and water vapor from a low-perigee, near-polar orbit around the Moon. ☾



Source: Lockheed Martin

use the same service module that is the basis of the reusable "Jupiter" space tug the company has proposed for CRS-2 (AW&ST March 12, p. 60).

The habitat version would add an airlock with a second docking port, and a high-gain antenna for communications (see illustration). Life support would be handled by the Eclss in the Orion, with fans to circulate the atmosphere through the capsule, and thermal control systems inside the habitat. Oxygen and some other consumables would be carried in the "exoliner" portion of the Jupiter bus, outside the pressurized section, while drinking water might be used to help shield the crew from space radiation.

Thales Alenia built many of the pressurized modules already attached to the ISS. The proposed Lockheed Martin habitat would be sized to accommodate as many as eight standard station experiment racks that could house ad-

Digital Extra See images of the crew vehicles proposed for NextSTEP by Bigelow, Boeing and Orbital ATK at AviationWeek.com/Habitats



Tough Times

Launch incumbents try to adjust to shifting government/customer market landscape

Amy Butler and Guy Norris **Colorado Springs**

Two mainstay U.S. launch companies—United Launch Alliance (ULA) and Aerojet Rocketdyne—are struggling to keep their edge in a changing government market that is increasingly interested in contractors backed by private investors.

While fighting its own battle against a privately funded SpaceX to retain its hold on the U.S. national security launch arena, ULA is, in turn, taking advantage of Blue Origin's funding to build its next-generation propulsion subsystem for the new Vulcan rocket.

ULA is struggling to keep its Atlas V competitive against SpaceX's Fal-

con 9; ULA hopes to retire the costly Delta IV single-core rocket, but needs more Russian-made RD-180 engines in order to pit Atlas V against the Falcon.

Amid these challenges, ULA is offering no lifelines to Aerojet Rocketdyne, which is caught in a similar situation; its AR-1 engine needs government money to compete with Blue Origin's BE-4 methane-based system to power the Vulcan.

ULA CEO Tory Bruno dismissed Aerojet Rocketdyne's claim of delivering an AR-1 rocket engine by 2018—a year earlier than previously stated—as “ridiculous.”

“It is not going to happen. I would love for them to prove me wrong, but [it is not] realistic,” Bruno says. “They believe they can do some clever things with new materials in additive manufacturing and analytical models that shorten the [traditional] development cycle. I believe that they are overly optimistic. Our assessment is they are 1-2 years behind Blue Origin at this time.”

Bruno expects to downselect between the two in the next 18 months, but he prefers BE-4.

This is a double whammy for Aerojet Rocketdyne, which has invested in an engine that apparently now has little chance of earning its way onto a U.S. Evolved Expendable Launch Vehicle—either Vulcan or Atlas V. Although the company is marketing AR-1 as a “drop-in” replacement for the RD-180 for Atlas V, Bruno does not support the plan. “We could integrate an engine into a launch vehicle while it is being certified,” says Linda Cova, program manager at Aerojet Rocketdyne.

Some House lawmakers, however, are steering funding toward a poten-

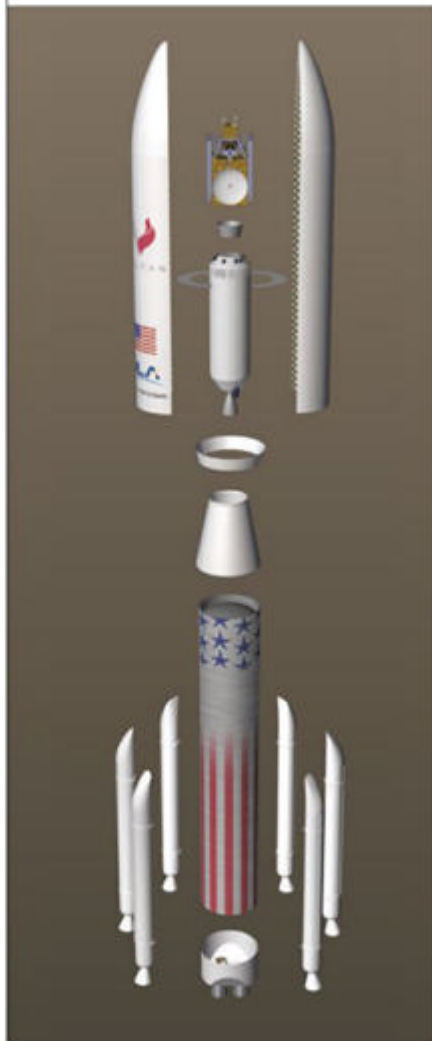
tial AR-1 replacement for the RD-180. In their markup of the fiscal 2016 defense authorization bill, they limit rocket-propulsion-system program spending to an engine “to replace non-allied space launch engines by 2019,” a clear show of support for the AR-1. Air Force Space Command chief Gen. John Hyten says USAF only wants to buy launch services, not directly manage an engine development.

“Getting to certification [for AR-1] by 2018 is definitely within the realm of reason if you have the money,” Julie Van Kleeck, vice president of space and launch systems at Aerojet Rocketdyne, says. “There will be an acquisition. We have to go through that process as we are right now. We started working this last year and here we are a year later, and no one has made a decision to do anything yet.” The frustration of Aerojet Rocketdyne, however, is a byproduct of the company's own reliance on government funding.



ULA CONCEPTS

ULA's Vulcan rocket family is designed from the 441 (left) to the 561 (right) configurations to handle all missions now executed by the Atlas V through to the Delta IV Heavy. The larger version would rely on strap-on solid-fueled engines and a new upper stage to loft the heaviest satellites into orbit.



Aerojet Rocketdyne is planning to conduct a preliminary design review for AR-1 in December, Cova says. The company is depending on additive manufacturing to shorten development and production-cycle times.

Ultimately at issue could be how much the Pentagon is willing to trust the claims of a relative newcomer to defense, the well-heeled Blue Origin. One industry source suggests Pentagon policymakers are intrigued but leery of relying on the unproved BE-4.

Bruno's downselect decision will not allow for much wiggle room once made. The BE-4 design that relies on methane requires much larger tanks

than the AR-1, which operates with kerosene. The outcome will dictate the design of the rest of the booster.

Aside from its earlier schedule, Bruno is backing the BE-4 for its partial reusability. His decision to reuse only the BE-4 engines—not the entire first stage—was driven purely by the economics and the engine's use of the "clean burning" methane fuel.

"It takes a good 7-8 reuses before you can pay off the additional cost of all the extra equipment and the logistics of recovering it and then bringing it back to the factory with a reasonable amount of refurbishment that you have to do," Bruno says, referencing reuse of a full

first stage. "You can't just dust it off and reuse it. You have to do plumbing and new cables and insulation and all this kind of stuff. Our calculations say [it takes] 7-8 uses to break even. . . . To really make it worthwhile, you [must] reuse it about 15 times."

Rival SpaceX failed to successfully land a Falcon 9 v1.1 first stage after an April 14 launch. "I'm surprised they didn't make it," Bruno says. SpaceX plans to attempt its fourth first-stage recovery during NASA's seventh Commercial Resupply mission, slated for the summer, and it is eyeing a future landing on land, not the floating-barge recovery currently targeted.

TECHNOLOGY

Swarm Theory

At-sea demo will focus on rapid launch-and-swarm formation with autonomous small UAVs

Graham Warwick **Washington**

A demonstration to show whether autonomous, swarming small unmanned aircraft can overwhelm an adversary more cost-effectively than conventional weapon systems is planned for fiscal 2016 by the Office of Naval Research (ONR).

Under the Low-Cost UAV Swarming Technology (Locust)

network, sharing position and other information. They will form a "parent/child" relationship, with one of the UAVs acting as the lead and the others following, he says.

"They know where they are, and tell everyone else where they are. That is part of the communications," says Mastroianni. The UAV acting as parent may change depending on maneuvers, and the demo will look at how tightly they can formate, at what altitude and through what maneuvers, he says.

ONR's goal is for the swarm to be autonomous. "I want to hit launch and not talk to them," Mastroianni says. Commands can be sent to break the swarm into different packages, or to send individual UAVs off to perform other missions such as intelligence, surveillance and reconnaissance.

The UAVs are intended to be expendable, to avoid the cost of recovering them after a mission. "We need to make them cheap and disposable to make them attractive to use," he says. ONR's goal is a unit cost under \$10,000. "It would be nice to get to \$5,000-7,000."

For the at-sea demo in 2016, the UAVs will be recovered to avoid any harm to sea life, but that may involve flying them into a target on land, says Mastroianni.

Demonstrating rapid launch of 30 UAVs in 30 sec. or less, and subsequent fast formation of the swarm is a key enabler for the use of low-cost battery-powered vehicles. "Rapid launch is driven by endurance, which for small UAVs is not long," he says.

Although the technology behind Locust is intended to be platform-, payload- and mission-agnostic, says Mastroianni, the need for useful endurance drives the size of the UAV and the choice for the demo of the 12-14-lb. Coyote, which can fly for 90 min.

The Locust demo "is a big first step in autonomy, and helping people get comfortable with the autonomy," he says. Last August, in a demo on the James River in Virginia, ONR showed that swarming small unmanned surface vessels could overwhelm a hostile ship.

The technology involves a transportable kit that can be installed on almost any boat. Locust is part of an effort to develop autonomy technologies that can be applied across surface, undersea and air domains, says Rear Adm. Mat Winter, chief of naval research. ☐



program, ONR plans to launch 30 Raytheon Coyotes from a ship off the coast of Florida, with the expendable UAVs rapidly forming a swarm and autonomously conducting a mission.

Coyote is a tube-launched electrically powered small UAV originally developed for ONR by Advanced Ceramics Research, which was first acquired by BAE Systems then sold to Sensintel, which was acquired by Raytheon in January.

ONR conducted several Coyote launches in March, and also demonstrated autonomous synchronization and formation flight with nine UAVs. The swarming demo is planned from ONR's Sea Fighter technology-demonstration ship, offshore from Eglin AFB in Florida, says Lee Mastroianni, Locust program manager.

After rapid launch the Coyotes will establish communication between themselves using a low-power radio-frequency

ONR has demonstrated rapid launch of Raytheon's tube-launched Coyote small UAV.

"We applaud all efforts to bring reusability into today's launch systems," a SpaceX spokesman says of ULA's stance. "However, SpaceX is thinking beyond just saving money—we're working toward making human life multiplanetary."

ULA, however, is embracing a different form of reusability with its newly unveiled Vulcan rocket that should pay off with only three reuses, Bruno says. ULA intends to reuse only the main engine for Vulcan.

"The issues around reusability in the kind of lift we are doing now are all economic," Bruno says, acknowledging that single-stage-to-orbit reusability is the ultimate goal.

"You can accomplish the economic advantage in about five or so" reuses, Bruno says of a methane engine such as the BE-4. "If you happen to use a very clean-burning propellant like liquid natural gas or methane, then the refurbishment is even less and the ultimate number of reuses is even greater."

Bruno says after the main engine cut-off, the paired BE-4s will be physically detached from the base of the core by a shaped explosive charge; they will employ a hypersonic inflatable aerodynamic decelerator and, when in the atmosphere, deploy a parafoil. This will direct the BE-4 to a rendezvous point where a heli-

copter will pluck it from the sky.

In the case of the BE-4, ULA is planning only to include a separation interface with a shaped charge for decoupling the engine from the rest of the stage, the inflatable heat shield and the parafoil for recovery. "It is not going to be bathed in plasma and recirculating rocket exhaust on the way down, because there is no rocket exhaust. It is covered up in this conical heat shield; it experiences a very benign environment on the way in," Bruno says. "Our approach is such that the engine, during recovery, will see less severe environments than it does in its normal operation." ☼

Ready To Fire

U.S. Navy program to arm destroyer could be first to field laser weapons

Graham Warwick Washington

While fashions in high-energy lasers have changed as technology progresses, from gas to diode and now fiber, General Atomics Aeronautical Systems (GA-ASI) has stayed its course over more than a decade and believes its third generation electric laser weapon is ready for prime time.

The company has responded to an Office of Naval Research (ONR) solicitation for a 150-kw laser weapon suitable for installation on DDG-51-class destroyers to counter unmanned aircraft and small boats.

Under ONR's **General Atomics' third-generation tactical laser weapon module is sized to fit on its Avenger UAV.** Solid-State Laser Technology Maturation program, the weapon is to be demonstrated in 2018 on the USS Paul Foster, a decommissioned Spruance-class destroyer that now serves as the U.S. Navy's ship-defense test vessel.

GA-ASI has proposed its Gen 3 High-Energy Laser (HEL) system, which recently completed independent beam-quality and power testing for the U.S. government. The Gen 3 system is the third generation of electrically pumped laser using the architecture developed for Darpa's Hellads program.

Under development since 2003, the 150-kw Hellads will be tested this summer at White Sands Missile Range in New Mexico. A smaller, lighter and more efficient Gen 2 system was built and tested in 2010-12 for the Pentagon's HEL Joint Technology Office (JTO), says Jim Davis, director of laser weapons.

Gen 3 has increased electrical-to-optical efficiency, improved beam quality and further reduced size and weight, says GA-ASI. A mockup of the Tactical Laser Weapon Module was unveiled at the Sea-Air-Space show here April 13-15.

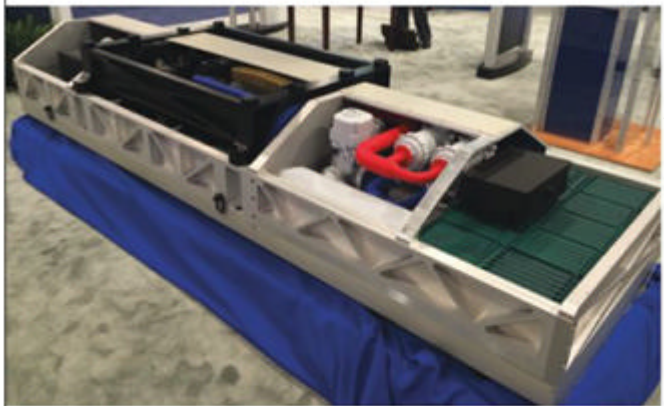
The module includes high-power-density lithium-ion batteries, liquid cooling for the laser and batteries, one or more laser unit cells and optics to clean up the beam before it enters

the platform-specific beam-director telescope, says Davis.

The unit cell is a laser oscillator that produces a single 75-kw beam. Modules can be ganged together to produce a 150- or 300-kw beam. There is no beam-combining, Davis says, as there is in systems that use multiple lower-power fiber lasers.

The Pentagon and several other manufacturers have shifted focus to fiber lasers because they are a commercial technology and have higher electrical-to-optical "wallplug" efficiency than diode lasers that previously exceeded 100 kw.

But the Gen 3's efficiency is at the level of fiber lasers, Davis says, adding that the company has worked for several years to improve beam quality and achieved "excellent quality" in the latest tests. Adaptive optics adjust the beam to compensate for atmospheric distortion.



GRAHAM WARWICK/AMST

In the independent unit-cell tests, beam quality was measured over a range of operating power and run time, which is limited only by the "magazine depth" of the battery system. "Beam quality was constant throughout the entire run of greater than 30 sec.," says GA-ASI.

"Fiber lasers are interesting, but it is a matter of maturity," says Davis. "We are where fiber may be in five years. We have built several versions of this laser over the last 10 years, and we believe [the Gen 3 system] is affordable as is."

Davis says GA-ASI's Avenger unmanned aircraft has sufficient onboard power to recharge a 150-kw-class Gen 3 airborne laser module in flight. "That's the utility; you don't need to go back to reload," Davis says. ☼

Painful Divorce

Three members are leaving the Association of European Airlines over a policy dispute

Jens Flottau **Frankfurt**

If executives at the Association of European Airlines (AEA) were hoping the worst was over after the departure of International Airlines Group (IAG) carriers British Airways and Iberia, they were clearly wrong. Air Berlin's decision to follow shows how deeply divided European carriers are over crucial policy issues, and how influential the Gulf carriers really are.

"We see no future in a protectionist aviation policy in Europe," Air Berlin's CEO Stefan Pichler said. "The liberalization of bilateral agreements will promote further consolidation and new innovative business models, thereby benefiting all passengers. With its current focus and representation of interests, AEA is not fulfilling these ideas, but allowing itself to be driven by airlines which desperately try to erect a new wall around Europe."

Air Berlin's move follows a decision by IAG to terminate the AEA membership of subsidiaries British Airways and Iberia. Like Air Berlin, IAG cites a fundamental disagreement on aviation policy as the reason for its departure. "Our position on some important policy issues is not aligned with many other AEA airlines," IAG stated earlier this month, adding that "global liberalization of our industry is fundamental to our future growth and we are not willing to compromise on it." The group also noted its long-standing demand to eliminate ownership and control limitations and its position on the Norwegian Air International U.S. operating permit, which IAG—unlike most European and U.S. legacy carriers—supports.

After almost a week of silence since IAG's departure, on April 21—the day

Air Berlin announced its decision—AEA reacted, stating that it was "totally incorrect to portray AEA as a protectionist association that is creating a wall around Europe." AEA insists that "none of the campaigns initiated by AEA on liberalization, external relations or ownership and control have advocated protectionism," and that "all positions taken by the association are the result of discussions between its members."

AEA maintains it supports market liberalization if there is an added value for European airlines, and that ownership and control rules should "evolve over time on the basis of reciprocity."

IAG and Air Berlin's exits from AEA are also driven by other factors. Qatar Airways is now IAG's biggest shareholder, and Air Berlin would likely cease operations without the continuing financial support of its largest shareholder, Etihad Airways. Industry sources say Alitalia, another Etihad affiliate in Europe, is also considering exiting AEA, which raises the question of what role Etihad is playing in these moves.

Similar to a recent initiative in the U.S., Air France-KLM and Lufthansa are driving a campaign to curtail the growth of Gulf carriers at their expense. In particular, the two large airline groups are opposing any further liberalization of bilateral agreements with the United Arab Emirates (UAE) and Qatar until an agreement is reached on what level of government support for airlines should be permitted. Air France-KLM CEO Alexandre de Juniac and Lufthansa CEO Carsten Spohr made their position clear in a joint letter to the European Commission late last year.

But the departure of the IAG air-

lines and Air Berlin from AEA leaves legacy European airline interests and representation in limbo. European policy-makers can no longer be sure that AEA's position reflects the common view of the region's airlines—in fact, it has become clear that in some crucial points it does not.

The situation raises the question of what is needed to reformulate a strong European airline lobbying group. Some insiders say a new body is needed to supersede the AEA. Some have hinted AEA might merge with the International Air Carrier Association (IACA), which mainly represents European charter airlines. The low-cost airline industry is represented by the European Low Fare Airline Association (ELFAA) and regional airlines are grouped in the European Regions Airline Association (ERA). Any larger body merging two or more of these would have to take into account their differing interests and clarify who is in charge. Similar moves have been made on the national level. In Germany, industry association BDL was created to represent all of the country's airlines and airports, albeit with significant ongoing internal conflict.

The drastic move by Air Berlin also reflects the enormous pressure the airline is under for various reasons. It has an extensive code-sharing arrangement with Etihad, but the German transport ministry plans to withhold approval for large parts of the next winter timetable, arguing that the code-sharing flights are not in line with the bilateral between the UAE and Germany.

In particular, flights from Berlin and Stuttgart to Abu Dhabi operated by Air Berlin are at risk, because Etihad may no longer be able to put its code on these flights or on many other connections beyond Berlin. If the ministry holds its position, the commercial relationship between Air Berlin and Etihad would suffer massively, raising the question of how long Etihad would remain committed to its partner if little or no code-sharing is possible.

The latest revision of the UAE/Germany bilateral pre-dates Etihad's creation. The transport ministry says it allows code-sharing only on German domestic routes. Air Berlin and Etihad argue that its long-haul code-sharing flights have already been approved for many seasons and should therefore be allowed to continue. ✎

Air Berlin exits AEA, saying it is trying to 'erect a wall around Europe.'



Not Interested

Lack of A330 Regional orders makes transition to A330neo harder

Jens Flottau **Frankfurt** and Bradley Perrett **Beijing**

The transition from the current Airbus A330 to the A330neo was never going to be easy. But that it has become as difficult as it is now has a lot to do with one market that Airbus thought would be ideal for both aircraft: China.

In late 2013, Airbus launched the A330 Regional. Certifying the A330 with a low maximum weight to save a little on operational costs was supposed to add to its attraction. Airbus hoped the regional variant would help secure a Chinese order for up to 200 A330s, which would have helped considerably with keeping the A330 line at or close to its current production rate for about two more years. As an added incentive, Airbus was prepared to open an A330 completion center in China to fit interiors to otherwise complete aircraft flown in from Toulouse.

But the chances of Airbus actually setting it up in the short term look increasingly dim. An industry official familiar with the thinking of Chinese airline representatives and those in charge of state-controlled orders says the carriers are now quite unlikely to place a large order for A330s. They are instead looking more at the A350 and Boeing 777-300ER and 787.

For Chinese airlines, the A330-300 has been notably useful over the past decade in supplementing narrowbody aircraft on crowded domestic airways, but growth in the country's economy, and thus domestic passenger traffic, has slowed markedly.

The air force, meanwhile, continues to allow incremental capacity growth on commercial air routes. To the extent that more A330-300s will be needed, they may become available as larger aircraft, such as 777-300ERs, take over Asian regional services.

For Airbus, further orders are crucial for the A330 ahead of the transition to the A330neo. Last year, the company cut monthly production to nine from 10 aircraft and was forced to reduce it to six, effective in early 2016. However, the first A330neo will only be delivered in late 2017. The current A330 backlog stands at 317 aircraft but that includes 145 NEOs, leaving only 172 for the current variant. Not all of those will be delivered before the end of 2017.

But to bring Chinese customers back on board for the A330, any industrial agreement would have to be broadened to include the -800neo and -900neo versions. The situation is further complicated by an internal Airbus study under the project name "Icon," which is essentially about developing an upgraded cabin for the aircraft. The extent of the upgrade is not clear and several suppliers, including those from China, have expressed an interest in the work. If a deal with China comes through, this almost certainly would lead to a resumption of talks about a completion center. However, according to industry sources, Airbus is uncertain when the changed cabin should be introduced. ☛



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Defending the Schedule

Citing 'normal development problems,'
Mitsubishi Aircraft slips MRJ's first flight

Bradley Perrett **Beijing**

The weather is better in Moses Lake than Nagoya. And there is less air traffic, too.

So Mitsubishi Aircraft, aiming at preserving the first-delivery target of the MRJ regional jet despite a new development delay, will switch one of its test aircraft to the group due to fly from the Washington state city, where it can spend more time in the air.

Ground testing has revealed a software bug and a need to change some of the structure of the MRJ, the company says. For those reasons, it has moved the first flight to September or October from the previously scheduled second quarter of 2015.

"These are, however, problems that arise as a normal part of the aircraft development process," the company says in a statement issued to Aviation Week. "They do not, at any rate, represent the kind of major trouble that would cause a delay in the overall schedule."

The target for the first delivery, the second quarter of 2017, is unchanged, says the company. The time allowed for flight testing has therefore been compressed. This will be done by flying four of the five flight-test aircraft in the U.S., instead of three.

"We will be able to make flight tests in the U.S. with a high frequency of three to four times on a daily basis, which will help us acquire useful data in a more efficient way," Mitsubishi Aircraft says. The expected duration of flight time for testing, around 2,500 hr., has not changed. The company has previously cited the good weather and light traffic around Moses Lake's Grant County International Airport as reasons for sending the originally planned group of three aircraft there for flight testing.

In announcing the delay, Mitsubishi Aircraft said the results of tests needed to be incorporated into the first aircraft, which was rolled out in October. It now adds: "In ground tests, a bug occurred in a portion of the software, as did design changes in some system parts. In considering these issues in

detail, we looked at feedback on the airframe software and hardware. One specific example of this feedback is a problem with the degree of RAT (ram-air turbine) structural strength."

U.S. flight testing has been due to begin about two quarters after the first flight. If that interval is unchanged, then one of the flight-test aircraft should begin flying at Moses Lake around a year from now. Mitsubishi Aircraft has contracted Seattle engineering company Aerotec to support the flight testing.



Four MRJ flight-test aircraft are in final assembly at Mitsubishi Heavy Industries' Komaki South plant.

Mitsubishi Heavy Industries (MHI) is the main shareholder in Mitsubishi Aircraft and is building the MRJ airframe. The type uses the Pratt & Whitney PW1200G engine.

Company photos taken in the past few weeks show that the fifth flight-test aircraft is now in final assembly at the MHI plant at Nagoya Airport, Komaki South, that is performing this work before volume production begins. All fuselage modules of the fifth except the tail cone had been joined together by April 3, when the photograph was taken.

As of January, the latest aircraft to enter final assembly was the fourth. By early this month that unit had been painted but, like the fifth, did not have its tail surfaces or left and right wing boxes attached. The third airframe looked complete, but fairings had been

left off, allowing access to equipment, and the engines were not fitted. The second airframe had its engines.

These flight-test aircraft are built to the design of the MRJ90, the longer of the two versions of the regional jet intended for 92 passengers in a standard, all-economy configuration. The two static-test airframes, one for verifying the strength of the aircraft and the other for confirming its fatigue resistance, also have MRJ90 structures. The eighth airframe will be an MRJ70, the version intended to seat 78 passengers.

European airlines are interested in the proposed MRJ100, with all-economy seating for 100, but the company cannot launch development of that version while focusing on protecting the delayed schedule of the MRJ90, originally due to enter service in the last quarter of 2013. The same engine is used on the MRJ90 and MRJ70, but derated for the smaller version.

Customers expecting early deliveries include All Nippon Airways, Trans States Airlines and Skywest Inc.

Mitsubishi Aircraft and MHI say they have finalized the manufacturing scheme for the MRJ. This will include final assembly of PW1200Gs by Mitsubishi Heavy Industries Aero Engines.

As previously planned, a new plant beside Nagoya Airport will finally assemble, outfit and paint the aircraft. Mitsubishi Aircraft's head office has moved to the airport terminal building. The Japanese side of flight testing will be based at Nagoya Airport.

MHI's Tobishima plant, part of the Nagoya Aerospace Systems Works, will build the MRJ wing, using parts from the manufacturer's Kobe Shipyard & Machinery Works. ☼

Back to Sea

Operational tests leading to F-35B's summer debut may not feature all hardware

Amy Butler and Michael Fabey **Washington**

The U.S. Marine Corps is preparing for its first and only operational testing (OT) period for the Lockheed Martin F-35B before declaring initial operational capa-

bility for the fighter as early as July.

The trials—set for May 18-29—are the first shipboard operational tests for any of the three F-35 variants. Six F-35Bs from VMFA-121 and

VMFAT-501 are slated to participate in the trials off the Atlantic coast on the USS Wasp, according to Maj. Paul Greenberg, a Marine Corps spokesman. This will be the first time six of the single-engine, stealthy aircraft have been deployed to sea on the same ship simultaneously.

Operators will assess the ability of the fighter to function not only on take-off and landing but also in navigating around the deck and in the belly of the ship, where maintenance operations take place. The trials largely focus on validating that users can maintain a



An F-35B conducts a vertical landing on the deck of the USS Wasp during developmental testing trials at sea.

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Meet and Defeat

Israeli missile defense system moves closer to deployment

Israel's David's Sling weapon system for air and missile defense completed its third test series (DST-3) last month, performing successful intercepts of targets representing relevant threats: missiles and rockets of different sizes, fired from medium and long ranges, and flying at low, medium and high altitudes. David's Sling will be ready for operational deployment following the fourth test phase planned for later this year, according to the Israel Defense Forces.

Conceived in 2006 as the Short Range Ballistic Missile Defense System, David's Sling was developed with U.S. cooperation and joint funding of \$250 million. Israel has requested additional U.S. funding of \$150 million for the initial procurement phase. Deployment will involve two systems controlling multiple fire units and covering all of Israel.

David's Sling will expand Israel's air defenses, enabling effective engagement of medium- and short-range ballistic missiles, guided ballistic missiles, cruise missiles and other weapons. David's Sling is by 2016 expected to become part of the national missile defense system, which includes Arrow 2 and Iron Dome. The Stunner interceptor missile will be the primary endo-atmospheric interceptor of the

system. The Arrow 3 ballistic missile weapon is expected to join the network after 2016, adding exo-atmospheric interception capabilities.

Like the Arrow systems, David's Sling will provide coverage from two central locations, rather than the distributed deployment of Iron Dome. With a protected footprint larger than that of the Iron Dome batteries, David's Sling will be more effective in intercepting long-range rockets such as those used against Israel in recent conflicts. Such weapons, with ranges of 60-300 km (37-186 mi.), were supplied by Iran to Hezbollah. It will also be effective against guided ballistic missiles supplied by Iran to Hezbollah, and shorter-range rockets (75-160 km) produced by Hamas.

DST-3 represents the third series



ISRAELI DEFENSE MINISTRY

The Stunner missile is the primary interceptor of David's Sling.

of tests of the Stunner interceptor, developed for David's Sling. The Stunner missile is slated to become part of other air-defense systems, including the future Patriot 4 planned by Raytheon. Stunner is compatible with Patriot fire units, thus extending their range and engagement capabilities and improving battle economy against overwhelming threats. Raytheon and Rafael are proposing the Stunner-Patriot option to international customers.

The prime for David's Sling is Rafael, with Raytheon a prime subcontractor. The multi-mission radar is from Israel Aerospace Industries/Elta Systems. Elbit Systems/Elisra developed the battle management center. ☛

—David Eshel

Gas Rationing

New rebreather counters helium shortage

The U.S. Office of Naval Research (ONR) has developed a prototype helmet and rebreathing system that will reduce the amount of helium used by Navy divers underwater.

One of the project's goals is to lessen the service's reliance on helium, a key component of rebreathing systems that has become difficult to source and increasingly expensive in recent years, while maintaining the safety of divers.

A rebreathing system protects divers from dangerous—even fatal—levels of carbon dioxide and nitrogen that build up when they breathe oxygen

mixtures underwater in a closed-circuit system. The Navy's standard Fly-Away Mixed Gas System supplies divers with complex mixtures of oxygen and helium to dilute CO₂ and nitrogen and maintain desired levels of oxygen in the breathing mix. The helium replaces toxic nitrogen buildup and helps divers avoid physical traumas such as the bends, a decompression effect that debilitates the body and, in extreme cases, causes death if untreated.

Prototype rebreather system reduces helium in its oxygen mix.



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A surge in demand for helium in recent years is what makes the gas difficult and expensive to acquire. Much of the demand is driven by its use as a cooling agent in medical systems such as MRI machines, computer electronics manufacturing, scientific research and other applications. (The Large Hadron Collider in Switzerland, for example, requires 120 tons of liquid helium for cooling.) Conventional rebreathers expel large amounts of helium into the water during dives, which compounds supply and cost issues.

The rebreathing prototype, developed by ONR's TechSolutions program, is described as a hybrid system

that "alternates between different breathing systems," which "reduces the amount of helium needed" by a diver. No figures were provided as to how much of a reduction can be achieved.

ONR officials, who displayed the rebreather, helmet and a dive suit for it, cite advantages of the system.

First by "reducing the amount of helium needed" for diving, less space is needed onboard ships for helium tanks, so smaller ships could as a result be used for operations. ONR also says that the use of multiple gas mixtures in the system could "extend the time divers remain underwater safely." ☛

—Pat Toensmeier

Green Heat

Biofuel formulated for hot rations

An army marches on its stomach, Napoleon famously observed (though some claim it was Frederick the Great, a military tactician Napoleon admired, who said it first). And while cold, precooked rations are common among land forces, hot food is a clear preference.

With this in mind a Welsh company has formulated a "green" fuel that is intended to make hot meals cooked in the field safer—from an environmental standpoint—if not tastier. BCB International Ltd. of Cardiff developed FireDragon, a solid biofuel supplied in tablet form of 27 grams (0.86 oz.) each. It is described as nontoxic, non-drip, and made

entirely from natural ingredients including ethanol sourced from U.K. grain.

FireDragon is offered as an alternative to cooking fuels such as hexamine. In a statement, Managing Director Andrew Howell calls hexamine an "outdated substance" that can emit noxious fumes.

The tablets are claimed to be effective and efficient. One tablet reportedly boils 500 ml (17 oz.) of water in 5-6 min., at least 2 min. faster than most competitive fuels. A tablet typically burns for 7-8 min., and can be ignited when wet.

No word yet as to whether any militaries are considering FireDragon for use. ☛

—Pat Toensmeier



FireDragon tablets are derived from ethanol and other green sources.

BCB INTERNATIONAL



The U.S. Army recently purchased 300 licenses of MetaVR visuals for embedded training in its Universal Ground Control Stations and for Institutional Mission Simulators.

Since 2002, the Army has used MetaVR visuals for simulated UAV camera payload video for Shadow, Grey Eagle, Aerosonde, and Hunter training.



With MetaVR visuals used for simulated UAV camera payload video in ground control stations and in manned aircraft simulators, UAV operators, pilots, and JTAC trainees can achieve fully correlated HD H.264 simulated sensor video with accurate KLV metadata that replicates the actual sensor payload imagery of ISR assets during MUM-T and other distributed training exercises.

Real-time screen captures are from MetaVR's visualization system rendering 3D virtual terrain of Kismayo, Somalia, and are unedited except as required for printing. The real-time rendering of the 3D virtual world is generated by MetaVR Virtual Reality Scene Generator™ (VRSG™). 3D models are from MetaVR's 3D content libraries. Copyright © 2015 MetaVR, Inc. MetaVR, Virtual Reality Scene Generator, VRSG, the phrase "Geospecific simulation with game quality graphics," and the MetaVR logo are trademarks of MetaVR, Inc.



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Securing Airspace

UAS developments focus on survivability and forward operations

David Eshel Tel Aviv

Unmanned aerial systems (UAS) have long since proved their worth as critical intelligence-gathering assets. But can they assure data transmission all the time? Are they secure from enemy attack? What happens when an enemy has access to weapons that can shoot down UAS or otherwise deny operations in certain areas?

Since missions are often covert operations, information about UAS loss rates is sketchy. In the past, they were used in areas where air superiority had been gained. Uncontested by enemy air defenses, UAS were exposed to ground fire only when flying low—during takeoff and landing, to gain a better view of targets, or dropping below the cloud base on rainy days.

While generally safe from enemy fire at high altitude, UAS are susceptible to electronic attacks on their command and control links or electro-optical (EO) systems.

Lack of air supremacy can be devastating. For example, the U.S. Air Force, the largest UAS operator in the world, has lost 14 General Atomics Reaper and Predator aircraft since January 2014, on missions over Afghanistan, Syria, Yemen, Libya and Central Africa. Some losses were attributed to enemy action, although the Pentagon declines comment.

In recent years, Iran has increased its UAS awareness and integrated combat platforms in all major training exercises, so ground forces and air-defense units can practice shoot-down skills. In 2014, Iran reportedly downed an Israeli Hermes 450 UAS flying near its uranium enrichment center in Natanz. The Iranians have repeatedly contested incursions of U.S. platforms into its airspace. The most notable was the

loss of a Lockheed Martin RQ-170 Sentinel over eastern Iran in 2011, which was attributed to electronic or cyberattack. Iran has also downed or captured a Boeing Insitu ScanEagle UAS operated by the U.S. Navy. Iranian jets attempted several times to fire at USAF Predators over the Persian Gulf, but were chased away by fighter escorts.

The Iranians also have lost quite a few UAS, deployed in support of Iranian and Iraqi forces fighting the Islamic State in Iraq. Since 2006, Israel faced incursions by Hezbollah from Lebanon, trying to fly Iranian-made armed UAS over land or the Mediterranean, to hit strategic targets in Israel.

At first, the Israeli air force (IAF) intercepted these with fighter jets. In recent years ground-based air-defense assets have been used. The IAF has shot down a number of Iranian-made Lebanese and Syrian UAS since 2006. Israeli-operated Patriot missiles recently shot down enemy UAS over the Golan Heights as they turned toward Israel. Patriot missiles also downed UAS over the eastern Mediterranean that had been launched from Gaza.

Syria is another example of counter-UAS warfare, since coalition forces face ad-hoc defenses. UAS that sometimes operate without support are vulnerable to enemy fire. In recent months Syria has shot down a number of aircraft over its territory, among them a U.S. Predator, an undisclosed Turkish platform and one that supported an Israeli air strike but has not been identified.

In eastern Ukraine, both sides claimed to have downed UAS. Last year, the Russians said they used electronic countermeasures to down an allegedly U.S.-operated IAI/Northrop Grumman Hunter RQ-5B. The Russians did not substantiate the claim and the Pentagon denies it operated such a vehicle over Crimea.

While current counter-UAS (C-UAS) capabilities are based on existing assets, new systems becoming available improve the ability of ground forces to deny UAS operations.

Modern tactical radars that deploy with ground forces enable detection and early warning. For example, the AN/MPQ-64 Sentinel from ThalesRaytheon and Giraffe AMB radar from Saab are available with enhanced C-UAV capability, as part of the counter-rocket, artillery and mortar (C-RAM)



Brazil equipped its Elbit Hermes 900 UAS with the Skyeeye multi-payload system to provide persistent surveillance of wide areas. Skyeeye operates with the standard Compass EO/IR payload.

BRAZILIAN AIR FORCE

upgrade that improves radar tracking of high- and low-velocity targets in the cluttered environment above the horizon. RADA's Multi-mission Hemispheric Radar provides such capabilities in a small package suitable for deployment with tactical forces. And Russia's NNIIRT has developed vehicle-mounted phased-array 3-D radar (IL121E) to detect UAS and guided weapons. Company sources say the radar operates on the move to provide target data for other air-defense assets.

Being alerted to the presence of a UAS is one thing, but denying it from completing its mission is another. The most basic form of attack is GPS jamming, although this is likely to affect only the simplest aircraft. More advanced platforms employ navigation systems enabling the UAS to sense an attack and switch to inertial guidance. An anti-jamming GPS device could also render simple jamming ineffective.

Since UAS effectiveness depends on maintaining an active data link with the user, disrupting the link is a valid countermeasure. Such a capability was developed by SRC working with the U.S. Army, combining the company's AN/TPQ-50 radar with the AN/ULQ-35 Duke electronic warfare jammer to disrupt UAS data links. Cyberattacks also exploit UAS dependence on external communications and control.

The U.S. Army is seeking to field an air-defense system dedicated to C-RAM and C-UAV missions. The truck-mounted system will be part of the Indirect Fire Protection



NOAM ESHEL/AN&ST

The Sparrow miniature multi-rotor UAS from Torquing Group has 14 acoustic sonars providing a safety bubble around it to enable safe flights in dangerous areas.

Capability Increment 2 Intercept Program of Record, to improve protection for rapid deployment forces on contingencies beyond 2020. The interceptor missiles that could be deployed with such a system range from the Miniature Hit-to-Kill missile from Lockheed Martin to the combat-proven Tamir, the interceptor developed for Israel's Iron Dome C-RAM system.

The Army-funded HEL-MD (high-energy laser-mobile demonstrator) from Boeing has defeated mortars and UAS using a 10-kw off-the-shelf laser. Rheinmetall demonstrated the ability to combine several laser beams on a single target, which develops sufficient power to destroy UAS and cruise missiles (*AW&ST* March 30-April 12, p. DTI 6). In 2013, the company demonstrated a successful engagement of three UAVs, using high-energy laser effectors. Even without high power, laser beams can be used against EO systems, either to dazzle sensors or burn through optics.

To evaluate such capabilities the U.S. Defense Advanced Research Projects Agency will conduct a "High-Energy Laser Rodeo" at White Sands Missile Range, New Mexico, Nov. 15. The event will open the door for laser weapon system developers outside official Defense Department programs to demonstrate their capabilities.

As ground forces improve C-UAV capabilities, aircraft must evolve to provide needed data. One way of doing this is with standoff capabilities similar to those used by pi-

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lotted aircraft against surface-to-air missiles. UAS are limited in payload—only larger medium-altitude long-endurance versions such as the General Atomics Reaper and Predator, IAI Heron TP and Heron I or Elbit Hermes 900 carry payloads that effectively perform standoff missions. IAI recently tested a standoff payload, the M-19HD, on a Heron I. With up to seven different sensors, including large-aperture, high-zoom cameras and thermal imagers, it engaged in persistent surveillance at long range.

The opposite trend is reducing the size and cost of UAS to enable deployment by tactical elements, where countermeasures aren't available. Two platforms developed in Israel, the ThunderB from BlueBird and Orbiter 3 from Aeronautics, represent different approaches. Powered by an internal combustion engine, ThunderB carries a 3-kg (6.6-lb.) payload on a 20-hr. mission. Orbiter 3, powered by an electric motor, is a flying wing that deploys a 5-kg payload for seven hours. Both are designed for tactical forces at brigade level and below. They are typically equipped

The Army operates hundreds of AAI RQ-7B Shadow 200 UAS, configured to carry multiple payloads in the payload bay as well as under wing. Some have been upgraded to carry miniature weapons, such as Raytheon's STM or Textron's Fury.

BOEING/ERIC SHINDELBOWER



The U.S. Army has evaluated Boeing's High-Energy Laser for C-RAM and C-UAV missions.

with payloads of 1.5-3 kg, and reportedly provide the same data collection capability as much heavier systems operating at high altitude.

Employing integral micro-UAS on the front lines would make warfighters less dependent on larger UAS support from high command levels. These miniature tactical systems rely on winged or flying-wing platforms, such as the AeroVironment RQ-11 Raven and Wasp, IAI Birdeye and Elbit Skylark. Pocket-sized versions employ rotary wing or small multi-rotor platforms for missions. British forces in Afghanistan have used the Black Hornet nano-UAS to gain situational awareness for force protection. Black Hornet is effectively a "flying camera," intuitively controlled by the user at a range of a few hundred meters.

Sparrow and Firecast miniature multi-rotor vehicles from

Torquing Group are fully autonomous UAS, even in complex urban terrain, and enable multiple UAVs to operate in synch with each other. In fact, Sparrow's operation system allows one vehicle to operate autonomously for 20-40 min., or several to swarm. Each Sparrow carries 200 grams (14 oz.) of payload that is not limited to EO. ☛



NOAM ESHEL/AVIAST

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Wind Talker

'Pseudo satellite' shapes up as communication relay platform

Angus Batey Farnborough, England

The record-breaking Zephyr unmanned, solar-powered aircraft is undergoing enhancements by operator Airbus Defense and Space (AD&S) to increase performance and expand its payload.

The system, designated HAPS (High-Altitude Pseudo-Satellite) since its acquisition by AD&S from Qinetiq in 2013, is intended to meet emerging military and commercial requirements for a surveillance and communications relay platform that is more responsive than a satellite and has far greater persistence than conventional aircraft.

No customers are yet confirmed for the system, which achieved FAI (*Federation Aeronautique Internationale*) world records for duration (14 days, 22 min., 8 sec.) and altitude (70,743 ft.) on the first flight of the Zephyr 7 configuration at Yuma Proving Ground, Arizona, in 2010. The U.K. Defense Ministry supports the program, most recently by funding a flight of more than 11 days in 2014, and the U.S. Defense Department has paid for flights. Civil applications are targeted by Airbus, and a flight last year, in Dubai, demonstrated the ability to launch and recover the system near a major airport.

"In remote sensing, the value metric is dollars per square kilometer of imagery (about 0.4 sq. mi.); in communications it's dollars per kilobits/sec. [of bandwidth]," says Paul Brooks, head of HAPS business development. "If we couldn't demonstrate a capability to reduce those significantly, Airbus would not be investing."

In the hangar where the new Zephyr 8 is being built, conventional tools are conspicuous by their absence. The only piece of heavy equipment is a crane, to load crated aircraft onto transport trucks.

The slimmed-down manufacturing stems from the design of the 50-kg (110-lb.) aircraft, which has a wingspan of 73 ft. Zephyr has to be strong enough to survive gusting and turbulence during ascent and descent, but at altitude it needs to be lightweight and efficient. The payload limit of around 5 kg could increase with a larger airframe.

"There is no limit to the size, but the economy is met by taking advantage of payload technologies to reduce the size and mass of a payload," explains Chris Kelleher, program technical director and Zephyr's lead designer. "Once you introduce carbon optics, we can put on a Zephyr the [electro-optic] capability of [the Northrop Grumman RQ-4] Global Hawk [unmanned aerial vehicle]. There are some payloads—and we're looking at, maybe, radars for the future—where



Airbus Defense and Space technicians build a wing section of the Zephyr 8 aircraft.

mass is an issue. But there is a family of aircraft that we can work with for that."

The refinements being made to Zephyr 8 over previous iterations offer significant capability gains. New solar cells afford a threefold increase in power, and are combined with larger, improved batteries.

"Because [Zephyr 7] was a prototype, we didn't manage to embed all of the mass reductions we'd intended," Kelleher says. "It was also carrying reserve structural margins on board. We've made Zephyr 8 a bit bigger, to use up those margins. We're lightweighting and improving the efficiency on the power subsystems, so there'll be orders of magnitude more power coming into the aircraft off the solar array, and a very large improvement in power storage. It's still a 5g ultimate airframe, because we have to go through weather systems, and we're delighted how well it handles wind shear and turbulence."

Airbus declines to disclose where the 11-day Zephyr 7 flight took place, but a Defense Ministry representative told a London conference in March that the sortie was flown from Ascension Island. Flying in the Southern Hemisphere during winter enabled Airbus to expand the system's operational limits.

"Zephyr 7 can stay above the weather, but it depends on the latitude and time of year," says Brooks. "We're extending that window of operations with Zephyr 8, which will stay above the weather between +/-40 degrees latitude year-round."

Last year's flights also advanced the program's regulatory compliance. The Defense Ministry's Military Aviation Authority certified Zephyr 7 before the Southern Hemisphere flight, and the Dubai flight was conducted in partnership with Dubai Civil Aviation Authority. Despite the weight penalties, Zephyr flies with navigation lights and an ADS-B transponder, for access to civil airspace.

"We've got a fantastic head start on what you need to have on the aircraft to be allowed to fly, which is a real issue for UAVs," says Brooks. "We're making sure we've got everything in place so the aircraft can be certified, and we've already got a strong base for that because we've got civil and military authorities involved in the program who are saying they're happy with what we're doing." 📍



The lightweight Zephyr 7 aircraft comes in for landing during a 2014 test flight.

Minecraft

U.S. explores standoff sea mines

Bill Sweetman Washington

In an almost unpublicized test on Sept. 23, 2014, a Boeing B-52H bomber demonstrated a variation on a centuries-old tool of naval warfare. Flying north of Guam, the bomber released an experimental combination of the in-service Quickstrike sea-bottom mine with a BSU-104 Joint Direct Attack Munition-Extended Range (JDAM-ER) wing and tail-kit, designated GBU-62B(V1)/B Quickstrike-ER. The weapon impacted on target 40 nm downrange.

Deputy Defense Secretary Robert Work identifies “advanced aerial mines” as one of the new weapon classes to be explored under the Third Offset initiative. That is a big change, given that there has been little investment in new mine technology for decades.

U.S. airborne mining has not changed significantly since the May 1972 Operation Pocket Money mining of Haiphong and other North Vietnamese harbors, carried out by carrier-based A-7 and A-6 attack aircraft. The mines used in that campaign were unguided, and delivered from low altitude to lay a dense and consistent field. The bombers had to be protected by escort fighters and surface-to-air missile coverage from Navy cruisers.

Quickstrike-ER’s accuracy is largely irrespective of range provided GPS is available. A standoff weapon, it is deliverable by a large bomber that can carry a heavy load of mines. Because of its accuracy, the mine pattern can be controlled more closely than from a low-level unguided release. Two standard air-delivered mines, the 500-lb. Mk62 and 1,000-lb. Mk63, are, respectively, based on Mk82 and Mk83 bombs, which are integrated with JDAM.

There has been one recent improvement in U.S. mine warfare: the introduction and retrofit of the Mk71 target-detection device (TDD), a digital, programmable fuze that senses magnetic, seismic and pressure signatures. It can use different target-processing algorithms and counter-countermeasures to detect, classify and localize threats, discriminating between submarines, fast attack craft, air-cushion vehicles and large warships.

Aside from the TDD, U.S. mines are the most basic type: influence bottom mines designed to explode as a ship passes over them. However, even these mines are highly lethal. An Italian MN103 Manta mine with a 290-lb. charge exploded

under the fantail of the USS Princeton in February 1991, in 50 ft. of water, breaking the structure and causing the ship to “whiplash like a fly rod,” according to a witness. The superstructure cracked and broke free of the hull.

Air Force Col. Mike Pietrucha, who took part in the Quickstrike-ER trial, notes that the combination of lethality, limited effectiveness and slow speed of mine-clearing operations, and the ability to deploy mines precisely and quickly equate to a new form of mine warfare.

In offensive mining, Pietrucha writes in *Air & Space Power Journal*, “mines with guidance kits can be laid in an unpredictable pattern, making mine clearance that much more difficult,” and the minefield pattern can be tailored to the depth and width variations of waterways. Harbor mining could be as effective against naval forces as it is against shipping, he notes, and possibly more so since some naval ports have restricted approaches—easy to defend against surface combatants or submarine infiltration but susceptible to mine interdiction. Iran’s main naval base at Bandar Abbas, according to Pietrucha, opens on to an anchorage with a breakwater that has a gap of only 1,300 ft.

“For navies that lack an underway replenishment capa-

bility, preventing naval combatants from returning to refuel and re-arm may effectively neuter them without a direct attack,” Pietrucha writes. “With no port available, most adversaries have little ability to project naval power.” This consideration applies strongly to fast attack craft and smaller submarines, which have limited endurance and range.

The technology

opens the way to new forms of defensive and reactive mine warfare, particularly if the weapons can be delivered by stealthy or otherwise survivable platforms, or at even greater standoff ranges. (Boeing has been designing and testing a powered JDAM, which combines the wing kit with a small turbine engine.) “Instant minefields” could be dropped ahead of a moving task force. “Anti-ship missile attacks must penetrate a warship’s air defenses,” says Pietrucha, “but a mine bracket dropped 30 or 50 nautical miles in front of a task force will not be intercepted and may not even be recognized.” Minefields could also be created to block amphibious assaults.

Other observers note that China uses air-delivered mines, has wing and guidance kits similar to JDAM-ER as well as a growing force of modernized H-6K bombers, and could adopt similar mine-warfare concepts. “They could pull it off, but they have to get there and [they] don’t have the stealth aircraft now; or they can develop a different risk-tolerance,” says Bryan Clark, naval analyst at the Center for Strategic and Budgetary Assessments. “That will change.” ☐



U.S. AIR FORCE/MSGT. KEVIN GRUENWALD

Guided, gliding mines combined with B-52 improvements could yield a new maritime warfare capability for U.S. forces.

Mine Set

Performance issues slow Navy mine-clearing program

Michael Fabey **Washington**

Developing and deploying an unmanned underwater vehicle (UUV) to hunt mines is turning out to be difficult. Nonetheless, the U.S. Navy is committed to replacing sailors and ships with UUVs for the dangerous mission of clearing waterways of mines.

All eyes are on the remote mine-hunting system (RMS) that is slated for deployment on Littoral Combat Ships (LCS). The RMS includes individual mine-hunting systems that will be launched from large UUV mother ships—54-ft.-long, 22-23-in.-dia. platforms the Navy wants to deploy in this decade or early next.

There are other UUV systems on the radar. For example, the service has deployed the MK18 Mod 2 Kingfish autonomous UUV in the 5th Fleet's area of responsibility (Persian Gulf, Arabian Sea, Red Sea and Indian Ocean), following more than 30 sorties over 15 days of mock deployment testing in the Gulf of Mexico. Kingfish is designed for mine-detection missions and intended to replace the in-theater Swordfish system.

The U.S. Navy is promoting the remote mine-hunting system for future countermining missions.

Ensuring the most efficient unmanned mine-hunting system is worth the cost, Navy officials say. Mines have damaged more U.S. warships since World War II than missiles, guns and bombs combined.

But clearing mines is a demanding task. One mistake or misinterpretation of data can mean disaster. Rear Adm. John Ailes, who until recently was in charge of keeping the RMS on track, has likened the mission to ballistic missile defense (BMD).

Ailes, now chief engineer for Space and Naval Warfare Systems Command, notes: "Mine warfare is similar to BMD in this way: It's all about discrimination. What's the target? In BMD you try to figure out the reentry vehicle. They use penetration aids and all kinds of things to confuse you. In mine warfare," he continues, "the environment provides that. It is more complex. You've got trashcans and buoys and various things that have been thrown overboard from ships, and the natural contour of the bottom. And mines are in different parts of the water. Some are at the top, some in the middle, some at the bottom."

To provide effective discrimination capability, the Navy is outfitting proposed UUVs with sophisticated sensors, tethered to a host ship or, in the future, other vehicles through a complex and dynamic communications network. Integrating all of this and making it work reliably, however, has eluded engineering efforts thus far.

Ailes and other Navy officials identified reliability and related issues early on. Also, the RMS was initially slated to

go on destroyers, thus alterations were needed to put them on LCSs. Contractor Lockheed Martin says it worked out many of the bugs and Navy officials are reportedly pleased with the progress.

But in a report released earlier this year, the U.S. Government Accountability Office notes RMS delays of six months over the past year, and adds that delivery of initial capability had previously been delayed by more than seven years.

Moreover, the office of the Director, Operational Test and Evaluation (DOT&E), says in its most recent report, also released this year, that the Pentagon in the fourth quarter of fiscal 2014 delayed RMS low-rate initial production until the third quarter of fiscal 2015.

The RMS, which includes a remote multi-mission vehicle (RMMV) and AN/AQS-20A sonar, "had not demonstrated sufficient performance or successful integration with interfacing LCS systems to demonstrate the Navy's minimum Increment 1 warfighting capability," DOT&E advised last year.

"Although the Navy is working on upgrades to improve system performance and LCS capability in the version 6.0 RMMV and the AN/AQS-20A/B sonar, developmental testing completed [in fiscal 2015] demonstrated continued perfor-



U.S. NAVY

mance issues and RMS mission package integration challenges," DOT&E stated in this year's report.

Solving these issues is critical for RMS success. The sonar-equipped RMMV navigates its way into a suspected minefield and captures images, data and other information to determine the location of mines. It is key to keeping ships and sailors out of danger.

The Navy needs the RMMV to operate in the water as much as possible. But DOT&E says reliability is a problem. Developmental and integrated testing from fiscal 2014 for a version 4.2 RMMV showed a mean time between operational mission failure of 31.3 hr., DOT&E reports. Developmental testing completed in the first quarter of this fiscal year yielded a mean time between operational mission failure of 34.6 hr.

"Statistical analysis of all test data indicates the result is not sufficient to conclude that reliability has actually improved since 2010," DOT&E states. "Test data currently available do not support the Navy's assertion that vehicle reliability has improved." ☒



Hishammuddin Hussein Defense Minister of Malaysia

Age: 53

Education: Law degree, University of Wales, 1984; Master of Laws, London School of Economics, 1988

Background: Worked as a lawyer after university, then entered politics. Key government posts: youth and sports minister; education minister; home affairs minister; and since May 16, 2013, defense minister. Hishammuddin was also acting transport minister from May 16, 2013–June 25, 2014.

Personal: Married Marsilla Tengku Abdullah, a princess, in 1986. He is also the cousin of Prime Minister Najib Razak.

Maintaining Momentum

The past year has been challenging for Malaysian Defense Minister Hishammuddin Hussein. Low oil prices have depleted procurement funds, and in March 2014 the disappearance of Malaysia Airlines Flight 370 occurred when he was acting transportation minister. Current concerns range from greater cooperation among Asean (Association of Southeast Asian Nations) members and potential threats from the self-proclaimed Islamic State. Leithen Francis interviewed him in his office about these and other issues.

Defense Technology International: Malaysia has requirements for fighters to replace the RSK MiG-29s, for airborne early warning and long-range maritime patrol aircraft (MPA). But with budget pressure because of lower oil prices are these practical?

Hussein: If you look at Malaysia's needs and the present economic climate, we have to ask: 'Can we afford them?' Future procurements will be outlined in the 11th five-year plan that we aim to table this year.

We've heard that long-range MPA is now a higher priority than fighters.

We have to be creative in securing our security. But we can't compromise our security even though we don't have money. Another idea I am exploring is joint assets. Is it not possible for Malaysia, Brunei and Indonesia to work together? Why have separate assets? Sharing assets is a workable solution.

Is the plan still to retire the MiG-29s this year?

That gets back to affordability and potential threats. That is not for discussion here.

What is your opinion of the recently released interim report into the disappearance of MH370?

It is very technical. Things have settled down; earlier I was faced with conspiracy theories. My heart goes out to the families; we must continue to engage them and give them confidence that the search will go on.

Malaysia had no MPA capable of assisting in the

search because the area involved—800-2,500 km (1,118-1,553 mi.) off western Australia—was too far for your Beechcraft King Air aircraft to access. Does that spotlight Malaysia's need for long-range MPA?

The deployment of assets was the biggest undertaken. We don't have Lockheed Martin P-3 Orions or Boeing P-8 Poseidons, but we had both in the search. Chinese Ilyushin Il-76s were working alongside U.S., Australian and New Zealand P-3s. The joint effort is something we are proud of. Just because we don't have assets such as long-range maritime patrol aircraft doesn't mean we won't find ways to deploy them.

In hindsight, would you have done anything differently?

No. We hope to get to the bottom of this. We will not find the answers until we find the black boxes.

What do you think of Malaysia's home-grown defense industry?

There's a lot more we can do. I keep telling defense companies, don't just look at Malaysia—look at Asean as a market. The opportunities are huge.

What topics will be key in upcoming meetings with Asean defense ministers?

I want to highlight our stand on ISIS. Second, I want to suggest a United Nations peacekeeping force of all 10 Asean nations. Third, I want to highlight humanitarian and relief work and establish standard operating procedures [for dealing with crises] so future Asean leaders have a working template.

Why is an Asean peacekeeping force for overseas missions important?

If all 10 nations [are involved], it will underscore the unity and solidarity of Asean countries. It would be relatively easy to establish and run because there are precedents. For example, Malaysia and Brunei already have joint forces in Lebanon.

Is ISIS a threat to Asean?

It is a mistake to assume Southeast Asia will be isolated from ISIS. We need to take a stand and be clear that what ISIS is doing is wrong. ☹



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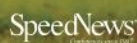
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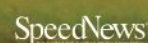
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relevant operations tempo at sea with the short-takeoff-and-vertical-landing F35B. "The desired aircraft-ready-for-training rate of the F-35B aircraft during OT-1 is 100%," Greenberg says.

"This exercise will evaluate the full spectrum of F-35B measures of suitability and effectiveness to the maximum extent possible," he notes. "Specifically, the trial will assess the integration of the F-35B while operating across the array of flight operations, maintenance operations and logistical supply chain support while embarked at sea." The Wasp, an amphibious assault ship, was also used for the F-35B's first developmental testing sea trials; the first F-35B vertical landing took place on its deck in October 2011.

During the trials, the Marines plan to execute numerous day and night short takeoffs and landings and conduct "standard" day and night extended-range operations, Greenberg says. Also part of the testing will be an assessment of the aircraft-to-ship network communications interoperability as well as the efficacy of the landing signals officer's launch-and-recovery software.

Though Greenberg says operators will assess day and night weapons loading, no live-fire testing is slated; most live-fire activities are handled for the program by the test force at Edwards AFB, California.

The F-35Bs will be expected to fly in both optimal and inclement weather: "Only extreme weather conditions will halt operations during OT-1," Greenberg says.

The six aircraft used in the OT-1 trials will operate with the 2B software package, which was not originally intended for operational use. However, delays earlier in the program prompted the Marine Corps to prioritize 2B, which allows for use with limited weapons, with no external weapons stations approved. Marine Corps officials say the aircraft will provide better capability than the F-18s and AV-8Bs they are intended to replace.

The Marines will also use the Automatic Logistic Information System Standard Operating Unit Version 1 (ALIS SOU V1); this is not the hardware with which they plan to declare initial operational capability (IOC) and eventually deploy. An updated hardware unit, the ALIS SOU V2, is slated for delivery for VMFA-121 by early June. This hardware is smaller and designed to be

deployable on the small-deck ships on which the F-35B will operate. The SOU V2 is required for IOC.

Though operating with the 2B software, the operational test team will not be able to fly with the software patch designed by engineers to improve ship-to-ship "sight picture" sharing. As part of the F-35's so-called data-fusion attribute, the aircraft are required to share targeting data among themselves using their Multifunction Advanced Datalinks, which can operate covertly to preserve multiple aircrafts' stealthy characteristics in high threat environments.

In fact, the OT series is more geared to demonstrating sortie generation and maintenance tempo. Ship-to-ship targeting is not expected during the trials.

Test pilots at Edwards had reported problems with targets on the cockpit

F-35s feature an array of sensors and data links that will require more attention and offer more capability than the F-18s and AV-8B Harriers the Marines have been using, according to Marine Corps Maj. Gen. Robert Walsh, Navy director of expeditionary warfare.

The services also need to figure out the requirements for operating the aircraft with carriers and other ships in the fleet, he says. It will be a learning process, says Rear Adm. Peter Fanta, director of surface warfare. "We will not be able to bring that data completely aboard on that first deployment," he said during the roundtable. "We will learn where the gaps are."

"What are the C5I [command, control, communications, computers, collaboration] requirements for the F-35B? Because they are not going to be how we operated the Harrier," Walsh said April 9, during a media roundtable. "What is the requirement for the F-35 to be able to disseminate data across the battlefield? What pipes need to be there?"

The learning curve needed to codify the integration is likely to prompt frustration by some. "There will be disappointment," he says, because there will be a desire to capture more of that data and information.

Just preparing the JSFs and big-deck amphibious ships for the first deployment in fiscal 2018 will be difficult enough, the admirals say. "It's a real challenge," Walsh says.

The LHD 1 USS Wasp has already been modified with a reinforced flight deck and a new heat-resistant material to better withstand the exhaust from the F135 engines powering F-35B short takeoffs and vertical landings. The LHA 6 USS America will undergo similar work.

"In the America, the very time-consuming piece is going inside the ship and dropping lighting and ventilation and piping wiring and everything down far enough so you can install new material and weld it in place and then restore all that stuff," Rear Adm. David Gale, program executive officer for ships, said during the roundtable.

About a dozen modifications are needed for the ships to house the F-35Bs, he says. ☛

Just getting the JSFs and big-deck amphibious ships ready for the first deployment in fiscal 2018 will be difficult enough, the admirals say

display associated with more than one symbol, a sign the system had not fully "fused" the data collected on that target from multiple F-35s. In some other cases, wingmen are not seeing the same objects other pilots are in multi-ship formations.

Program officials opted earlier this year to move forward to develop the software patch to correct the deficiency; they created the code in 22 days, according to Joe Dellavedova, F-35 spokesman for the F-35 Joint Program Office.

Marine Corps officials say they are confident the 2B package will be sufficient for IOC in July; F-35 test officials hope to have the patch ready for the Marine Corps IOC, however.

The F-35B is slated for its first deployment to MCAS Iwakuni, Japan, in 2017. Separate ship trials are slated for the F-35C on an aircraft carrier this fall.

As the squadrons ready the aircraft, Marine Corps and Navy officials are also preparing the USS Wasp for the trials and laying the groundwork for the aircraft-to-ship integration that will be key to that first deployment in 2017 as well as those to follow.

As fifth-generation aircraft, the

Utilitarian Excellence

Latest Top-Performing Companies results confirm A&D companies run well, above all else

Michael Bruno **Washington**

A funny thing happened on the way to the aerospace and defense industry's maturation. The companies became good businesses—maybe too good.

Twenty years ago when Aviation Week started its annual review of Top-Performing Companies, the concern was that Western A&D companies did not operate well as businesses, at least not compared with other sectors and Wall Street benchmarks. While they provided amazing weaponry, airliners and spacecraft, when it came to operating performance, A&D enterprises seemed to lag by decades automotive, oil and gas, and other industries in basic business prowess.

A look at this year's TPC rankings and results indicates they have learned their lessons well. Not only did A&D as a whole post record revenue for 2014, but many companies simply became operationally better. What is more, this change came about despite two years of so-called sequestration spending restraints, the historical halving of the price of a barrel of oil, the dramatic strengthening of the U.S. dollar, airliner disasters and international volatility such as in Ukraine.

"The core of the big primes and the U.S. defense industry continue to do really well despite all the angst and observable trauma," says TPC adviser Jacob Markish, principal at Renaissance Strategic Advisors. "Another measure that was unsurprising is that the well-focused and disciplined mid-tier, whether in electronics or in one of the commercial parts of the components sector, continues to do very well."

Above all, the record up-cycle in commercial aerospace, led by the now nine-year backlog of large airliner orders, continues to drive up the whole sector. "The story last year, in 2014, was commercial," says Tom Captain, vice chairman and global

2015 TPC Council of Advisers

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Director

Capital Alpha Partners

Tom Captain

Vice Chairman, Global A&D Sector Leader

Deloitte

Antoine Gelain

Managing Director

Paragon European Partners

Steven Grundman

Principal, Grundman Advisory

Lund Fellow at the Atlantic Council

Harlan Irvine

Principal

Deloitte

William Lay

Principal

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A&D sector leader for Deloitte and a TPC adviser. "The story will be the same in 2015. There is no bubble."

TPC rankings of publicly traded A&D contractors are the result of composite scoring of four equally weighted performance categories that place significant emphasis on operating excellence. They are: return on invested capital (ROIC), measuring investment decisions; earnings performance, i.e., revenue quality and expansion; asset management, or how efficiently a company employs its resources; and financial health, as in a company's strength, including overall solvency.

In turn, the TPC council of advisers this year identified several common attributes among companies that can claim success in the rankings. For starters, A&D companies appear better managed from the top down; even defense units are run as much like commercial operations as possible. Next, companies are increasingly focusing on areas of expertise, becoming dominant players in niches and shedding non-core operations.

"The thing that keeps coming back at me, year after year, is the companies that do well have a proprietary position; they know what business they're in," says Harlan Irvine, a TPC adviser and Deloitte principal. "The folks that have a defensible position, either they own a program of record or they own intellectual property that they can lever. They do a decent job of running the business according to the levers that are relevant."

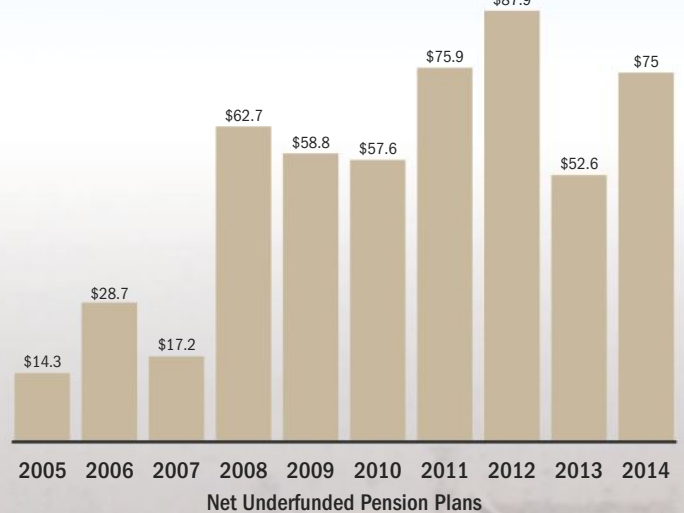
In defense, companies are trying to develop or harness commercial technology—like Rockwell Collins and its Pro Line Fusion avionics—to the extent possible rather than the Cold War approach of government-first. And, paradoxically, when focusing a company, Top-Performing Companies are buttressing revenue by diversifying customer types and sources, such as by boosting international sales, finding new clients for current offerings, and even tiptoeing into adjacent markets.

Surpassing these trends, however, is the idea that the companies in general are leaner, more efficient and more productive, per worker. If possible, major assets and inventories are placed or left in the hands of others,

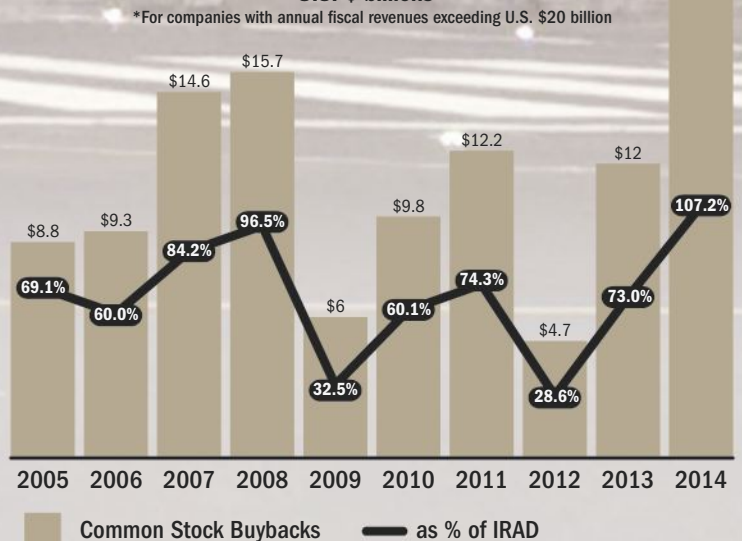
Independent Research and Development Spending (IRAD) U.S. \$ billions*



Pension Underfunding U.S. \$ billions*



Stock Buybacks vs. IRAD U.S. \$ billions*



2015 Aerospace & Defense Rankings

RANK	Company	Results Ending	2014 Revenue (\$ millions)	Total Score
REVENUES GREATER THAN \$20 BILLION				
1	Boeing	Dec. 14	\$90,762	97
2	Lockheed Martin	Dec. 14	45,600	96
3	Honeywell International	Dec. 14	40,306	88
4	Raytheon	Dec. 14	22,826	77
5	BAE Systems	Dec. 14	24,029	74
6	Northrop Grumman	Dec. 14	23,979	73
7	General Dynamics	Dec. 14	30,852	73
8	United Technologies	Dec. 14	65,100	64
9	Airbus Group	Dec. 14	73,445	56
10	Rolls-Royce	Dec. 14	21,391	51
11	Bombardier	Dec. 14	20,111	9
REVENUES BETWEEN \$5-20 BILLION				
1	Thales	Dec. 14	\$15,694	69
2	Rockwell Collins	Dec. 14	5,164	69
3	Precision Castparts	Dec. 14	10,039	65
4	Spirit AeroSystems	Dec. 14	6,799	65
5	Textron	Dec. 14	13,878	62
6	Finmeccanica	Dec. 14	17,738	54
7	Huntington Ingalls	Dec. 14	6,957	54
8	Safran	Dec. 14	18,199	54
9	GKN	Dec. 14	10,873	52
10	Orbital ATK	Dec. 14	5,146	51
11	Zodiac Aerospace	Aug. 14	5,482	49
12	Embraer	Dec. 14	5,621	45
13	L-3 Communications	Dec. 14	12,124	44
14	Rheinmetall	Dec. 14	5,671	42
15	Babcock International Group	Sep. 14	6,042	38
16	Serco Group	Dec. 14	6,159	1

RANK	Company	Results Ending	2014 Revenue (\$ millions)	Total Score
REVENUES BETWEEN \$1-5 BILLION				
1	Teledyne Technologies	Dec. 14	\$2,394	67
2	Dassault Aviation	Dec. 14	4,452	64
3	FLIR Systems	Dec. 14	1,531	62
4	Harris	Dec. 14	4,959	62
5	Hexcel	Dec. 14	1,856	56
6	Heico	Oct. 14	1,132	51
7	Woodward	Dec. 14	2,060	49
8	OHB	Sep. 14	1,030	46
9	Exelis	Dec. 14	3,277	46
10	Ultra Electronics	Dec. 14	1,112	46
11	Cubic	Sep. 14	1,398	45
12	Elbit Systems	Sep. 14	2,919	43
13	Senior	Dec. 14	1,278	43
14	CAE	Dec. 14	1,975	41
15	Kaman	Dec. 14	1,795	40
16	MTU Aero Engines	Dec. 14	4,735	39
17	Moog	Dec. 14	2,636	39
18	Esterline	Oct. 14	2,051	39
19	Barnes Group	Dec. 14	1,262	39
20	B/E Aerospace	Dec. 14	2,599	39
21	Curtiss-Wright	Dec. 14	2,243	39
22	TransDigm Group	Dec. 14	2,430	37
23	Saab	Dec. 14	3,018	36
24	Meggitt	Dec. 14	2,420	35
25	Triumph Group	Dec. 14	3,745	32
26	GenCorp	Nov. 14	1,597	32
27	BBA Aviation	Dec. 14	2,290	32
28	AAR	Nov. 14	1,939	30
29	Cobham	Dec. 14	2,884	26
30	Kennametal	Dec. 14	2,898	25
31	Wesco Aircraft Holdings	Dec. 14	1,505	24
32	Allegheny Technologies	Dec. 14	4,223	23
33	Indra Sistemas	Sep. 14	4,064	15
REVENUES BETWEEN \$250 MILLION-\$1 BILLION				
1	AeroVironment	Apr. 14	\$252	97
2	Astronics	Dec. 14	661	92
3	e2v Technologies	Mar. 14	363	90
4	Motor Sich	Sep. 14	863	85
5	National Presto	Dec. 14	412	77
6	Esco Technologies	Sep. 14	531	75
7	Sparton	Jun. 14	336	64
8	RTI International Metals	Dec. 14	794	63
9	Magellan Aerospace	Dec. 14	726	60
10	Jamco	Mar. 14	629	59
11	Chemring Group	Oct. 14	645	51
12	Sypris Solutions	Dec. 14	355	47
13	Sumitomo Precision Products	Mar. 14	436	44
14	KeyW Holding	Dec. 14	291	42
15	S&T Dynamics	Dec. 14	511	40
16	Erickson	Dec. 14	347	38
17	Ducommun	Sep. 13	742	36
18	DigitalGlobe	Dec. 14	655	30
19	LMI Aerospace	Dec. 14	388	29
20	Kratos Defense & Security	Dec. 14	868	21

e.g., shipyards with the government instead of defense shipbuilders, or Tier 1 aerospace providers instead of the nameplate original equipment manufacturers (OEMs). Liabilities such as pensions, once proverbial albatrosses around the neck of industry, are being optimized (see page 46). Finally, free cash flow, the money generated and left over after assets are dealt with, is maximized and most of it is returned to shareholders and investors (see page 48).

"It has to do with the treatment of assets," says Steven Grundman, a TPC adviser, George Lund Fellow at the Atlantic Council, and former assistant secretary of defense for industrial affairs and installations. "Utility-style companies that manage assets well and generate cash succeed in this model. That does not tend to be a thing we all celebrate."

For John Stack, managing director and aerospace leader at the McLean Group, and other advisers, the true measure of a company is in what it makes beyond the financial reports. What the numbers show and what industry executives and analysts can point to can be different and worthy of consideration. "It should be about value creation," he says.

Take Boeing, which won both its TPC category (\$20 billion or more in annual revenue) and scored the best among all companies (97 this year, and a five-year average of 93). Captain points out that the leading OEM looks to be on the verge of reaching \$100 billion a year in revenue in a couple of years, and maybe even next year when the company marks its 100th anniversary. If no new airliners were ordered this year due to a cataclysmic event—think a 9/11-

type terrorist attack or pandemic flu, which shuts down air travel—the backlog would slip to just an eight-year wait-list.

"Boeing is a fundamentally unique company," Markish says. "Their commercial operations . . . effectively constitute half of a hugely valuable duopoly and [it] has consistently known how to make money." Results from 2014 do not rep-

Business Segment Winners – Fiscal 2014

RANK	Category	Company Business Segment
REVENUES GREATER THAN \$500 MILLION Multiple Units Within a Single Category Are Aggregated		
1	Avionics/Flight Management/Control Systems	Woodward Aerospace/Energy
2	Business Aircraft	Embraer Executive Jets
3	Subsystems/Subassemblies	Eaton Aerospace
4	Missile & Weapons Systems	Lockheed Martin Missiles & Fire Control
5	Military Aircraft	Lockheed Martin Aeronautics
6	Naval Systems	General Dynamics Marine Systems
7	Commercial Aircraft	Embraer Commercial
7	Rotorcraft	Textron Bell Helicopter
8	Forgings/Castings/Precision Components	Curtiss-Wright Commercial Industrial
8	Civil & Military Training & Support Services	Northrop Technical Services
9	Radars/Sensors/Electronic Warfare/C4ISR	FLIR Surveillance/Instruments/OEM/Maritime/Security
9	Propulsion	Safran Aerospace Propulsion
10	Space Systems	Lockheed Martin Space Systems
11	Land Systems	Oshkosh Defense

Note: Ranked by fiscal 2014 median category scores

resent a new era or new direction “It is business as usual at a macro level.”

Yet while the OEM and Pentagon prime is eyeing or pursuing new programs like a “middle-of-the-market” 757-replacement airliner or the U.S. Air Force Long-range Strike Bomber, these are seen more as derivative innovations. Boeing Chairman and CEO Jim McNerney last year famously declared no more “Moonshots” when it comes to development efforts, and the company has been reaping the benefit of its steady market dominance for years.

TPC advisers recognize that it took Boeing a lot of investment and innovation—as well as some course corrections—to reach this point. Five to six years ago, the company’s problems with major programs and customers were headline news, and TPC advisers at the time criticized both management execution and program performance. Now it is “smooth sailing,” one adviser says.

The company is not only reaping the benefit of earlier investments and corrective actions, the learning curve is being extended into other programs. In February a reorganization of Boeing Defense, Space and Security was announced that resulted in a new entity—the BDS Development office. Modeled after a similar unit in Boeing Commercial Airplanes, the office “will address development risks and affordability.” Six programs now managed elsewhere in BDS will be the first to be overseen by BDS Development, including the USAF KC-46 aerial refueling tanker and NASA Space Launch System rocket.

Still, for an industry that can claim hypersonic vehicles, landing humans on the Moon, and helping to build—here in the U.S.—what is arguably the most powerful military on Earth, the emphasis on shareholder value maximization and relatively lower independent research and development are less inspiring to many observers (see charts, page 43). It also comes as Pentagon officials are pushing their so-called Third Offset strategy for technology development, with a soon-to-be-unveiled Long-range R&D Plan crafted with industry in mind.

TPC advisers such as Byron Callan, a director at Capital Alpha Partners, say they see potential changes coming to industry’s makeup as managers and directors shift their focus to longer-term positioning. In 2016-18, the “overwhelming” investor focus on defense contractor capital deployment could give way to accommodation of the Pentagon’s changing acquisition practices and emerging competition.

“Managements that do not make strategic decisions on their participation in defense but overwhelmingly deploy capital in favor of shareholders could be caught flat-footed by these changes,” Callan cautions.

Stack agrees: “You can only lever to pay buybacks and dividends and everything else for so long. You can’t save your way to greatness.” ☒

Average 5-Year Ranking

RANK	Company	Average 5-Year Score
REVENUES GREATER THAN \$20 BILLION		
1	Boeing	93
2	Lockheed Martin	90
3	BAE Systems	80
4	Rolls-Royce	79
5	Honeywell International	75
6	Raytheon	75
7	Northrop Grumman	73
8	General Dynamics	68
9	United Technologies	65
10	Airbus Group	54
11	Bombardier	30
REVENUES BETWEEN \$5-20 BILLION		
1	Rockwell Collins	82
2	Precision Castparts	73
3	GKN	64
4	Thales	62
5	Safran	61
6	Rheinmetall	59
7	Orbital ATK	53
8	Textron	51
9	Embraer	49
10	Zodiac Aerospace	49
11	L-3 Communications	46
12	Babcock International Group	45
13	Finmeccanica	45
14	Spirit AeroSystems	38
15	Serco Group	34
REVENUES BETWEEN \$1-5 BILLION		
1	Teledyne Technologies	71
2	FLIR Systems	66
3	Harris	60
4	Cubic	58
5	Ultra Electronics	57
6	Dassault Aviation	54
7	OHB	52
8	Heico	52
9	Hexcel	50
10	Woodward	50
11	MTU Aero Engines	48
12	Saab	46
13	Senior	46
14	GenCorp	45
15	Elbit Systems	43
16	TransDigm Group	43
17	CAE	42
18	Triumph Group	41
19	Cobham	40
20	B/E Aerospace	39
21	Meggitt	39
22	Moog	37
23	Kaman	36
24	Esterline	36
25	Kennametal	36
26	Wesco Aircraft Holdings	35
27	Indra Sistemas	35
28	Curtiss-Wright	34
29	BBA Aviation	31
30	Barnes Group	30
31	AAR	29
32	Alleghe Technology	27

HOW IT WORKS, IN BRIEF

Aviation Week's Top-Performing Companies (TPC) ranking methodology this year incorporated changes that subtly but significantly influenced the results.

Chief among the changes was that prior-year results and financial statements were calibrated within a 14-year time frame of 2000-13, versus the 12 years of 1998-2009 in earlier TPC assessments. This was done in an effort to achieve more accurate and complete data comparisons, including full business cycles, across the aerospace and defense industry. Also starting this year, Reuters Eikon was the underlying database, replacing Standard & Poor's Capital IQ.

Other changes for 2015 reflect recommendations by the TPC Council of Advisers regarding treatment of independent research and development (IRAD), as well as goodwill relief from mergers and acquisitions. The advisers and Aviation Week agreed that companies should not be unduly affected by pursuing IRAD and strategic portfolio-shaping activities. In turn, IRAD was added back to calculations for operating profits, as in some previous TPC reviews.

Asset-based metrics with a goodwill component, meantime, were revised to roll in new additions to goodwill over a five-year period—rather than wholly in the year of acquisition—if the initial change in goodwill-to-total-assets ratio exceeded 5%.

Aviation Week believes none of these changes, by themselves, have led to decisive differences in final TPC results. But taken together, they lead to different rankings than would have been determined under earlier TPC reviews. A full explanation of the TPC methodology can be found online at AviationWeek.com. ☎

WALL STREET'S TAKE

Wall Street's outlook on the aerospace and defense industry and its companies can be a universe apart from Top-Performing Companies (TPC) and other rankings, and 2015 is no exception.

To be sure, traders of publicly held stock and debt have always had a different perspective than aviators, engineers, warfighters and even industry managers. Traders focus on making money, of course, while the others often put a higher value on advances in technology, safety and efficiency.

For traders, the method for making money typically revolves around changes in stock prices, as well as share repurchases, dividends, debt transactions and other investment plays. Hence, Wall Street can favor individual A&D companies or the sector as a whole, even as others lament mediocre program performance (see page 50) or shareholder value maximization that may come at the cost of research investments (see page 48).

In turn, companies like Precision Castparts (No. 3 in its TPC category) and Spirit AeroSystems (No. 4) are recommended as stock "buys" by a slim majority of financial analysts who cover them—the first has been on an acquisition binge, and the second is considered a turnaround story—even though they do not lead their TPC categories or five-year averages. Not surprisingly, TPC-leader Boeing also is seen as a "buy" by most professional stock pickers.

Yet Lockheed Martin (TPC No. 2) sees more than twice as many "hold" recommendations as "buys," according to

Engineering The Numbers

Pensions, foreign-exchange hedging and other accounting moves boost A&D appearances

Michael Bruno **Washington**

Lockheed Martin had a fantastic 2014, by the numbers. With sales revenue of \$45.6 billion and net earnings above \$3.6 billion, it seems little wonder the prime Pentagon provider was barely nosed out by Boeing in winning the 2015 Aviation Week Top-Performing Companies category for their peer group. Indeed, with a 2015 TPC score of 96—behind Boeing's 97—and a five-year running average of 90 (Boeing, 93), Lockheed is otherwise well above the rest of the aerospace and defense industry, and

has reason to boast (see page 42).

Thanks, that is, to its retirees.

If not for a growing tailwind benefit of how Lockheed accounts for its pension liabilities, as well as its experienced foreign-exchange (FX) hedging and other asset-management accounting moves, Lockheed's 2014 financial results and TPC scores would look worse. Indeed, they could look significantly worse if the final numbers reflected only the suburban Washington-based contractor's core business operations, especially as Pentagon budgets have flatlined in recent years.

For instance, Lockheed's cash from operations for 2014



LOCKHEED MARTIN

Lockheed Martin CFO Bruce Tanner sees the company generating "organic" growth in 2016. In the meantime, pension treatments will help.

Dow Jones & Co. data. That is despite high annual and five-year TPC scores that—after Boeing—far exceed the rest of industry. One reason cited by analysts is a lack of organic growth from core operations (see article below).

Still, as a whole, analysts continue to suggest A&D as an investment sector for their clients, albeit with more caution this year than last. One concern is that the U.S. federal budget is again uncertain as Congress wrestles with the potential return of so-called sequestration spending caps. “The budget will be key for the sector,” say Sanford C. Bernstein analysts. “It is probably too early for management teams to know where their program budgets are headed in fiscal 2016.”

But analysts expect brighter days ahead, nonetheless. “The outlook for defense contractors has improved, as military spending in the core U.S. market is now heading back up, complementing budget growth in Asia and the Middle East, and potential stability in Europe,” say RBC Capital Markets analysts. After the financial crisis of 2008, the Great Recession and the end of the wars in Afghanistan and Iraq, “U.S. defense spending looks to have troughed in 2015.”

In the meantime, commercial aerospace remains an attractive niche segment and can carry the whole sector into profit. “Our stable outlook reflects our expectations that strong demand for large commercial aircraft will con-

tinue to offset budgetary pressure for defense contractors,” says Moody’s Investors Service.

According to Moody’s, “favorable” air traffic trends and “robust” airline profitability will continue to support sustained commercial demand. And despite lower oil prices that could dilute incremental replacement demand for airliners, fleet expansion should be largely unaffected. Above all, record backlogs provide an “ample” cushion if there are greater-than-expected order deferrals and/or cancellations. “Demand fundamentals remain strong in the commercial aerospace sector,” Moody’s says.

Moody’s said April 1 that it expects overall operating profit growth for the A&D sector of 2-4% during the next 12-18 months, an improvement from a December forecast of flat to 2% growth for 2015.

Based on stock prices, RBC said April 13 that the global A&D sector it covers has rallied by 212% since March 2009, 63% over the S&P 500 index’s growth. ☼

Precision Castparts’ drive to be a leading provider of aerospace and defense parts pleases Wall Street.



was \$3.9 billion after making a discretionary, advance pension-liability contribution of \$2 billion. That compared to cash from operations for 2013 of \$4.5 billion after pension contributions of \$2.25 billion.

And even as those pension payments may sound robust, Lockheed still had a “large” pension deficit of \$11.2 billion at the end of 2014, according to Fitch Ratings. Yet executives said in January they do not plan to make any more payments through 2017.

In the meantime, pension income swung to \$376 million for 2014 after a \$482 million loss the year before, in part due to arcane accounting treatments and benefits enjoyed by federal contractors. That income stream should only improve.

“We expect Lockheed Martin will be the industry’s biggest beneficiary of rapidly growing pension expense recoveries over the next several years,” Moody’s Investors Service says.

In looking over 2014 results, the TPC Council of Advisers noted the strong and growing effect of pensions, FX and other bookkeeping in annual financial results. More than any other factor, pension treatments increasingly are underpinning A&D results, an effect that is

only expected to gain steam (AW&ST Oct. 13, 2014, p. 50).

“It’s based on the growth in their pension,” says Byron Callan, a widely followed defense industry analyst at Capital Alpha Partners and a TPC adviser.

“Some of these numbers are going to be driven more by these swings in the pendulum and the [federal contractor accounting] rules, the Financial Accounting Standards rules on pension treatment,” Callan says. “It’s fascinating if you look at forward analyst projections, particularly for some of the large U.S. primes; they’re going to show pretty good earnings growth over the next couple of years.”

Callan says the benefit was most pronounced at Lockheed, but other companies on the TPC list also bask in the afterglow of financial engineering.

“They will be the top-performing firms when it’s really not something that’s coming from how they fundamentally manage their programs as much as it is from the fact that, as in Lockheed’s case, they’ve prepaid a lot of their pension plan,” he says. “They’ll recover that under the cash roll.”

Companies in the two top TPC peer groups also are collectively doing a “very good job” of hedging their international revenue mix denominated in other than their native currencies, according to industry analyst Mike Lowry,

who compiles TPC scores as a service for Aviation Week.

For example, even as the U.S. dollar approached an almost five-year-high value compared with other currencies last year, TPC companies in the over-\$20 billion revenue category lost only \$421 million in FX effects on cash via hedging. That is down from \$505 million in 2013. In 2014, Boeing lost just \$87 million while many companies such as Lockheed reported no change.

Analysts see the numbers play out in many other ways, too. One so-called quality-of-earnings measurement that Wall Street tracks is the Dupont calculation. According to Investopedia.com and Lowry, return on equity (ROE) is a closely watched number indicating how a company's management does in creating value. But it can be misleading, too. The advanced Dupont model defines the percentage contribution of a ROE result from

Inflated Expectations

Stock buybacks and dividends are soaking up industry's free cash flow

Anthony L. Velocci, Jr. **New York**

Shareholders in aerospace and defense have never had it so good.

The largest publicly traded companies in recent years have generated billions of dollars in free cash flow, as defined by operating cash flow minus capital expenditures, with most of it returned to shareholders in the form of dividend increases and stock repurchases. In investment circles, the strategy is commonly known as shareholder value maximization.

In most cases, it has driven companies' market valuations to historic levels. "They've been monster stocks," said Byron Callan, a director at Capital Alpha Partners, an independent strategic policy adviser to financial institutions.

In 2014, Northrop Grumman was the most aggressive, funneling \$3.3

billion, or 159% of its free cash flow to investors. At General Dynamics, share repurchases and dividends consumed \$4.2 billion, 131% of free cash flow; at Boeing, \$8.1 billion, 123%; Lockheed Martin, \$3.7 billion, 120%; and at BAE, \$571 million, or 263%.

United Technologies—which last fall saw a headline-making abrupt turnover of CEOs—returned \$3.5 billion, or 71% of its free cash flow. It plans to double share repurchases and increase dividends by about 8% in 2015, while drawing down research and development (R&D) spending.

The practice is not unique to the A&D industry. General Electric recently announced a multibillion-dollar share buyback plan. "It is an industry-wide phenomenon across many mature sectors—shareholders pressuring com-

panies to return cash to them," Callan notes. "Your primary focus becomes cash flow at the expense of almost everything else."

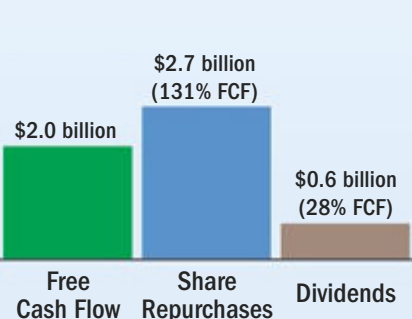
What troubles Callan and other TPC advisers—and many A&D observers, including some former chief executives—is that contractors may be shortchanging their future by under investing in R&D as the preferred means of creating long-term value. In addition, they believe the strategy of creating short-term value by returning so much cash to shareholders is simply unsustainable.

Companies are creating false expectations, according to Jacob Markish, a TPC adviser and principal of consulting firm Renaissance Strategic Advisors. "Eventually shareholders will be in for a rude awakening as companies realize they need to concentrate on more strategic, longer-term goals," he says.

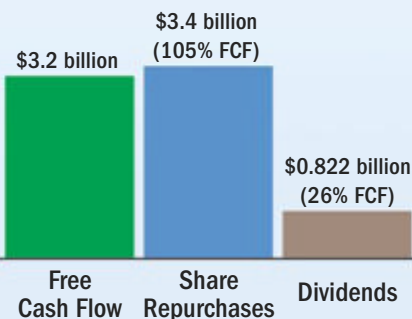
Historically, when A&D companies generated large amounts of free cash, they have tended to invest in new products and technologies, Callan points out. In the last 10 years, the focus has shifted to owners, with a huge jump in dividend payouts and share repur-

2014 Free Cash Flow (FCF) and Investments

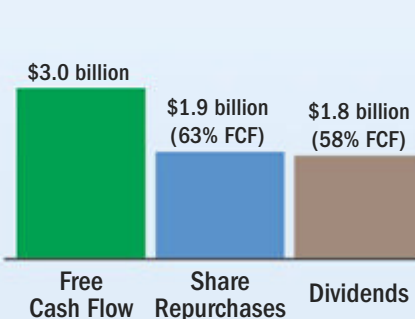
Northrop Grumman



General Dynamics



Lockheed Martin



operating and/or debt sources, i.e., financial engineering.

Across the top TPC category (revenue-weighted), 30.2% of ROE was attributable to financial engineering in 2014. At Boeing, it was 29%; Lockheed, 57.1%; Honeywell International, 27.7%; Raytheon, 22.2%; BAE Systems, 44.9%; Northrop Grumman, 34.1%; General Dynamics, 19.4%; United Technologies, 29.8%; and Airbus Group, 17.8%. Rolls-Royce's was not measurable.

In the end, TPC advisers suspect that if pension treatments could be stripped out of calculations, then BAE Systems (No. 5), Airbus Group (No. 9) and Rolls-Royce (No. 10) might all move up in the Top 10 listing of the highest, over-\$20 billion annual revenue category. General Dynamics, which accounts for its pension differently than other primes, might too, as the way it handles its pension now does not let it enjoy the same benefits. ☹

chases (*AW&ST* June 9, 2014, p. 49). In 2000, the total was less than \$1 billion industry-wide, he noted. "This raises the question of whether companies' other two constituents—customers and employees—are getting a fair break."

Not all primes have rushed to return everything to shareholders; General Dynamics and Raytheon had been relative laggards. Last year, Raytheon returned 88% of its free cash flow to shareholders. "Management's priority is growth, so they are stepping up company-funded R&D in such high-priority areas as cyber and "anti-access and area denial-related technologies," according to Jim McAleese, founder of McAleese & Associates, which provides consulting and legal services to government contractors.

Raytheon Chairman and CEO Tom Kennedy told a financial conference at the end of 2014 that his company's share repurchase program would continue, but it also planned to allocate more of its capital to acquisitions and next-generation technologies. "When defense spending rebounds, we expect our investments will be well matched with the customer's most pressing re-

quirements," he said.

Still, some contractors claim the Pentagon is not providing enough incentive to justify more investment in R&D. "We don't see many good opportunities that will generate attractive returns," L-3 Communications CFO Ralph D'Ambrosio said at the same conference. The company returned about 117% of free cash flow to shareholders in 2014.

Raytheon has been leading some of its peers in communicating to investors that they intend to continue allocating resources toward their future while trying to take care of their shareholders, according to Markish. "As the run-up in share prices begins to taper off, other contractors will need to figure out how to prepare their investors for a shift they will have to make in their capital-allocation policy," he says.

So-called independent R&D (IRAD) by contractors has been steadily declining since 2010, according to Tom Captain, a TPC adviser who leads the global A&D practice of Deloitte Consulting. Among U.S. companies, it fell 12.3% in the last five years, while the Defense Department's baseline budget

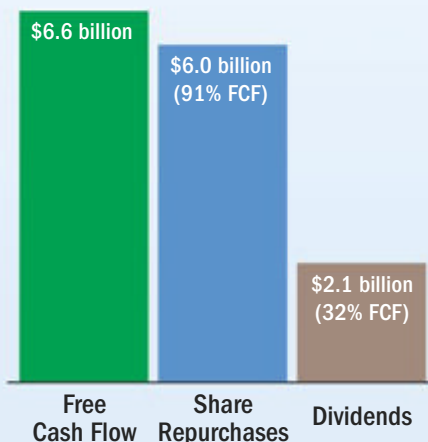
for research, development, test and engineering (RDT&E) dropped more than 21%.

Meanwhile, the U.S. risks losing dominance. "European companies are competing harder on pricing and advances in technology, and they have more support from their governments for RDT&E-type funding," Captain says. The industry also is facing the prospect of increasing competition from the commercial sector.

Nonetheless, many senior A&D managers, including some who have retired, insist the industry is spending enough on IRAD, and that the real problem is the government's lack of commitment to greater RDT&E spending.

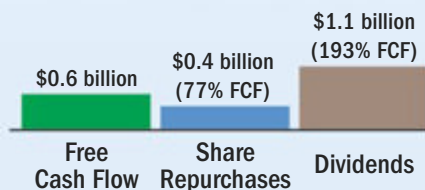
Referring to the imbalance between short-term and longer-term capital-deployment strategies, Callan bristles at the suggestion that there are no investment opportunities. "Some of the greatest game-changing innovations in the past were created when contractors chose to accept more business risk, allowing them to conceive technologies and create new markets that previously didn't exist," he says. "Some companies have lost sight of their legacy." ☹

Boeing

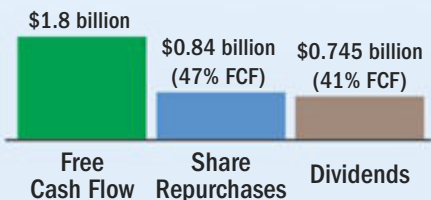


Billions of dollars are being returned to shareholders, causing some industry observers to question whether companies are shortchanging their R&D investment.

BAE Systems



Raytheon



British Is Best?

Top-Performing Companies and top Pentagon performers are not the same

Michael Bruno **Washington**

Although it may not pay to perform well for the Pentagon per se, somewhere down the line there could be a payoff for being a master of the Iron Triangle.

That is one plausible conclusion after comparing the latest Top-Performing Companies (TPC) from Aviation Week with the most recent list of “superior suppliers” and prime contractors on major defense acquisition programs from the U.S. Defense Department. While TPC has been published since the mid-1990s, this is the first time results can be weighed against new contractor performance rankings released by the Pentagon since last summer.

To be sure, TPC and Pentagon data do not provide an “apples-to-apples” comparison directly because the data being measured is different—e.g., financial performance in TPC versus cost and schedule performance by the Pentagon.

But TPC data also show a company's average score over five years, up to 2014, while the Performance of the Defense Acquisition System report last June from the Defense Department measured price and schedule growth in development and production con-

tracts over 14 fiscal years through 2013.

In turn, many companies can be evaluated using longer-term results available in both surveys that paint bigger, albeit circumstantial, pictures. One point of particular interest is that the best contractor across the TPC and Pentagon surveys seems to be Britain's BAE Systems.

In TPC results covering 2014 financials, BAE ranked fifth in its category, and over a five-year period it came in third, behind Boeing and Lockheed Martin, respectively (see page 42).

In Pentagon performance rankings on schedule growth in development programs, however, “BAE Systems had the best performance (with no schedule growth on any of its six contracts),” according to the June report. Likewise, in price growth from 2000 to 2013, BAE notched a -3% result—a far cry from other primes like Boeing (8% growth), Lockheed (37%), Northrop Grumman (41%), General Dynamics (22%) and Raytheon (32%).

Although BAE was not named by the Pentagon when it listed price and schedule growth by prime contractors in production contracts, competitors were. These included: Lockheed

(-1% price growth, 0.5 years schedule slippage), Boeing (24%, 1.1 years), Northrop (-3%, 2 years), GD (-4%, none), Raytheon (-2%, none), Huntington Ingalls Industries (21%, 0.8 years), and Oshkosh (13%, -0.7 years).

Yet when it came to the best-performing providers as named by the U.S. armed services and the Defense Logistics Agency in their three-tier “superior supplier” lists, BAE was regularly cited. For example, BAE Electronic Systems was named a top-tier performer by the Air Force and Army, and second tier by the Navy Department. BAE Global Combat Systems also made the Army's top tier. BAE Systems Land and Armaments is on the Navy's second- and Army's third-tier lists. And BAE Systems Intelligence and Security is in the Air Force's third tier.

Not surprisingly, Boeing and Lockheed Martin units also are prevalent in the superior supplier lists, particularly for the Air Force. At the same time, the TPC advisory council as a whole viewed BAE as a “challenged organization, operationally and financially.” It may have suffered from an overreliance on U.S. land warfare business tied to the wars in Afghanistan and Iraq, and BAE's “value creation” as a business in recent years has been pegged to acquired business lines, not necessarily organic growth.

In the end, BAE may not be leading the pack of its TPC peers, but it is managing its business portfolio, and performing relatively well for the Pentagon. ☼

The Pentagon may want to look farther northeast, to the U.K., to find its overall-best contractor.



Electric Rocket

Rocket Lab plans weekly launches using battery-powered turbopumps

Frank Moring, Jr., and
Guy Norris **Colorado Springs**

Rocket Lab, a sounding rocket and launch vehicle company co-located in the U.S. and New Zealand, is preparing to begin testing a smallsat launcher dubbed Electron that would use battery-powered turbomachinery and other innovations to hold the cost per mission below \$5 million.

The company, which received U.S. Defense Department funding before branching into commercial development, unveiled its Rutherford engine at the 31st Space Symposium here April 13-16. The engine uses high-performance brushless DC electric motors to drive its liquid oxygen and kerosene turbomachinery, drawing power from lithium polymer batteries. The approach, says CEO Peter Beck, eliminates the complex valves and other plumbing required to use hot gas to turn turbomachinery, boosting efficiency from 50% for a typical gas generator cycle to 95%.

"For us it was really about decoupling that thermodynamic problem," Beck says. "And the beauty with an electric turbopump is that it takes that really complicated problem and turns it into software."

Each Rutherford engine has two electric motors the size of a soda can, Beck says, one for each propellant. The small motors generate 50 hp while spinning at 40,000 rpm, which is "not a trivial problem," he says. "The battery technology is also a little bit special. We're drawing huge currents and huge energies from those batteries to provide the energy, but really it just provides such a simplified and efficient system," he adds.

The efficiency is needed for the company's business model, which foresees customers with payloads weighing up to 100 kg (220 lb.) launching into 500-km (310-mi.) sun-synchronous orbits or to inclinations as low as 46 deg. The payloads can be readied for flight at the customer's own facility and then shipped to the launch site, which is under construction in New Zealand at a location Beck says is still "a closely guarded secret." The company has about 30 "commitments" from customers, he says.



ROCKET LAB

Rocket Lab's Rutherford engine will use battery-powered turbo pumps, additive manufacturing and other innovations to help hold mission costs below \$5 million.

A former Crown Research engineer, Beck established Rocket Lab with the support of seed-investor Mark Rocket, an Internet entrepreneur who changed his name from Mark Stevens.

"In 2009, we launched R-1, our first sounding rocket, on a suborbital ballistic arc," Beck says. "That got the attention of agencies in the U.S., particularly Darpa." Rocket Lab subsequently studied and tested propellant and launcher technologies for Darpa, Lockheed Martin and the U.S. Operationally Responsive Space Office.

"In 2013, the company reached a crossroads," says Beck. "Did we want to follow the road of being a U.S. defense contractor? Or did we want to get into the commercialization of space, which is always what I wanted to do? So we chose the latter."

The company secured additional funding in late 2013 under the New Zealand government's Callaghan Innovation Growth Grants program, and since then "we have been flying under the radar for about a year, working on the development of the Electron launch



ROCKET LAB

Hot-fire testing sets up the Rutherford engine for suborbital flight on the Electron launch vehicle by year-end.

vehicle," Beck says. The Electron is "the crux of the project and is aimed at what is expected to be a huge growth of 60% or more in the small satellite business over the next five years," he says.

The company is banking on the lightweight structure of its two-stage vehicle and the power-to-weight efficiency of the Rutherford engine to make a cost breakthrough in the small-satellite launch market. Rocket Lab is targeting a cost per launch of \$4.9 million, which it says will reduce the average orbital delivery costs by 95% versus the current launch infrastructure and its large reliance on ride-share payloads.

In another effort to increase efficiency and hold down cost, Rocket Lab is building the regeneratively cooled engine using 3-D, additive-manufacturing techniques that include laser and electron-beam sintering, with Inconel and titanium powder as the feedstock.

Nine of the engines will be used to power the 59-ft.-tall Electron vehicle, which will have a total combined thrust of 27,000 lb. at liftoff, with a targeted peak thrust of 34,000 lb. during ascent. The second stage will be powered by a 4,000-lb.-thrust vacuum variant of the Rutherford engine, essentially identical to the main-stage engine but with an extended nozzle.

Beck says that commonality extends down to the fastener level, with standardized parts used wherever possible to lower costs. For efficiency at the launch site, the Electron upper stage is designed for independent payload integration before it is literally bolted onto the top of the main stage with four bolts.

"The first flight is scheduled for the end of this year and the program is pretty mature," Beck says. ☼

Icing Invention

Easy-to-apply icing protection aimed at unmanned aircraft and general aviation



Graham Warwick Washington

BATTELLE PHOTOS

U.S. research and development organization Battelle is ready to flight-test a carbon-nanotube coating that can protect unmanned and general-aviation aircraft from icing with a low weight penalty and power consumption, enabling operation in adverse weather.

Icing protection is rare in unmanned aircraft, limiting the conditions in which they can be flown, but conventional anti-ice and deice systems can be too costly, heavy and power-hungry.

Battelle's HeatCoat technology disperses carbon nanotubes into aircraft paint to make a conductive coating that heats up like a resistor when electrical power is applied. The coating can be sprayed on to conform to aircraft surfaces or applied as a laminate.

Early in February, Battelle placed a section of wing and the engine inlet of an unidentified unmanned aircraft in a major manufacturer's icing tunnel for tests that took the system to technology readiness level 6, says Ron Gorenflo, HeatCoat program manager.

"We performed a lot of testing over the last 18 months to identify and lock down the materials. Now that we have a stable technology, the next step is to scale up to flight test," he says.

Both the spray and laminate versions were tested in the icing tunnel. "HeatCoat sprays on like a paint and is very thin as applied, conforming to complex curves, so it maintains the wing's aerodynamic performance," says Gorenflo. The laminate version uses premanufactured heater panels.

"HeatCoat is a retrofittable solu-

tion," he says, adding that the system is much lighter than thermal blankets, does not affect the structural characteristics of the aircraft and does not involve consumables, unlike the fluid-

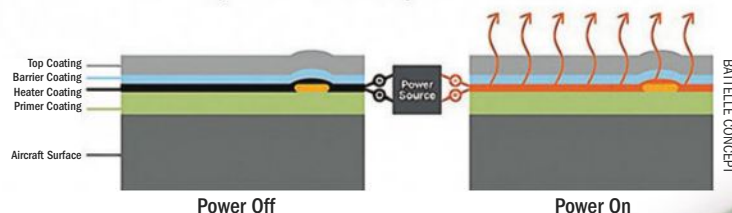
In icing conditions in the tunnel, the wing section with HeatCoat applied (right side) is free of ice.

have the capability within their power budget," he says.

The system can provide anti-icing to prevent ice formation while an aircraft flies through icing conditions or can deice the leading edges once ice has formed. "When transitioning through icing, the ground control station can turn on the system, [which then] will operate automatically," says Gorenflo.

Deicing can use less power than anti-icing, but "some platforms have control issues in icing for which anti-ice is the best solution. In some cases we can use anti-icing while deicing other parts of the airframe," he says.

Battelle has funded development of HeatCoat internally, with support from the U.S. Air Force in fiscal 2010-12. "We made a major investment in 2013-14 and will continue to invest in flight test," Gorenflo says.



A heating layer is applied between the primer and barrier coatings under the paint top coat.

The laminate form comes as premanufactured carbon-nanotube panels.

based icing protection used in general-aviation aircraft.

For unmanned aircraft, the power required for icing protection can be a challenge. "Some [UAVs] do not have a power budget, but HeatCoat is the most efficient electrothermal system there is. The ones we have looked at

"We are talking to manufacturers as well as the user community on the government and GA [general aviation] sides and they are very interested," Gorenflo adds. He expects a customer to emerge within the next 6-8 months.

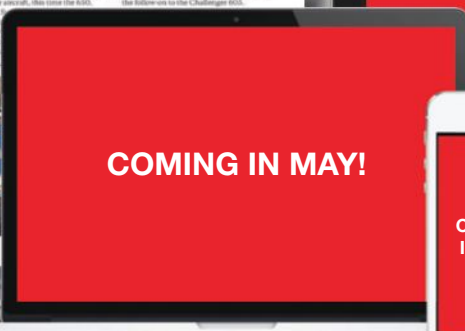
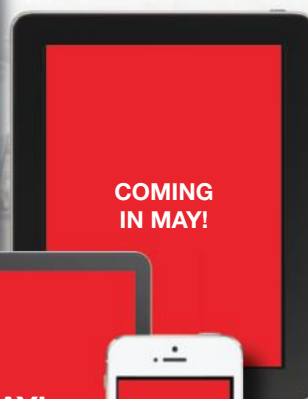
"We have been heading down the path of UAV first, but they may not be the first [to move]," he says. Battelle has the capacity to provide integration kits for a number of aircraft but could seek a partner for the wider GA market. ☒



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Defining Defiant

Suppliers invest as Sikorsky and Boeing move closer to advanced rotorcraft demonstrator

Graham Warwick **Washington**

Components for the SB-1 Defiant high-speed rotorcraft will begin arriving at Sikorsky and Boeing this year as the team begins building the system integration laboratory, propulsion system testbed and eventually the flight vehicle for the U.S. Army's Joint Multi-Role (JMR) technology demonstration.

The team has announced 48 suppliers for the Defiant, with more selections to come. Two-thirds of the companies listed are partners that are investing

testbed [PSTB] will come on line early in 2017 to test the dynamic components," says Pat Donnelly, Boeing's JMR program manager.

The 230-kt.-cruise Defiant will have rigid coaxial rotors and a tail-mounted propulsor with clutch, all driven by two Honeywell T55 turboshaft engines. "The PSTB will validate all the systems are working and allow us to get some time on the components," says Donnelly.

Structures partners are Swift Engineering for the fuselage, Triumph

developing the flight control computers and cockpit interface units. Lord is providing the active vibration-control system and Honeywell the integrated vehicle health management computer.

The Defiant's cockpit "is just what is basic to flying the aircraft," says Donnelly, noting that a second phase of the JMR program will demonstrate mission-system technology. "We are trying to reuse what we can from existing programs." Aitech is supplying the mission computer, Garmin the radio, L-3 the displays and Northrop Grumman the inertial navigation unit.

Sikorsky went through a similar supplier selection process for its industry-funded effort to build two prototypes of the S-97 Raider high-speed light tactical helicopter, the first of which is being prepared for flight, but the JMR selection was run independently.

Some of the same suppliers are now on the Defiant, but many are different, says Shidler. "When you want to build a one-off versus 2,200 aircraft, that's attractive to a different type of company," says Donnelly, noting prototyping specialist Swift "is good at building one-offs."

Suppliers have signed up just for the JMR demo, as the future of FVL remains uncertain.

The Army, meanwhile, says it expects to complete its business case analysis for the follow-on Future Vertical-Lift (FVL) Medium program of record by the end of this year, with a "materiel development decision" planned for the end of fiscal 2016. This would launch the analysis of alternatives that would lead to a Milestone A decision in 2019 that would launch the program and begin technology maturation. The Army expects to award contracts in 2021; under current plans, the first aviation brigade will be equipped with FVL in 2037.

Industry and the Army are concerned that further budget cuts could force a delay between completion of the JMR technology demonstration in 2019 and the start of FVL Medium design. "We are concerned that a long gap before establishing platform requirements [for FVL] could have an impact on retaining talented staff," says Shidler, adding the near-term issue is maintaining industry's technical capability to design an efficient rotorcraft. ☼



SIKORSKY/BOEING

in the program with in-kind labor or by providing parts, says Doug Shidler, Sikorsky's JMR program director.

The program to demonstrate technology for the Army's next generation of rotorcraft involves significant cost-sharing by industry. A recent Sikorsky investor presentation values JMR at \$500 million, but in August 2014, when it signed agreements with both Bell and Sikorsky/Boeing to build flight demonstrators, the Army said funding for the air-vehicle phase of JMR is \$217 million.

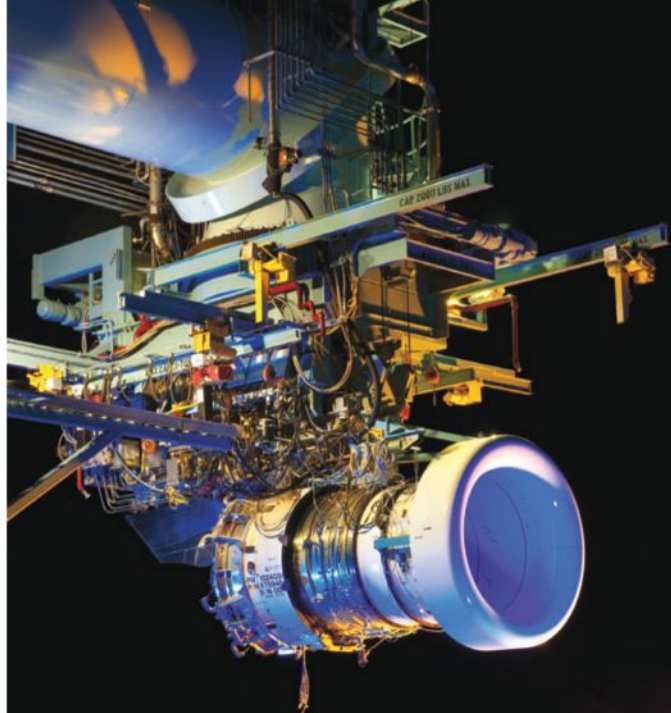
Critical design review for the Defiant demonstrator is scheduled for late this year, with the system integration lab (SIL) to be operational early next year, says Shidler. "Mid next year we will start final assembly," he says. First flight is planned by the end of fiscal 2017.

"We will start with the SIL to ensure all the electronics are working together. Then the propulsion system

Group for landing gear, Martin-Baker for crew seats, East/West Industries for cabin seats and PPG for transparencies. Swift will build the composite fuselage and deliver it to Sikorsky's West Palm Beach, Florida, development flight-test center for final assembly, says Shidler. Boeing will produce the rotor blades and perform final assembly of the main-rotor gearbox, says Donnelly.

The gearbox leverages both companies' experience building and testing different transmission designs. "In the end we have a product neither of us could have come up with independently," says Shidler. "We believe we have the lowest-weight, most-efficient solution," adds Donnelly.

Several companies are providing components of the vehicle management system, but the principal supplier—Sikorsky's United Technologies sister company UTC Aerospace Systems—is



Hot Blades

Engine architectures and advanced alloys push Pratt's CMC focus from static to spinning parts

PRATT & WHITNEY

Guy Norris East Hartford, Connecticut

Pratt & Whitney is focusing on development of very-high-temperature ceramic matrix composites (CMC) in rotating structures for its future commercial and military engines. The company says it is "not convinced" of the utility of the lightweight material for static parts.

The approach, which Pratt says is partially driven by the low stage-count configuration of its newer engines, and partly by a growing preference for thermally conductive advanced alloys, appears to be sharply at odds with that of CMC pioneer and arch-rival General Electric.

Pratt & Whitney materials and systems chief engineer Frank Preli says, "We are focusing on the 2,700-deg. class of CMCs mostly because we have very few stages in our engines. We don't have big low-pressure turbines with 5-7 stages. We only have three, so low-temperature CMCs don't have as much of an advantage in our architectures." Instead, Pratt is focusing on using higher-temperature CMCs in the rotating blades of future high-pressure turbines. "That's where we see we will get the biggest benefit. That's the real payoff for CMCs because of their low densities," he explains.

In contrast, Pratt does not see the material being used for static parts such as those in GE's latest engines. "We are not convinced CMCs are the best material for static parts," says Preli. "There are a couple of issues with CMCs beyond the cost of manufacturing and one is thermal conductivity. It is relatively low, so in a static part where weight is not as important as in a rotating part, you find there are materials with far superior thermal conductivity, like some of the advanced alloys.

"In non-rotating parts, you can take advantage of that very-high-thermal conductivity and get parts that are more effective and which require less cooling air than would be required

by CMCs. So that's why you have to look at the exact system architecture and the exact part."

Pratt is also looking at monolithic ceramics for air seals, as well as classes of advanced alloys of niobium, cobalt and molybdenum. "These are alloys that can give you very-high-temperature capability in the parts that don't rotate and, combined with high thermal conductivity, you get huge improvements in performance," says Preli.

GE, which introduced turbine shrouds made from first-generation CMCs into ground-based power engines in the 2000s, is pushing for its wider use for jet engines, initially in static parts. CMCs will make their commercial engine debut in 2016

Pratt says the low-stage count of engines like the PW1524G, seen here on test, makes CMCs less cost-effective for static parts.

when the GE-Snecma CFM Leap-1 enters service with turbine shrouds made from the material. Its commercial use will greatly expand from 2020, when GE's GE9X for the Boeing 777X will enter

service with CMCs used in the combustor liner, first-stage high-pressure (HP) turbine nozzle and shroud, and the second-stage nozzle. Earlier this year, a modified GE9X-1B 787 engine began tests of the first full GE9X suite of CMC components.

CMCs are generally divided into non-oxide or oxide-based materials. The non-oxide material systems used or studied for high-temperature propulsion applications include carbon fibers in a carbon matrix (C/C), carbon fibers with a silicon carbide matrix (C/SiC), as well as silicon-carbide fibers in a silicon-carbide matrix (SiC/SiC). Oxide-based materials are made up of an oxide fiber and oxide matrix (Ox-Ox).

GE has also introduced Ox-Ox CMC structures into the Passport business jet engine, where it is used for the exhaust, centerbody and core cowls. Late in 2014, the engine maker also validated the temperature capabilities and durability of CMC-made low-pressure (LP) turbine blades in an F414 turbofan. The tests of the material, used in the second LP turbine stage, represented the first successful application of CMCs in a rotating stage. GE has spent over \$1 billion in developing SiC ceramic fiber and ceramic resin material for engine applications.

Rolls-Royce also wants to introduce CMCs into its commercial and military engine lineups, and has outlined plans for an advanced shroudless HP turbine with a rub-in CMC liner for smaller members of its Advance family, as well as CMC nozzles in its UltraFan concept. Together with Orbital ATK company COI Ceramics, Rolls recently joined forces with Boeing on its 787 ecoDemonstrator program to test a ceramic nozzle on a Trent 1000 as part of the FAA's Cleen program. Results indicated the CMC material system exceeds the temperature capability of superalloys at a weight 20% lighter than titanium, reducing fuel consumption. Rolls also recently acquired California-based CMC specialist Hyper-Therm, a manufacturer that also worked with NASA on development of the first actively cooled, continuous fiber-reinforced SiC-matrix composite thrust chamber for a liquid-fuel rocket propulsion system.

Pratt meanwhile remains confident that it is on the right track to develop the capability for the highly demanding HP turbine. "We have what we believe are clear pathways to doing matrix consolidation; matrices that are capable of 2,700 deg.," says Preli. "We have a clear path toward coating systems, though one of the things we are concerned about is the fiber. High-temp fibers sort of exist today and there are some development fibers showing promise, but our focus has to be on getting fiber capabilities," he adds. ☛

With Joseph C. Anselmo and Jen DiMascio in Washington

Adaptive Change



CALSPAN AEROSPACE

Test pilot program proves viability of adaptive controller for civil airliner safety application

Guy Norris **Edwards AFB, California**

An adaptive flight controller that could help pilots save a critically damaged or out-of-control aircraft is being proposed for possible commercial development following a rigorous evaluation by U.S. Air Force Test Pilots School (TPS) students here, using Calspan's variable-stability Learjet 25 test aircraft.

The L1 controller is designed to automatically intervene in the case of control problems, immediately reconfiguring the flight-control system to compensate for degraded flying qualities, from mechanical failure or battle damage to a control surface, or even the unintended result of shifting center-of-gravity inflight for better cruise performance. Acting as a backup to the standard flight-control system, the L1 is designed to provide safe, predictable, reliable and repeatable responses that would free pilots to deal with the emergency and further compensate for reduced performance.

In development for more than a decade by researchers at the University of Illinois at Urbana-Champaign, the L1 controller architecture differs from most previous approaches to adaptive control systems. Until now, the standard has been gain-scheduled control systems in which the flight-control computer selects the appropriate preprogrammed gains to suit current

flight conditions and vehicle configuration. However, the L1 works in real-time to predict transient behavior; it estimates lumped uncertainties rather than every individual parameter that can affect system dynamics, and compensates for them within the bandwidth of a control channel.

The L1 controller comprises three blocks: a state predictor, a fast-esti-

“[With NASA’s help], we are focused on revolutionizing the flight-control systems of commercial aviation”

mation mechanism and a control law. The fast-estimation element includes a state predictor and a fast-estimation law that together approximate the dynamics of the aircraft to generate estimates of the uncertainties. These range calculations are provided as input to a bandwidth-limited filter that generates a control signal to the flight control system.

Unlike other adaptive controllers that use the estimated values of uncertain parameters directly as control gains, the L1 system decouples

Tests of the controller in Calspan’s variable-stability Learjet included dealing with roll-coupled yaw while simulating a lifting body and high adverse aileron yaw while replicating an F-100 Super Saber.

the estimation loop from the control loop. This architectural change, which is achieved via the bandwidth limited filter in the control structure, avoids the high-gain response of earlier adaptive systems, making it safer, robust and easier to certificate, say developers.

“We can quantify ahead of time the transient steady-state performance specification and robustness margin in an aircraft and set guidelines for the trade-off between performance and robustness and the adaptation piece,” says TPS Flying Qualities Master Instructor Chris Cotting. “If I have a stability augmentation system, I can make it incredibly stable but not very maneuverable, or very maneuverable but not very stable. L1 [allows you] to make those kinds of trades with this adaptive controller.”

L1 development from theory to flight test has been led by Naira Hovakimyan, a professor of mechanical science and engineering at Illinois, who worked on

the concept under Air Force funding between 2004-08 at Virginia Tech with postdoctoral fellow Chengyu Cao (now at the University of Connecticut). The TPS evaluation was the first time the controller had been flown on a manned aircraft and was a vital step toward implementing L1 as a flight safety system, says Hovakimyan. "This is just a pure flight-control system like an autopilot, but you can augment it with features such as envelope protection, different pilot interfaces and so on." She adds, NASA is funding that endeavor, "and now we are focused on revolutionizing the flight-control systems of commercial aviation."

Although studies into adaptive flight control systems in the U.S. go back to the X-15 program in the late 1950s, the L1 originated with lessons learned from the Boeing/Air Force Research Laboratory X-36 Restore program, says Hovakimyan. Under this effort, which ran from 1996 to 1999, researchers attempted to stabilize an unstable, tailless unmanned air vehicle (UAV) with several simulated control-system failures.

"Predictability is the key word," Hovakimyan says. "In the Restore program, when they tested it with adaptive controllers they didn't know how to tune it. It was stable but not predictable and they got different transients every time. Adaptation can help; however, the architecture itself had deficiencies. It was good for slow adaptation but was not correctly structured to maintain robustness in the presence of fast adaptation." Subsequent studies focused on development of a fast-adapting controller that could also maintain robustness. "That's what we nailed down architecturally," she adds.

The L1 was flown for the first time in 2006 in the Rascal UAV at the Naval Postgraduate School and again starting in 2009 when NASA evaluated the controller on the AirSTAR

Dynamically Scaled Generic Transport Model research aircraft. In 2011, L1 was tested on the Simona motion-based research simulator at the Delft University of Technology in the Netherlands. Versions of the L1 controller are used in marine autopilots and industrial machines, and are being studied for UAVs and missiles.

Flight tests were conducted at Edwards AFB under one of the school's Test Management Projects, which provide students and staff with the opportunity for short-duration, real-world flight tests. Industry, academia or other military customers contribute the research concept and any required funding, and the school provides test aircraft, a team of test pilots and engineers as well as resources ranging from the Edwards airspace to flight-test data and analysis (*AW&ST* Dec. 1/8, 2014, p. 57).

Testing was conducted throughout two weeks in February and March on a Calspan Learjet 25D modified with a variable stability simulator (VSS). This feature changes the apparent stability of the aircraft, allowing it to be used as an inflight simulator of other aircraft types. The L1 was overlaid on top of the VSS, which simulated various aircraft in up-and-away flight at 250 kt. and

15,000 ft., and powered approach with gear down and flaps at 20 deg. If the Learjet encountered dangerous flight conditions, a series of safety trips disengaged the VSS, returning control to the safety pilot in the left seat.

"The VSS puts in the good or bad dynamics we want, and the L1 was designed to restore the reference set," says Cotting. "If we make the VSS better than the L1, it will degrade it to the reference model, or if we make it worse, the L1 will make it better," he adds. Students assessed flying and handling qualities over 14 hr. of test time at the two test conditions, as well as measured the robustness of the adaptive controller. Data also were collected for offset approaches and straight-in landings.

Specific failures—applied either individually or in combination—included reduced pitch damping, aft-center-of-gravity for neutral static-longitudinal stability, reduced yaw damping, high adverse and proverse aileron yaw, reduced roll damping and a coupled roll-spiral mode. During simulations of a lifting body, the L1 overcame lateral direction and oscillation control issues, and while representing an F-100 Saber at high angles of attack, the system enabled normal roll control. ☐



GUY NORRIS/AW&ST

The L1 was evaluated by the pilot in the right seat using a joystick. The left seat, with the conventional Learjet controls, is for the safety pilot.

Good Vibrations

New technologies open the way for HUMS on light helicopters

Tony Osborne *Orlando, Florida*

The use of health and usage monitoring systems (HUMS) on helicopters has transformed not only rotary-wing safety but also maintenance and operations.

Mandatory for offshore operations since the early 1990s, HUMS have proliferated, becoming standard equipment on all heavy- and super-medium helicopters. However, adapting the system for lightweight rotorcraft has proved more of a challenge, until now.

Engineers at Airbus Helicopters in the U.S. will soon begin bench-testing a new method of collecting HUMS data that is less than half the weight and 1/100th the price of current third-party systems. If the tests pan out, HUMS could become a standard feature before the end of decade on every new-build Airbus light and medium helicopter and be retrofitted to many more.

The problems of installing HUMS on light helicopters are threefold. First, payload is at a premium on any helicopter, and current-genera-

tion HUMS—with a weight penalty of about 20 lb.—are considered too heavy for light helicopters. The systems' point-to-point distribution of analog sensors, wiring harnesses and processors contributes to the weight.

Then there is price. Vibration-monitoring systems for a light twin-engine helicopter can cost \$100,000 and might not be linked to flight data. Even when it is linked to the data, it is useful for maintenance departments but not much more, since many owners cannot actually make use of the large amounts of data. While oil and gas operations have maintenance departments devoted to exploiting this data, in an industry where 85% of operators have five aircraft or less, that capability would not be compelling.

Nonetheless, Airbus says it is confident it has solutions to all these questions. "Enormous things can be done with this information," Airbus Helicopters' Brent Butterworth told Aviation Week at HAI Heli-Expo on



March 5. Butterworth is manager of avionics technical support at Airbus Helicopters in Grand Prairie, Texas. "HUMS is so much more than just health and usage; it is position and flight data, vibration and usage. I wanted to put all that information together and understand how the machine is being utilized."

Widespread adoption would make it easier to extend the time between component overhauls or warranty arrangements, Butterworth says. It could also predict maintenance issues long before the operators realize there is a problem.

Smooth Turning



Hub-mounted active suppression system tests aimed at 'zero-vibration' helicopter

Guy Norris *Orlando, Florida*

Eliminating rotor-blade vibration in helicopters has been a long-running target for rotorcraft manufacturers. Now Sikorsky, teamed with Lord Corp. and the U.S. Army, is poised for final flight tests of an active vibration control system it believes will achieve the goal of a zero-vibration helo with "jet-smooth" operation throughout the entire flight envelope.

Vibration occurs in helicopters because the loads on the main rotor blades constantly shift as they rotate and their direction of travel changes from moving forward at nearly supersonic speed to traveling aft at near stall. To help absorb these vibrations, particularly in-plane, Sikorsky has for decades been adding simple swinging masses known as bifilars close to the rotor hub. Although relatively effective, these mechanical devices cannot, however, absorb all the vibration, which results in a degraded ride quality and contributes to pilot fatigue and maintenance costs.

Flight tests of the HMVS have been conducted on a U.S. Army UH-60L based at Fort Eustis, Virginia.

To combat these issues Sikorsky, together with noise and vibration control specialist Lord, has developed a hub-mounted vibration suppressor (HMVS). The system monitors and analyzes the vibration at the hub and, through a series of actuators, generates a countervibration to cancel out the effect. "This is the first active rotor technology that I think will hit the market," says Chris Van Buiten, vice president of technology and innovation at Sikorsky.

The system was initially tested in the horizontal plane in 2014 on a UH-60L operated by the U.S. Army Aviation Applied Technology Directorate (AATD) at Fort Eustis,



AIRBUS HELICOPTERS

In a normal HUMS, vibration data are collected by accelerometers placed at key points on the various dynamic components. These send analog data along heavy wiring harnesses to a processor that digitizes the signals so data can be collected.

Airbus's new solution has emerged from the wind turbine industry.

Working in collaboration with Britain's Ultra Electronics and its New-York-based affiliate Flightline Systems, Butterworth and his team are using a new generation of accelerometers that digitize the data they collect at the source and relay it to a

The EC130/H130 would be an early beneficiary of a lightweight HUMS system.

bus, eliminating the need for heavy harnesses and additional black boxes to crunch and process the data.

"I had to find something small, but not something less capable or with less functionality," Butterworth says. "By using a digital-distributed architecture, we found it can do some very interesting things with data preprocessing."

Work toward testing the technology is underway. The team has already collected benchmark data from the main gearbox of an EC145 light twin and the tail-rotor gearbox of an AS350/H125 Ecureuil/A-Star helicopter using a current-generation HUMS.

On April 27, the team was due to begin testing the digital HUMS to see if the new data collected correlate with that from the old one.

"There is great confidence it will work," says Butterworth. "It already works in the wind turbine at low frequencies, and there is greater amplitude in helicopter components. We just need to prove the technology can survive in a helicopter environment."

If successful, the engineers will flight-test the system on the EC145 in June.

"We need to make sure we can hear all the gear mesh frequencies, the bearing tones, shaft orders, all the things you need to do to have a compliant HUMS system," he explains.

With the new technology, Airbus believes it can create a 10-lb. HUMS for an EC145-size helicopter at about 1% of the rotorcraft price.

Butterworth also has mapped out three service plans, with Airbus downloading the data and then accommodating customers with what they need. Basic service would deliver rotor track and balance information; the second would add helicopter flight-data monitoring to satisfy new emergency medical service regulations; the third and highest level would allow operators to examine all health information, with a "go, no-go" service for components provided via a traffic light system. HUMS data could be downloaded automatically using wireless Internet connections or tablet computers that would also feature flight manuals and navigation charts.

If the flight trials go as planned, Airbus could file supplemental type certificates for HUMS fitment with the FAA before the end of year, and the equipment could be fitted across the light-helicopter product range, from the EC120/H120 to the EC145/H145 before the end of the decade. ☼

Virginia, and it will be tested with additional "perpendicular" control features in 2015.

At the recent HAI Heli-Expo 2015 show in Orlando, Florida, Van Buiten outlined the progress on testing of the HMVS. The ultimate intent, he says, is to replace the mechanical bifilar on the S-76, Black Hawk and S-92 families with "a computer-controlled, active vibration control device that understands the vibration going into the helicopter from the rotor system and cancels [it] out in the rotor hub."

"The aircraft was flown both with and without a bifilar absorber to collect baseline vibration levels," says Douglas Leroy, Lord's business development manager, of the 2014 test series. "The tuned cabin absorbers [already widely used to null in-cabin vibration] were locked out, and HMVS became the only vibration treatment. The six months of flight testing included complete ground, hover and envelope-expansion test procedures." Leroy adds that, until the test program, UH-60s had never flown without a bifilar. "So the data needed to be carefully collected," he notes. "With the



SIKORSKY

Mounted on top of the rotor hub, the HMVS system incorporates box-like structures for external power and data interface. Black cabling, seen on this unit, is for test instrumentation and would not be a feature on a production system.

HMVS in operation, it was the only vibration treatment operating. On the final flight, the aircraft achieved max horizontal speed."

Van Buiten says Sikorsky and Lord are now adding more "functionality this year to attack vibration in an additional axis." This will probably be demonstrated on a Black Hawk jet-smooth flight in the full helicopter envelope, he notes.

The additional testing being undertaken as part of a program called the Combat Tempered Platform Demonstration will "take results from the hub-mounted system and combine them with the cabin system," adds

Kristopher Burson, global director of business development, marketing and strategy at Lord. "By putting vibration suppressors on the hub, you also get benefits in the cabin because you can reduce the passive treatments such as heavy weights. These [suppressors] are placed under the floor and usually tuned to a narrow band of frequencies. By varying the hub and cabin in tandem, you will be able to take out lots of weight—we are talking hundreds of kilos." ☼

Pelican Brief

Tandem-rotor Pelican UAS could see agricultural and military-supply applications

Guy Norris **Orlando, Florida**

As the proliferation of unmanned air systems into new roles continues, rotary-wing UAS specialist Dragonfly Pictures Inc. (DPI) is developing a large, tandem-rotor vehicle aimed at autonomous heavy-lift applications ranging from agricultural aerial spraying to air supply for military forward operating bases.

Resembling the configuration of the CH-47 built at Boeing's nearby Philadelphia facility, the tandem-rotor DP-14 Pelican prototype is expected to make its first flight early in 2016. Considered large by the standards of conventional rotary-wing UAS, the Pelican will be 13.5 ft. long and is designed to carry up to 450 lb. of payload within its 26 cu. ft. of cargo space or on external hard points. The vehicle is powered by either an 87-hp Solar T62 engine or 133-hp Micro-turbo eAPU turbine and is designed to operate on JP-5 or JP-8 heavy fuel, generating 4.2 kw of power for avionics and sensor payloads.

"We think tandem designs hold a lot of advantages over single rotors, which are like most of the UAVs you see today," says Bud Cary, DPI chief operating and financial officer. "Single-rotor UAVs do not necessarily work as well in certain applications, especially when you have to fly somewhere remote where you don't really know what the terrain is like. The tail rotor is what gets damaged by debris, plants and bushes. Tandem rotors are higher and have a wider center of gravity, offering greater loading flexibility."

The proof-of-concept display version, unveiled at the HAI Heli-Expo here in early March, was

The concept DP-14, exhibited at the recent HAI Heli-Expo show, features external containers and a spray rig for precision agricultural aerial spraying.



The U.S. Army is evaluating DPI's DP-12 Rhino unmanned aircraft system.

shown with external tanks and a spray bar rig for agricultural applications developed by Oregon-based Isolair Helicopter Systems. For this role, the system will likely be offered with nose-mounted sensor systems such as lidar (light detection and ranging) and visual cameras. "On precision guidance, one of the visions is to put advanced sensors on the front that are capable of detect-

ing which plants need applications," says Cary. "Right now sprayers [by helicopter or aircraft] cover the whole field, yet sugar growers, for example, might only need to kill weeds on 10% of the area. So 90% of the material being put down is wasted. We want to get it to the point on an application-cost-basis per hour that is competitive to anything that exists now and, because it won't waste all that material, it will end up being less expensive," he adds.

DPI also hopes to attract military interest in the Pelican, particularly since a smaller derivative, the DP-12 Rhino, is being evaluated by the U.S. Army. Also configured with a tandem rotor, the 6.7-ft.-long Rhino is designed to carry payloads of 32 lb. for 4.5 hr. or 150 lb. for 1 hr., and can be programmed to follow preloaded GPS coordinates to a landing site.

A version of the DP-14 will also be used under a joint project with NASA to study airworthiness requirements to support FAA certification for UAS that weigh 55 lb. or more, specifically for use in precision agriculture. DPI, which began the work with NASA in May 2014, says the agricultural variant is expected to be the first UAV over 300 lb. to operate with FAA certification. ✪



GUY NORRIS/AW&ST



AIRBUS

Pooling Power

Airbus eyes spares pools as significant A350 aftermarket opportunity

Sean Broderick Toulouse and Miami Beach

Airbus, eyeing a major share of the A350 aftermarket-support business, is finalizing its first maintenance, repair, and overhaul (MRO) agreement with an A350 customer and is in talks with several more, a company executive confirms.

The inaugural deal, a 12-year agreement, is at the airline's board-approval stage, says Pierre Yves Reville, Airbus vice president for services-solutions. A formal announcement is expected by summer.

"This is the first step into a very promising market," Reville says. "I think airlines understand that on a high-tech aircraft with parts that have very high reliability and very high costs ... investing by themselves in inventories or trying to manage maintenance by themselves doesn't make sense."

The deal will be an Airbus Flight Hour Services (FHS) agreement. Airbus offers two FHS packages: FHS Component, in which operators pay per flight hour for access to spares pools, including critical line-replaceable units; and the FHS Tailored Support Package (TSP), which adds options such as engineering services, airplane health monitoring and management of airframe work.

Airbus is talking with at least five other A350 customers about FHS packages, including one in Latin America, one in Europe, and three in the Asia-Pacific region.

As airlines look to minimize parts-stocking costs, particularly with the newest-generation aircraft, spares pools have never been more popular. Increased technological sophistication and improved reliability mean that complex components for models such as the A350 and Boeing 787 are needed less often than similar parts on earlier-generation aircraft. This makes them more expensive to stock—and more challenging to stock in the right locations within a single airline's network.

As a result, operators are turning to aftermarket services and logistics experts—ranging from traditional aftermarket providers such as Air France Industries-KLM Engineering & Maintenance (AFI KLM) and Lufthansa Technik—to component manufacturers themselves, to provide on-demand pools for certain parts.

The airframe manufacturers are involved as well and believe they are in the most strategically beneficial positions to help their airline customers. Boeing has about 1,700 aircraft under

Airbus expects up to 75% of the A350 fleet to be covered by spare-parts pooling agreements.

some sort of material management agreement, including deals that involve partners like AFI KLM, says Joe Dunne, director of material manage-

ment services for Boeing Commercial Aviation Services. He believes airframe manufacturers have a trump card that other pooling services providers cannot beat: depth of inventory.

"If I don't have it in my pool, I probably have it in my production supply chain or in my spare parts supply chain," he told delegates at Aviation Week's MRO Americas Conference in Miami Beach April 15.

Factor in the lower costs that make attractive so-called open pooling—in which all parts are shared among those who pay in—and the manufacturers are building a strong case. Re-

ville says that fewer airlines are investing in so-called initial provisioning (IP) spares packages for new fleets, which can run from \$10-20 million for an airframe with access to used-parts inventories, such as the Boeing 777 or Airbus A330, to twice that or more for the newest aircraft.

"This is where the FHS offering on a per-flight-hour basis is appealing," Reville says, noting that access to a pool of 600-800 A350 components would cost \$15-20 per flight hour.

Airbus calculates that an airline needs 80-90 A350s before it can economically justify its own spares pool. A typical A350 IP package for a fleet of 10-12 aircraft can run \$30 million.

Airbus's FHS Component and TSP offerings have been slower to take off than Boeing's comparable products. Reville says the size of the current pool of aircraft under Airbus's managed-care services is close to 200, with 11 announced customers, and includes A320s, A330s and A380s.

But the European manufacturer says interest in these services is picking up. Reville expects 70-75% of the A350 fleet will be covered by spares pools, either via Airbus FHS or competitive offerings.

Meanwhile, several FHS customers are looking to expand coverage to other aircraft in their fleets. Singapore Airlines (SIA) is in talks on a TSP setup for its A380s. The carrier has its A330s under an agreement that includes engineering services handled by SIA Engineering, and had its recently phased out A340s under a similar deal.

Thai Airways, which has A380s and A320s under an FHS deal, is considering adding both A330s and A350s.

Airbus is also talking to several would-be new aftermarket-support customers. It is in deep discussions with a Latin American A350 customer on a support package and is in "advanced discussions" with at least two carriers in China that could lead to deals "in the coming year," Reville says.

A380 FHS deals have proven particularly popular in part because of the costs of the aircraft's spares, but also because operators fly so few of them, rendering individual spares pools uneconomical. As of March 31, 156 A380s were in service with 13 operators, but only Emirates and SIA had at least 20. ☐

Analyze This

New aircraft, data analytics will change how aircraft maintenance is conducted

Sean Broderick **Miami Beach**

Technology's progress, combined with the massive turnover the global airline fleet is slated to undergo by 2025 will reshape the maintenance, repair, and overhaul (MRO) business. The main development behind the shift: a more data-driven business that powers predictive maintenance to help minimize unplanned work on next-generation aircraft.

Increasingly sophisticated aircraft are setting the stage. The newest, like the Airbus A350, generate several hundred thousand parameters that, with the right software, can be collected,

The ability to query specific datasets combined with the massive amount of data available on the latest aircraft make airplane health monitoring (AHM) a powerful diagnostic tool. The A380 has 250,000 parameters available, while the A350 has more than 400,000, Airbus says. The 1980s-era A320, by contrast, has 20,000.

Over the next decade, Oliver Wyman projects that 43% of the 18,500 new passenger and freighter deliveries will replace existing aircraft, leaving a fleet of about 34,400. This will help shift the fleet profile of 2025 to one in which 45%

lines, says Dave Marcontell, a vice president with Oliver Wyman-owned Cavok, while significant disruptions will occur elsewhere. "We believe these advances could cut or redistribute 15-20% of the total MRO spend," he says. Cavok puts the 2015 global airline MRO market at \$67 billion, rising to \$100 billion by 2025.

Manufacturers offering AHM and similar services will surely benefit, while carriers should see reduced maintenance costs. But Marcontell says independent MROs can use data they collect to cash in as well. "MROs out there that don't even own an airplane can start leveraging the computing power and algorithms being developed to better mine the data they are already collecting and own," he says.

Engine manufacturers, which have grabbed increasingly larger shares of the aftermarket with guaranteed-service agreements, are paving the way, using AHM to know precisely when engines need work. It is in their best interest to do so, as their service agreements—often structured as flat-fee, power-by-the-hour deals in which all maintenance is covered—shift risk from their customers to themselves.

The airframe side is more complicated. While Airbus and Boeing covet the levels of own-product aftermarket shares that the engine makers have, it will not happen anytime soon. Operators are turning toward service-level agreements for airframe components, but they are being shared among aftermarket players, including traditional MRO providers, suppliers with support programs, and aggregators that put together spares pools and manage repairs. These providers are often more nimble than the airframers, offering more flexible options—such as used parts—that keep operators' costs down.

Just how this environment will square with one in which airframers have all of the data remains to be seen. Marcontell believes a showdown is possible, with airlines and manufacturers facing off over which side owns the data.

"It has been the OEMs that have been the early movers on data," Marcontell says. "We believe this creates a potential conflict, as airlines are trusting their parts-removal history and analysis to the very same organizations that are trying to sell them replacement parts and services."

One possible solution, he says: a trusted third-party "intermediary" to serve as "a fair arbiter of data." ☛



Better analytics and more data to crunch should help reduce the amount of time next-generation aircraft spend in MRO shops.

analyzed, and used to spot a problem before it leads to a service disruption.

Airbus is already scratching the surface with its real-time health monitoring service, available for the A380 and A350 and being tested on the A330. Far more than pushing status information to the ground in real-time, Airbus uses onboard communications functionality to query sophisticated computers like Centralized Maintenance Systems and Aircraft Condition Monitoring Systems to obtain specific parameters related to a fault. The data help the manufacturer's around-the-clock technical support team get to the root of an issue and, working with the carrier's maintenance control center, determine what to do.

of the aircraft will have been delivered after 2000, compared to just 10% today.

As more next-generation aircraft enter the fleet and displace older models with less digital capability, airlines and manufacturers will have more opportunity to use data as a primary driver of maintenance programs. MRO providers are eyeing the opportunities, too.

An Oliver Wyman survey released April 13 at Aviation Week's MRO Americas conference found that MRO executives foresee AHM and predictive maintenance (PM) as the aftermarket's most promising new technologies in 2020, ahead of additive manufacturing and composite repair developments.

Most of the benefits will accrue to air-

Trial by Fire

Deficiencies in simulator training underscored in high-stress real-time events

John Croft **Washington**

A rapid chain of events in the cockpit of a Spirit Airlines Airbus A319 that was contending with thunderstorms while climbing out of Dallas-Fort Worth International Airport in October 2013 spotlights gray areas in training and documentation when failures occur in a high-stress situation playing out in a highly automated cockpit.

The NTSB final report on the incident reveals how the crew struggled to interpret multiple, recurring fault messages after the left engine began to fail and the cockpit and cabin filled

A portion of the third-stage high-pressure turbine from a Spirit Airlines A319 engine was found on the lawn of a home in Texas.

with smoke. The safety agency later determined that one second-stage high-pressure turbine blade in the International Aero Engines (IAE) V2500 turbofan engine had separated due to stress corrosion cracking, causing extensive damage to the high-pressure and lower-pressure turbine sections as it exited. In all, dozens of recovered second-stage high-pressure turbine blades were found to have stress corrosion cracking in the internal cavities used for cooling. IAE has since beefed up its inspection procedures and developed new aluminide coatings to prevent sulfur or other corrosive deposits from causing such problems. While the corrosion from pollution has not traditionally been considered a problem for aircraft that fly in the continental U.S., IAE says that “sulfur-related accumulation has been an increasingly common event for all engines due to pollutants in the air.”

Flight 165, with 150 passengers and crew, was navigating between two lines of thunderstorms as it climbed through 19,500 ft. when “a noticeable vibration was felt in the cockpit and throughout the cabin that progressively intensified,” according to crew interviews. Soon a series of fault messages on the aircraft’s electronic centralized

aircraft monitor (ECAM) made it clear that the left engine was the cause of the rumbling. The autopilot and autothrottle systems disengaged as the crew began performing an emergency procedure to address the initial ECAM message—an engine pressure ratio (EPR) mode fault. The pilots declared an emergency and began a turn-back to Dallas.

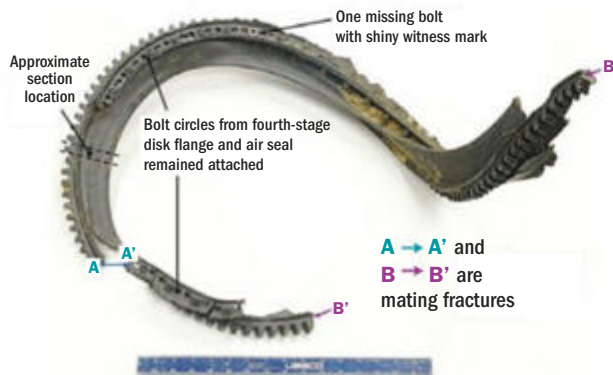


Photo 37—Recovered HPT Third-Stage Disk Rim

Although he did not recall the action later, the captain then advanced both throttles from climb power to the take-off/go-around setting, a move not referenced in any of the applicable Spirit abnormal and emergency procedures. The first officer was having difficulty determining which checklist to complete as the top-priority fault on the ECAM as it rapidly alternated between two key warnings—EGT over-limit and high-pressure turbine (N2) over-speed alerts, an issue Airbus later attributed to the engine’s full authority digital engine controller attempting to maintain engine speed. “Both crewmembers stated that Spirit pilots are trained to troubleshoot multiple ECAM messages, but not for situations where ECAM messages repeatedly switch priority,” says the NTSB of pilot interviews at Spirit. “The rated A320 pilots in the room all agreed with the assessment.”

The EGT over-limit procedures gave the crew the leeway to continue operating the engine until the next landing, with the caveat that thrust should be

reduced or the engine shut down if engine parameters could not be maintained within limits. During the incident flight, however, the EGT values had reached limit values, represented by amber “Xs” on the display. The N2 warning procedures were of no help because the engine did not reach levels that would have required the crew to shut it down. Spirit has a procedure for evaluating “high engine vibrations,” but the response is to monitor the parameters more closely rather than shutting down the engine.

Along with increasing the vibration levels, the captain’s decision to increase power on the left engine ultimately raised temperatures to the point where the engine shed “multiple

components” including the low-pressure turbine third- and fourth-stage disks, says the NTSB. Some of the engine components were later recovered on the ground in Ben Franklin, Texas.

The crew did respond correctly approximately 4 min. after the captain boosted the power when the left engine’s fire-warning

activated and the cockpit filled with smoke, fumes and a burning odor, limiting visibility of the instruments. The pilots donned oxygen masks, making it more difficult to communicate during a series of checklists that followed—including fire-suppression activation and engine shutdown procedures—and avionics, lavatory and cargo-compartment ECAM smoke notifications. At one point during the engine shutdown procedures, with warning bells sounding almost continually, the captain asked the first officer if they had lost both engines. The latter confirmed that only the left engine had failed.

The aircraft eventually made a safe return to Dallas with no injuries to the passengers or crew.

The NTSB did not issue any recommendations to the airline regarding the actions after the failure but noted that IAE had changed its inspection procedures and developed a new anti-corrosion coating for the high-pressure turbine blades that had cracked in this incident and one other. ☐

In a Squeeze

Airbus looks to more seats to aid revenue-conscious carriers

Jens Flottau **Hamburg**

When Airbus launched the A380 15 years ago, the focus was on inflight lounges, shopping and spas. But this has shifted to a more proletarian view as the manufacturer pushes for denser cabin layouts across its aircraft portfolio.

Airbus presented the mock-up of an 11-abreast economy configuration in the A380 main deck at the Aircraft Interiors Expo in Hamburg April 14-16. A380 operators will have the choice of operating the aircraft in the 10-abreast standard economy seating or of adding another seat per row. Two seat manufacturers, Zodiac and Geven, are on tap. The seats are to be installed on the existing rails and no extra floor work is needed, says Ingo Wuggetzer, vice president of cabin marketing for Airbus. The configuration will be available in 2017 and is independent of any decision to launch the reengineered A380neo.

With one seat added per row, Airbus sees a need for some changes to the inboard bins, which will be moved slightly outboard to make access easier.

The number of seats depends on airlines opting for either a new configuration on the entire main deck or specific layouts; typically about 45 rows of economy seats are on the main deck.

Emirates Airline was initially behind the idea of an 11-abreast economy section as part of its drive to make its existing A380 fleet more efficient. But the carrier became increasingly concerned that such a move would dilute its image as a high-quality economy-class operator; even though Airbus says the 11-abreast rows would still allow for 18-in.-wide seats.

Other options to create more space on the A380 include removing the sidewall storages on the upper deck. In herringbone arrangements in business class—where seats face outboard—another row of seats could be added after every sixth row, effectively converting storage space into seating.

For long-haul flying, Wuggetzer says, the legacy three-class layout (First, Business, Economy) no longer reflects market trends. He advocates for enhancing the economy product. “In the past, most innovation went into premium products, but that is only for 6% of travelers,” Wuggetzer says. And the trend is clearly pointing toward economy: The premium share has dropped from almost 7% before the 2008 financial crisis to

well below 6%, and it has not recovered. Many corporations have curtailed funding business-class travel for executives.

Airbus believes the premium, economy segment will grow more popular. Already 26 airlines are offering premium economy—equivalent to about 30% of long-haul available seat miles (ASM). Five of 11 A380 operators have introduced the class between economy and business. Wuggetzer believes that airlines can increase revenues by \$20 million per aircraft per year by adding 60 premium-economy seats.

But as the 11-abreast drive on the A380 indicates, Airbus also sees growth in what it calls the “budget economy” segment. Configurations will be offered that maximize the number of seats per row across its long-haul products in the “budget” category—nine on the A330, 10 on the A350 and 11 on the A380. The standard economy cabin would feature one seat less per row and, in premium economy, a second seat would be taken out. “Seat width has been underestimated. For years we’ve only talked about seat pitch,” Wuggetzer says.

He believes that airlines may not opt for all of the sub-cabins in economy on the A330 or A350 because they would become too small to be economical, but he envisions four-class A380s with two or even three different economy sections.

Randy Tinseth, Boeing Commercial Airplanes vice president of marketing, says Airbus is “apparently abandoning its heavily promoted push for an industry-standard 18-in. economy-seat width,” adding, “the last time I checked, Airbus cross-sections hadn’t changed.” He says Airbus has often tried to gain market acceptance for a nine-abreast A330; “Each time it has been soundly rejected by the airlines with scheduled service.” He argues that the proposed seats and aisles are too narrow, and window passengers are penalized because of the limited head and shoulder clearance.

Airbus counters that 60% of Boeing’s installed fleet falls into the “budget economy” category anyway because seats are allegedly so narrow.

The A320 family has been the starting point for more efficient cabins. The introduction of new aft galley and lavatory layouts (known as “Spaceflex”) has been a key part of adding another row of seats on that type. As part of the rearrangement, the rear galley is reduced to accommodate either 2.5 or four trolleys, compared to the standard seven. Two lavatories are moved into the space freed up immediately in front of the rear pressure bulkhead.

Similar ideas are now proposed for the A330 and A350 widebodies. A combination of ideas will enable Airbus to free up space for around 10 more seats on the A330 and 20 extra seats on the A350-1000, which is slated to enter service in 2017. The layout would also be available on the A350-900. ☛

Airbus is proposing an 11-abreast economy layout on the main deck of the A380.



Teaming Up

Four European ATC organizations plan to introduce common controller certification

Cathy Buyck **Madrid**

Slow progress in making the Single European Sky (SES) a reality and flying in Europe more efficient has been the subject of much criticism by airlines in the region. Air navigation service providers (ANSP) in Spain, Germany, the U.K. and the Netherlands say the launch of a joint project will take them one step further toward achieving what airlines want.

The four air traffic control organizations signed an agreement for the joint development of the next generation of the air traffic controller working position (CWP), which should lead to reduced costs, increased efficiency and ultimately take the Single European Sky initiative forward.

The common CWP is being devel-

Common software components used within the controllers' working desks across several European ANSPs should lead to increased efficiency and reduced costs.

oped under the umbrella of iTEC (Interoperability Through European Collaboration); it essentially extends the lifespan of the joint venture, which was established 10 years ago to develop a next-generation flight data processing system by Germany's DFS, Spain's Enaire (formerly called AENA) and the U.K.'s NATS, alongside systems provider Indra.

The Dutch ANSP, LVNL, has joined the group since, and "some promising talks are underway" with other European ANSPs, DFS CEO Klaus-Dieter Scheurle said at the iTEC CWP signing ceremony at the World ATM Congress in Madrid in March. The exact budget for the development of the iTEC AWP is not yet defined, but it is estimated it will be on the order of €20 million (\$21.6 million). The cost will be equally divided by the participants in the project.

The design phase of the iTEC CWP should take about two years, according to Ignacio Gonzalez, director of air navigation of Enaire and chair of the iTEC group board. "We want a com-

mon tool for our air traffic controllers and a common certification. In a sense, we are trying to follow the example of the airlines; a pilot of a Boeing 737 can easily transfer from one airline to another one," he says. Gonzalez notes that developing a common standard and system for the CWP will be a "challenging venture" because the iTEC partners manage different operational scenarios according to their particular needs.



DEUTSCHE FLUGSICHERUNG

The benefits of the collaboration, however, are evident, Gonzalez stresses. "In the short term, we share and rationalize development cost and investment, which in a regulated environment is of great importance," he says. "In the longer term, the interoperable solution increases efficiency in terms of services but also in training and maintenance."

The new agreement for the development of a common CWP for four ANSPs marks the "advent of a new component that has the potential to take the Single European Sky forward in an essential concrete manner," asserts Maurizio Castelletti, head of the SES unit of the European Commission's DG Move.

SES still requires major efforts to advance toward its ultimate goal of enhanced safety in parallel with the

elimination of inefficiencies, he admits. But he adds: "I note that this [iTEC CWP] development draws partners from three functional airspace blocks [FABs] and establishes an industrial partnership in line with the foundations of SES2+."

The SES2+ legislative proposal, which was drafted by the European Commission in December 2013, brings together the existing two SES regulatory packages. But member states have not yet officially endorsed the proposed legislation.

An essential SES objective is the optimization of air navigation services as well as optimum use of airspace resources, "including in particular technical resources," Castelletti says. "In this regard, advanced technology developed jointly among several part-

ners is essential, and it should focus on the right functionality to enable all expected SES benefits," he says. "The new-generation iTEC CWP certainly appears to meet both these criteria."

The project involves four European ANSPs now and should be extended across the FABs, Castelletti says.

The target for implementation of the iTEC CWP for the four partners is around 2022-23, says DFS's Scheurle. The German ANSP has already engaged with staff about the project. "This exchangeability of air traffic controllers between four countries is brand-new in Europe and requires a big change in mentality. Each ANSP has its own culture. But we have to show them, to convince them, this is a good thing. We have to team up." ☛

Proven Product

Cathay Pacific relies on a tested model to defend its market position

Adrian Schofield Hong Kong

It is somewhat surprising that Cathay Pacific CEO Ivan Chu claims to not lose any sleep over the competitive challenges facing his airline. After all, it operates in a region where the established mainline giants are under increasing pressure from several quarters. But Chu is adamant Cathay's business model is strong enough to thrive despite the new threats that are hammering many of its rivals.

Among these factors are the rapid growth of Asian low-cost carriers (LCC), the emergence of long-haul LCCs, Middle Eastern airlines capturing connecting flows in key markets, the rising international ambitions of the mainland Chinese carriers and the continuing expansion of competing Asian connecting hubs.

This daunting list contributes to the financial struggles afflicting many of the Asian legacy carriers. Some, like Malaysia Airlines, have required a government bailout, while others such as Garuda Indonesia and Thai Airways have launched restructuring efforts. Even Singapore Airlines—which has weathered the financial challenges better than most—is embarking on new strategic approaches.

Cathay, however, is sticking with the business model that has served it successfully for decades. It relies on a full-service product, high frequency on trunk routes, international connections via its Hong Kong hub, a growing home market and a large cargo operation (see related story). These facets are supported by the airline's fleet strategy and extensive aircraft order book.

Chu says Cathay's model is "very competitive" against the LCCs in particular. Its strength is based on multiple strands that the LCCs cannot match, such as brand power, premium yields and the scale of its international network and cargo services.

Such advantages allow Cathay to price aggressively in some of its economy offerings. For example, three years ago the carrier launched its "Fanfare" product, steeply discounted tickets that go on sale in Hong Kong every Tuesday. Cathay sells about 2,000 tickets a week through this channel, which is similar in size to a small LCC operation, notes Chu. "We do want to connect with the price-sensitive sector" as well as premium traffic, he says.

Chu cites the success of Cathay in the Hong Kong-Singapore market as a good example of its competitiveness versus other models. This route is served by many airlines, including LCCs, yet Cathay has managed to maintain its market share and yield.

The airline's approach is in marked contrast to many other Asian full-service carriers, which have been establishing their own LCC subsidiaries. Singapore Airlines has been actively growing its portfolio of LCCs and is directing much of the group's growth to these carriers.

While many overseas LCCs fly into Hong Kong, Cathay has not faced serious competition from budget carriers based there. This may change in the future, with Qantas and China Eastern Airlines attempting to set up a Jet-

star Hong Kong joint venture, along with local investors.

Recent financial results help vindicate Cathay's strategy. The carrier boosted its net profit to HK\$3.15 billion (\$406 million) in 2014, despite the fact that it received little help from lower fuel costs due to unfavorable hedges.

Passenger demand remains robust. The carrier set new records during the recent Chinese New Year travel period, with daily passenger numbers exceeding 110,000 on two days. It is also achieving a load factor of 84% this year, says Chu.

The scale of Cathay's operation means maintaining its premium brand strength is particularly challenging, with the need to ensure consistency across more than 10,000 cabin crew and about 8,600 ground staff.

"But the fact that it is hard gives us a strong competitive advantage, because we know most people can't do it," says Chu. While it is relatively easy to write a check and acquire the hardware, it takes many years to establish a premium brand reputation.

Cathay's well-established brand helps it meet the challenge of rapidly expanding mainland Chinese airlines, which are in some cases trying to emulate Cathay's success as a long-haul connecting carrier. The Hong Kong-based carrier has an entrenched product that is popular with corporate customers, and Chu believes that the other Chinese airlines will find it difficult to break into the mainstream of business traffic in the near future.

The vast potential of the China market also reduces the competitive threat. "The pie is growing so fast" that all players have the scope to increase traffic, Chu says.

The mainland Chinese carrier with the greatest international presence is Air China, which has close links to Cathay. They have significant cross-shareholdings, cooperate on some routes, and jointly own Air China Cargo. The cargo joint venture gives Cathay important exposure to the Yangtze River Delta manufacturing region, says Chu.

Rapid growth in outbound international Chinese travel will be one of the airline industry's biggest opportunities over the next



10 years, Chu predicts. He says Cathay is “uniquely positioned to capture this traffic,” thanks to its subsidiary Dragonair, which operates flights to 22 points on the mainland.

Hong Kong’s growing ground transport links to the mainland are effectively expanding Cathay’s home market. Instead of regarding just Hong Kong as its catchment base, Chu notes that Cathay can draw traffic from Guangdong province—a market of more than 100 million people. Already, thousands of cars, ferries and buses cross the border into Hong Kong every day, and new rail and road projects will make Hong Kong even more accessible.

This will balance Cathay’s reliance on connecting traffic to some extent. But Chu stresses that transit traffic via the Hong Kong hub will always be a core part of the airline’s business and currently comprises about half its customers.

Hong Kong’s hub status is highlighted by the fact that more than 63 million passengers came through the airport last year—making it the 10th busiest in the world—even though Hong Kong itself only has a population of around 7 million. Half of that passenger total flew on either Cathay or Dragonair.

A planned third runway is vital for the continued growth of the Hong Kong hub, Cathay executives say, particularly as other Asian hubs are vying for a larger share of connecting traffic.

Cathay’s network strategy is notable for its focus on building multiple daily frequencies on trunk routes, rather than spreading its flights more thinly over a larger number of destinations. Frequency is valued by business travelers, Chu says, and this approach also aids connectivity. For example, Cathay’s four daily flights to Sydney are timed to connect to five daily flights to London, making it one of the larger players on the Kangaroo route.

Transpacific flights to North America have always been a major strength for Cathay. It has more than 100 flights a week to seven points in the U.S. and Canada, including four flights a day to Los Angeles and five to New York City metropolitan area airports.

Cathay Pacific’s extensive long-haul network is based on its workhorse 777-300ER fleet.



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Chu notes that Cathay’s goal is to connect Asia to North America via its hub, and it has built out its North American service over the past five years. He cites the San Francisco route as one example, which has increased to twice daily and will soon grow to 17 times a week. If that goes well, it will increase to three times daily.

The next network goal for Cathay is boosting its European operation by adding more destinations and frequencies. It started flights to Manchester in December, to Zurich in March and will introduce a Dusseldorf route in September.

While the European economy and currency remain relatively weak, Cathay’s load factors and yields in this market have been quite high. Strong outbound travel to Europe has helped make it “a pretty profitable operation,” says Chu.

Cathay’s network strategy is supported by its fleet plans. The carrier has 22 Airbus A350-900s on order, with the first delivery expected in February. It also has 26 of the larger A350-1000s in its order backlog and has agreed to buy 21 Boeing 777-9Xs for delivery from 2021.

The -900s will be well-suited to routes between European cities and Asia, Chu says. These aircraft could either open new routes in this market, take over some 777-300ER services or add frequency to existing 777 flights. While Europe will be the primary focus for the -900s, the range and size of the -1000s will be a better fit for the transpacific routes, he says.

Cathay decided at the end of 2013 to order the 777-9Xs instead of taking additional A350-1000s. The airline already operates a fleet of about 50 777-300ERs and is very pleased with their performance. The fact that the -9Xs will be a further improvement over the -300ERs makes them a compelling choice, Chu notes.

The 777-9Xs will have more capacity than the -1000s, which will broaden Cathay’s size options on a given route. The carrier also likes the idea of having two aircraft families—777s and A350s—in its long-haul fleet.

In general, the new widebody orders can be used for either expansion or aircraft replacement, Chu says. If Cathay decides it does not want to add capacity, it can return some leased -300ERs as the newer types enter the fleet. This option, combined with its range of aircraft sizes, gives the airline considerable flexibility in its fleet plan and allows it to be nimble in its response to the industry environment, he says.

The A350s will begin arriving just as Cathay completes deliveries of existing fleet types. It is due to receive the last four 777-300ERs from its current order by the end of this year, as well as its final two Airbus A330s. The carrier is among the world’s largest operators of both types.

Despite its substantial widebody order book, Cathay is also considering what additional fleet moves it should make. Narrowbody replacement is one of the carrier’s next priorities, Chu says. This would cover the A320s and A321s operated by its subsidiary Dragonair. Although it is “not urgent,” it is “important that we look at” the replacement of these aircraft, he says.

At the other end of the scale, Cathay is also watching to see what sort of offering Airbus will come up with for an updated A380. If a new engine option yields greater efficiency, “we’d be interested in looking at it,” says Chu. However, he stresses that Cathay is a big fan of the widebody twin-engine aircraft types, and the carrier would only consider a larger type if it offered better operating economics. ✎

Cargo Comeback

Cathay Pacific grows freight business as market rebounds

Adrian Schofield Hong Kong

When Cathay Pacific opened a massive new cargo terminal and ordered three more Boeing 747-8 freighters in 2013, it seemed to be taking a major risk. At that time, the airfreight industry was in the doldrums with no end in sight. But Cathay persevered with its expansion plans and bet that cargo demand would come roaring back.

Fast-forward to 2015, and Cathay's bold moves have been justified. Cargo demand is growing again, and the new aircraft and Hong Kong cargo hub are helping the airline take advantage of improvement in key markets.

With a fleet of 22 freighter aircraft, Cathay is one of the largest cargo-carrying airlines in Asia. And the cargo division is crucial to the success of the company—"it tends to be that when cargo does well, the [overall] business does well," says James Woodrow, Cathay's director of cargo.

For many years, the opposite was true—the dire cargo market was dragging down the airline's profits, and the same was happening to the other large Asian cargo carriers.

The slump hit in earnest in early 2011, and lasted for almost three years. Demand finally began to improve in March 2014, and "got stronger and stronger

throughout the year," says Woodrow. Falling fuel prices, seaport congestion on the U.S. West Coast, the launch of new high-tech consumer products, and automotive recalls have all helped maintain the momentum.

Beyond those factors, the growing "underlying strength" of the U.S. economy has spurred demand on transpacific routes, Woodrow says. This is a big deal for Cathay, as the transpacific is by far its largest cargo market, connecting Asia to North America via its Hong Kong hub.

Cathay has deployed its new fleet of 747-8Fs on the North American routes, and has steadily increased transpacific frequencies to the point where it has 37 weekly freighter flights. The carrier operated up to 41 weekly flights in its October-November peak last year, and Woodrow hopes to build up to 43-45 weekly freighter flights during this year's peak.

Other markets are not as buoyant, however. Woodrow describes intra-Asia cargo demand as merely "OK." While there is volume growth, it remains a highly competitive market for airfreight.

Asia-Europe flows are the most challenging of Cathay's three main cargo markets. Asian carriers—including

Cathay—and Middle Eastern airlines have added a large volume of passenger aircraft belly capacity to this market, dampening freight yields.

In addition, the significant weakening of the euro has made imports into Europe more expensive. One positive effect of the devaluation is that it should boost exports from countries such as Germany, balancing flows in a market traditionally skewed toward imports from Asia.

Cathay has also been working to build new markets. For example, it has recently expanded freighter operations in Mexico, and now has a five-times weekly service that stops in Mexico City and Guadalajara. Mexico City is largely an import market, while a lot of produce and high-tech exports come from Guadalajara.

The Mexico service is an extension of its Hong Kong-Los Angeles 747-8F route. It would be risky to put five direct freighter flights a week into a relatively new market, but a freighter may be dedicated to Mexico "once we're confident that we've got steady volumes," says Woodrow.

India is another market where Cathay has been building its presence. It recently launched freighter service to Kolkata, its sixth Indian destination. The carrier has increased its cargo network in India dramatically over the last three years, as the Hong Kong hub is geographically well-placed to connect India and China, the world's two most populous nations.

Among Cathay's greatest strengths are its cargo services to the major high-tech manufacturing centers in

Cathay Pacific's 747-8F fleet gives it a strong position in the transpacific cargo market.



CATHAY PACIFIC

mainland China—with five freighter destinations—and Southeast Asia, which are connected to other regions via Hong Kong. Serving a broad spread of destinations from a strong hub “is the connectivity game that the Middle East carriers play, and we’re big enough that we can play it too,” says Woodrow.

Cathay will grow its overall cargo capacity by about 10% this year, with a similar increase in both its dedicated freighters and in the belly capacity of its passenger fleet, Woodrow says. It can do this because of the greater efficiency of the new 747-8Fs, and the rising number of passenger aircraft such as the 777-300ER that can also carry large cargo volumes.

The airline has 13 747-8Fs and will take delivery of its 14th next year—the last of its current order for the type. Cathay also has six 747-400ERFs, and five -400Fs of which three are operational with the remainder parked.

Boeing agreed in 2014 to buy back the six -400Fs that Cathay was operating at the time. One was returned last year, one will go this year, and the remaining four in 2016. The carrier will still finish the year with 22 operational freighters, since the one returned will have been a parked aircraft.

The freighter total is down significantly from the fleet in the “high twenties” it has previously operated, Woodrow says. But he notes that the carrier has steadily increased the size of its freighters, and also frequencies in key markets, such as transpacific.

Because the -8Fs are newer aircraft, Cathay can rely on high utilization rates. It achieves up to 16 block hours a day per aircraft with the -8Fs, much higher than Cathay’s older 747 freighter fleets. “We can keep pushing their utilization; these are expensive assets so we want to sweat them as much as we can,” says Woodrow. “And we can [also] try to work our ERFs a bit harder.”

Another potential option is retaining some of the -400Fs a bit longer. If Boeing has not found lease customers by the time they are due to be returned, Cathay could possibly continue to use them, Woodrow says. But any such decision would likely depend on demand strength and the price of fuel. For example, if oil is back to \$100 a barrel in 2016, the carrier would be unlikely to pursue this alternative.

The continuing growth of the passenger fleet is a major source of new cargo capacity for Cathay. Whereas

the carrier has reduced the number of freighters serving Europe in recent years, it has much more belly capacity in that market as the passenger fleet has added destinations and frequencies. This allows more direct connections to Hong Kong.

It also helps that the 777-300ERs in the passenger fleet have excellent cargo capacity. The airline now operates five daily 777 passenger flights to London, and if each carries 20 tons of cargo, that represents about the same capacity as a single daily 747 freighter. Similarly, Cathay has so many frequencies to Singapore with its A330s that it can carry 150 tons of cargo every day on that route as belly cargo, in addition to freighter services.

“You have to think of modern wide-

body [passenger] aircraft as mini-freighters,” Woodrow says. For example, a 777-300ER with a light passenger load recently carried 36 metric tons of cargo on a single flight from Manchester.

Cathay has no plans to order more freighters at the moment, says Woodrow. The carrier “continually looks” at its fleet plan, although it will “see what the underlying strength of this [cargo] recovery is” before contemplating more orders.

Because it has new belly space becoming available, and the option to increase aircraft utilization, Cathay still has the opportunity to raise cargo capacity over the next few years, Woodrow says. “We’ll keep evaluating [the fleet], but we’re not in a rush to get our checkbook out at the moment.” ☞

FREIGHT HUB

Cathay Pacific’s new cargo terminal in Hong Kong is proving it can increase the efficiency of freight operations, both for Cathay and a growing number of other airline customers.

The HK\$5.9 billion (\$761.3 million) facility completed its first full year of operations in 2014. Although it is still well short of its potential capacity, this year will likely see significant volume gains, says Kelvin Ko, CEO of Cathay Pacific Services Ltd. (CPSL).

Last year the terminal handled 1.45 million metric tons of cargo, while its upper limit is estimated to be 2.6 million metric tons per year. This year Cathay expects to increase its own freight volumes (see related story), and new customer EVA Air will also boost the facility’s tonnage.

Taiwan-based EVA shifted its freight operation to the Cathay terminal in January, becoming its largest external cargo customer. The facility already serves AirAsia, Thai AirAsia and Royal Brunei, as well as Cathay and its subsidiary airlines Air Hong Kong and Dragonair. CPSL is seeking more customers, and is “constantly speaking to other airlines,” says Ko.

Cathay’s new terminal joined other large players in the freight handling market at Hong Kong International Airport, which is the world’s busiest cargo hub. Ko says the terminal was always expected to have surplus capacity in the short-term. “You build a cargo terminal for long-term [demand]—you can’t open it bit by bit,” he says. “So once it’s open, it’s a big step up.”

The terminal will naturally increase its efficiency as volumes increase, says Ko. However, it is already taking advantage of new technology and processes to improve processing times.

Aircraft-to-aircraft transfers comprise more than half the freight handled at the terminal. The time it takes to unload, break down, process and reload cargo has been reduced from the standard 8 hr. to 5, and can even be cut to 3 hr. by prior arrangement.

Reducing the transshipment time between long-haul flights and Cathay’s Asian network gives customers more business opportunities, and makes additional connecting city pairs viable, says the airline’s Cargo Director James Woodrow. “Anything that drives speed and connectivity is good for our business.” ☞

Faster Carbon

Europe's aircraft industry seeks to pave way for high-rate production of carbon-fiber structures

Graham Warwick **Paris**

Composites have been a leap forward in performance for commercial aircraft, but a step backward for production costs. Advances made as the industry moved from riveting together sheet metal to machining complex parts from solid blocks of alloy have been surrendered in pursuit of saving weight.

Advances have been made in automating the layout of carbon-fiber parts, but the assembly of composite structures remains a labor-intensive task—which is problematic when manufacturers are considering ramping up narrowbody production rates to more than 60 aircraft a month.

The issue is not just that carbon-fiber structures have meant a return to the steel-metal paradigm of manually assembling many small parts, but that composites bring with them unique challenges with geometric variations from part to part that have introduced many nonproductive steps into assembly.

"You are making the material as you make the part," says Maria Weiland, director of research and technology (R&T) business development at Saab Aerostructures and coordinator of the EU-funded Low Cost Manufacturing and Assembly of Composite and Hybrid Structures (Locomachs) project.

Not only do the fibers themselves differ in diameter, but the volume of resin varies from one part to the next. This results in a buildup of tolerances in assembly that can be difficult to accommodate in fixtures. Composite structures have to be assembled and disassembled several times to measure and shim gaps and drill and clean holes. This adds time that must be eliminated if production rates are to increase.

Locomachs is a €31 million (\$33 million) research project, started in September 2012 with the aim of tackling the entire chain from design and simulation through part manufactur-

ing and inspection to joining and sealing to enable faster, more cost-efficient assembly of composite structures in high-rate production. The objective is to eliminate non-value-added, mainly manual tasks that consume time and induce costs and so pave the way for composite-aircraft production rates exceeding 50 a month.

Airbus is building 42 A320-family aircraft a month and considering increasing this by 50% to 63 a month to burn down its eight-year backlog of orders, says Weiland. The A320 does not have as much carbon-fiber content as the new A350 widebody, production of which is being ramped up to 13 a month, but when Airbus comes to replace the A320 with a new narrowbody it will need a rapid buildup in production to 65-75 a month, Colin Sirett, head of R&T for Airbus UK, told a manufacturing conference in September.

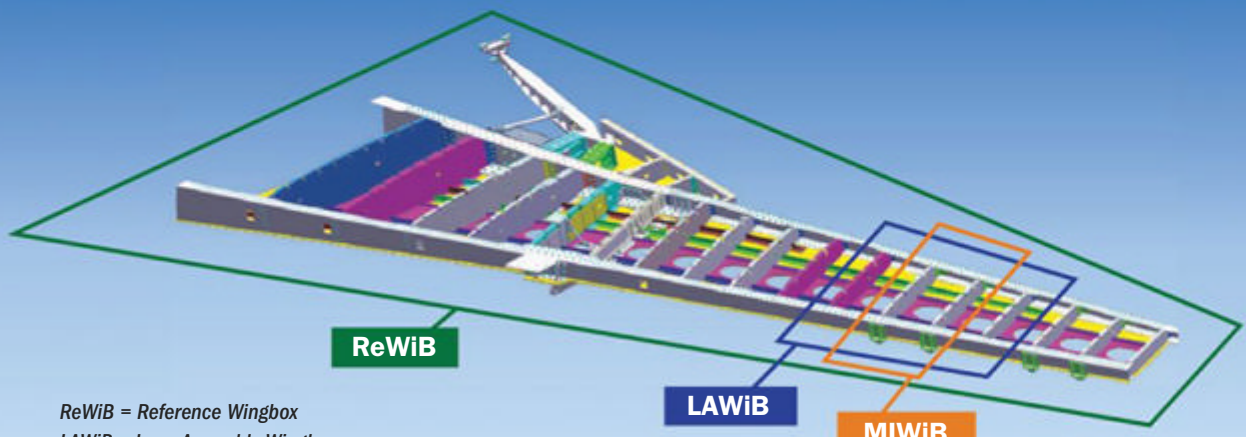
For carbon-fiber structural content of a next-generation single-aisle to be as high as it is in the A350 and Boeing 787 twin aisles, the assembly issues with composites must be overcome. "It's a costly problem," says Weiland. "We need to get the takt time down to as short as possible." In lean manufacturing, takt time is the average unit production time. To get to production rates exceeding 50 aircraft a month, "we need to take out a lot of manual actions and get a very quick takt time," she says.

An example of the issues encountered in composite assembly is the vertical tail plane (VTP) of the A350. Composite Technology Center (CTC) Stade, an Airbus company in Germany, developed the next-generation carbon-fiber VTP, which is designed for highly automated assembly. But problems with process stability and rate capability were encountered early in production, says Joachim Piepenbrock, head of production composite systems at CTC Stade, speaking at the JEC Europe 2015 composites-industry show in Paris in March.

The cost of "non-quality"—the costs incurred by having to inspect and sometimes scrap parts—was greater than 25% and the deviation in skin thickness ranged from +10% to -15%. CTC embarked on a process optimization and rebalanced VTP production to a two-shift from a three-shift operation. Vacuum

Locomachs includes two physical partial-wingbox demonstrators, the nearer-term LAWiB and farther-term MIWiB and the virtual ReWiB to demo how the assembly technologies scale up to a complete wing structure.

Europe's Locomachs Composites Assembly Demonstrators



ReWiB = Reference Wingbox

LAWiB = Lean Assembly Wingbox

MIWiB = More Integrated Wingbox

Source: Locomachs Project

Fabrication of large composite parts like this A350 wing skin has been automated, but assembly remains a complex task.

bagging for autoclave curing of the parts was simplified and skin thickness adjusted, and “within three months we got to more than 90% good parts and a cost of non-quality less than 5%,” he says.

Locomachs tackles the assembly problem in many ways, from designing more integrated structures with fewer interfaces between parts that need to be measured, drilled, shimmed and joined, to robots collaborating with humans to move and position parts and drill and join structures in areas that are hard for a person to access. The project is developing simulation tools to predict gaps and design shims for rapid additive manufacture, mobile systems for faster nondestructive inspection to keep parts moving, and flexible assembly tooling that can accommodate variations in part geometry.

Overall objectives of the project are to develop design and manufacturing rules for complex composite structures and fully integrate geometrical variation and tolerance management into the computer-aided design tools. The demonstration goals are to reduce the recurring costs of shimming joints in assembly by 50% and of dismantling operations by 30%, to increase the level of automation in joining operations and reduce the lead time for nondestruction inspection and test (NDI/NDT) by 30%.

The project includes two physical demonstrators—the Lean Assembly Wingbox (LAWiB) using nearer-term technologies, and the More Integrated Wingbox (MIWiB) looking into the future. Both are partial wingboxes designed to demo multiple joining technologies. There are also two virtual demonstrators designed to show that a selected set of technologies can be scaled up—the Reference Wingbox (ReWiB) representing a complete wing structure and the Reference Fuselage (ReFus) comprising a large composite side-shell panel, to show the technologies can also apply to fuselage structures.

“The challenges of composite structures include the complexity of the tooling required, the number of process steps, the more complicated compensation for part distortion and the need to develop new techniques for nondestructive evaluation,” says Kevin Peters, senior research project development engineer at GKN Aerospace. What is required “is a fundamental change from black-aluminum bolted carbon-fiber to one-shot integrated structures,” he says.

Locomachs begins by designing composite structures with fewer parts so there are fewer interfaces to assemble. LAWiB has an integrated wing upper cover, with stiffening stringers and rib feet co-cured and co-bonded to the skin. The stringers have tapered feet to maximize the co-bond area, improve peel performance and to enable the rib feet to be co-cured over them, which could not be done with a step join.

Inner mold-line tooling (the inside and not the outside of the skin is against the mold) provides the most accurate



control of the interface between the substructure and cover. Removing the feet from the rib and co-bonding them to the upper cover means bolting the rib to the cover involves a flat interface, and not a curved surface that is difficult to shim, says Peters. MIWiB goes a step further and co-bonds the spars to the upper cover. Outer mold-line tooling is used for the spar caps, to get a good interface.

A next step is increasing the accuracy with which parts are manufactured, to reduce geometric variation and tolerance buildup. German aerospace center DLR is working on an autoclave resin injection process for rate production of composite parts in a controlled environment. “The challenge is, at 50-plus aircraft a month, do composite parts have a chance?” asks Marcus Kleineberg, head of composite technology development at DLR. “Composites have their own idea of what tolerance means, so how can we produce competitive, high-accuracy parts?”

With a C-shaped machined aluminum rib as the reference part, GKN designed an L-shaped carbon-fiber rib (missing the upper feet) to be produced using DLR's process. This uses ultrasonic pulse-echo sensors to detect the flow front as resin is infused into the part in the autoclave. The sensors are used to monitor and adjust the fiber content volume and thickness of the part. Sensors also monitor the gelation point, when the resin sets, so the part can be removed from the autoclave as soon as it is cured.

“The geometric accuracy is comparable with aluminum. We produced eight ribs, and they all look the same,” says Kleineberg. “A production cost at the same level as aluminum is not easy, but we hope to get near to the cost of a heavily machined aluminum rib. We are still calculating,” he says. “We also hope to get some weight reduction.” Compared with the 7-kg metallic rib, the composite part weighs less than 3.5 kg. “We expect to end up with a 25-30% weight saving with resizing,” he says.

DLR is developing additional sensors to detect mold deformation during curing, to further increase part accuracy, and is working on wireless sensing. “There is a lot of wiring now. The next step necessary for series production is to go wireless,” says Kleineberg.

Another step is to build a tolerance simulation capability into the design tools. Predicting the variability is important, because forcing parts together to close gaps during assem-

bly introduces built-in stresses. “That’s a major concern for carbon fiber, which is why we use shimming,” says Hugo Falgarone, an engineer with Airbus Group Innovations.

Locomachs is demonstrating a tolerance simulation program, Anatoleflex, in which measurements of the first parts produced are used to create a deviation model. This is used in the simulation to predict gaps and create shim models for each individual aircraft on the production line. Shims are then 3-D-printed in situ by an additive-manufacture end-effector on a robot arm. “We will use Anatoleflex in Locomachs to demonstrate anticipated shimming requirements and see if it is possible to achieve shimless assembly,” says Falgarone. Robotic 3-D-printed shims will be tested on LAWiB.

One part of Locomachs is looking at alternatives to mechanical fasteners to reinforce joints. A technique being investigated by Airbus is a metallic plate with vertical Z-pins that is adhesively bonded or co-cured into the carbon-fiber joint to arrest disbands or delamination. The integrated reinforcing step reduces cost and time, and project results show it increases damage tolerance and fatigue life.

Another technique GKN is investigating uses through-thickness reinforcement instead of bolted joints as anti-peel devices at the ends of stringers. Narrow carbon Z-pins in

carrier foam are driven through the carbon-fiber layup by an ultrasonic gun, allowing for more integrated structures.

Nondestructive evaluation techniques now used with composites can keep parts immobile for long periods, so to reduce the takt time Locomachs is demonstrating several faster and more mobile NDI/NDT technologies. These include multi-channel air-coupled ultrasonic inspection of hybrid composite/metallic structures that cannot be immersed in water, the usual medium used for ultrasonic testing.

Acousto-ultrasonics enables instantaneous imaging within a zone defined by a sparse array of ultrasonic probes in direct contact with the part. This is suited to components with complex geometry and poor accessibility. Waves are generated within the part that are sensitive to delamination and can reveal flaws by comparison with the reference signature of a pristine specimen. Locomachs is developing a modular, reconfigurable 16-probe array for use with LAWiB and MIWiB.

With the goal of increasing automation in assembly, Locomachs is looking at several ways robots can be used. One way is to use multiple electric-driven hexapod positioners within the assembly fixture to pick up and position large components like a wing spar. The devices will require 6 deg. of freedom (dof) and force feedback. Hexapods used in the automotive industry are only 3dof and not accurate enough. Another approach is to use a robot arm as the tooling to hold a part in position for manual joining.

Locomachs is demonstrating compact automation for low-access areas by developing a robotic end-effector for one-shot drilling of hybrid composite/metallic stacks. Normally this is a manual process and the structure has to be disassembled to clean out waste from the drilling, but the robotic end-effector will both clamp and drill the component and eliminate the need for subsequent disassembly, says Weiland.

Work on robot-human collaboration during assembly is being led by Sweden’s Linköping University. The goal is to combine the dexterity of humans with the repeatability of robots. One example is having a person on the outside of the structure inserting the fastener and a compact robot in the cramped inside space pulling through the pin, placing the collar and swaging them together.

The project includes a demonstration of how a multi-camera vision system using four Microsoft Kinect motion-sensing systems can provide a 360-deg. view around the robot. This could be used to create dynamic safety zones keeping humans and robots apart as they move around a structure, and be combined with path-planning algorithms to predict the trajectory of the person and avoid collisions.

These techniques will be tested during assembly of the LAWiB and MIWiB demonstrators. Under current plans, assembly of the wingboxes is planned to begin early in 2016. Because of a slow start to the complex project, which involves 31 European partners including Saab, Airbus, Bombardier and Alenia Aermacchi, Locomachs is now expected to take about six months longer than the 3.5 years planned. But Weiland says the technologies being demonstrated remain well-aligned with the manufacturers’ priorities as they face the challenges of ramping up composites to high production rates. ☛



Optimizing A350 vertical tail-plane production at Airbus CTC Stade has reduced cost and increased the rate.

Auto to Aero

Can aircraft manufacturers use low-cost, high-rate composite technologies from the car industry?

Graham Warwick **Paris**

To the aerospace and automotive industries, high-rate production means different things. For airframers it is hundreds of aircraft a year; for automakers hundreds of cars a day. And those vastly different outputs drive divergent choices in structural materials and manufacturing processes.

But, at first glance, it would appear the automotive and aerospace industries are drawing closer as carmakers strive to meet targets for reducing fuel consumption and emissions by switching to lightweight materials for vehicle bodies, including aviation's staples: aluminum and carbon fiber.

Structural composites got their start in aerospace, but at the JEC Europe composites-industry show in Paris in March, there were many more displays related to cars, buses, trams and trains than aircraft. And as the automotive industry embraces composites, it is heading in new directions, driven by demand for low costs and high production rates. In high-volume carmaking, even 4 min. to make a part is too long.

"In the late 1990s, the only market for composites was in aerospace because of oil prices," says Edward Bernardon, vice president of strategic automotive initiatives at Siemens PLM Software. Vistagy, which developed the Fibersim composites engineering software and was acquired by Siemens in 2011, "started a group in Germany to look at the high-volume automotive market and how to make carbon-fiber parts more cost-effective," he says.

Initially, carbon fiber was used only in high-performance but low-volume supercars where material cost and manufacturing cycle times are less critical. Then in 2009, BMW announced it would build a small all-electric car using carbon-fiber composites. Deliveries of the i3 began late in 2013, but at 100 cars a day, it is at the lower end of the high-volume spectrum. Now automakers like PSA Peugeot Citroen are looking at composites, but for rates exceeding 900 cars a day.

According to Bernardon, automotive composites are unique because of the faster design cycles—"designs can change daily or weekly for packaging reasons," he says. As a result, manufacturing processes developed by airframers and carmakers have diverged. "Resin transfer molding of preforms is a big percentage in automotive, but only a small percentage in aerospace," he says.

But can the automotive industry's push toward low-cost, high-rate composites benefit aerospace? Darpa thinks so, and the Pentagon advanced research agency plans a program—Aerospace Composites with Automotive Efficiencies—to significantly reduce the cost and time to make small composite parts—less than 15 lb. and 15 ft.—for use in aircraft.

Darpa believes materials and processes developed by the automotive industry could enable "build-rate insensitive, less capital-intensive" composites production for aerospace—with the critical caveat that parts must maintain the performance of the intermediate-modulus carbon-fiber/toughened-epoxy systems now used in aircraft. And that is

an important stipulation, because low-cost composites used by carmakers will not meet aerospace strength, stiffness and damage tolerance requirements.

Darpa has requested information on short-fiber composites that have the same performance as continuous fibers but enable injection processes and forming over contours. Spraying chopped fibers onto a mold is one technique used by carmakers. But for aerospace use, unlike automotive, precise control of short-fiber orientation will be needed to provide the mechanical properties required.

The agency is also interested in rapid high-performance molding techniques to reduce cycle time, and conformable product forms that enable complex shapes and small parts that are now too expensive to use on aircraft. Darpa is looking for processes that allow multiple parts to be made on the same machine without drastic reconfiguration for each part. Other areas of interest include versatile automation to reduce touch labor with reasonable capital equipment costs.

An illustration of what might be possible if more composite parts can buy their way onto aircraft may be provided by Formula One, which represents an amalgam of aerospace



BMW's i3 electric car has a carbon-fiber passenger cell.

and automotive engineering. Design teams make extensive use of small carbon-fiber parts to shave weight off their race cars. "Our F1 car is 80% constructed of advanced composite materials," says Ian Goddard, research and development engineer with the Lotus team. "We use 34 different composite systems, 50 core variants and 10 structural adhesives. We make several thousand components and spend more than \$2 million a year on pre-preg [material]."

Lotus faces the same design challenges as larger carmakers—aerodynamics, packaging, stiffness and crashworthiness—and uses Fibersim software for composites engineering, says Goddard. "F1 has an absolute obsession with weight" and, like aircraft manufacturers, designers must pay extra attention to fiber location and orientation. F1 is obsessed also with reducing time, he adds, as faster design and manufacture can put better components into the car 1-3 races earlier.

The state of the art in composites use in volume car manufacture is BMW's Leipzig plant, where the i3 is produced as well as the i8 hybrid sports car. The i3 has an aluminum drive module that includes the batteries and motor; a passenger cell made from carbon fiber; a recycled carbon-fiber roof and unreinforced thermoplastic body panels. The structure is

manufactured by resin transfer molding (RTM) of carbon-fiber fabric supplied by SGF Automotive Carbon Fibers.

Fabric stacks are preformed in a heated mold press then trimmed to near-net shape with an ultrasonic knife. Next, the multiple preforms making up each structural part are placed in a hydraulic press for high-pressure resin injection. Cured parts are trimmed by water jet, drilled and random samples inspected. Parts are then adhesively bonded together to assemble the passenger cell. Handling and bonding of the RTM parts is performed by robots.

Other parts are added robotically, including metal door hinges, the thermoplastic crash-protection system and carbon-fiber roll bar; then the passenger cell is attached to the drive module with adhesive and screws. Body panels are injection-molded from thermoplastic in an automated operation, with recycled material used for interior parts such as door liners.

All this should sound familiar to the aerospace industry, except perhaps the mix of materials and use of robots—and the speed, BMW talking in terms of minutes for part forming to a few hours for assembly. But as volumes increase, so do the differences. PSA Peugeot Citroen is looking at composites to reduce weight and emissions but needs processes that work within existing factories as it cannot afford to build new facilities to assemble such vehicles. “It’s a big challenge to introduce composite structural parts into mass production,” says Catherine Tual, innovation project manager.

As it develops the technology, the European carmaker is claiming a first—demonstrating the crashworthiness of a composite front floor module. This replaces the traditional steel underbody with a self-supporting thermosetting resin floor reinforced with chopped glass fiber. The module saves 8 kg in a mid-range car, which should increase to 12 kg with optimization, Tual says.

Parts count is reduced to four from 30, and welding of the steel floor is replaced by gluing and screwing. Cycle time for the full module is 2 min., she says, allowing the composite floor to fit within a production system turning out 550 cars a day at PSA’s biggest plants. “The technology is compatible with the systems used to assemble car bodies and can be

used in a multi-material approach with steel,” says Tual. “We hope it will be in production soon.”

PSA began with crashworthiness testing because it is make or break for composites in cars, but it highlights a key difference between automotive and aerospace. Airframers can track the use of their aircraft through their lives, while carmakers have no idea how their vehicles will be treated after they leave the showroom. “After a crash, there will be cracks in the composite, and we need to understand what is critical. We do not yet understand how to measure the health of the structure,” she says.

In a glimpse of a possible future for automotive composites, at the Detroit Auto Show in January Oak Ridge National Laboratory (ORNL) unveiled a 3-D-printed Shelby Cobra sports car. The vehicle was produced in ORNL’s Manufacturing Demonstration Facility in Oak Ridge, Tennessee, using broad area additive manufacturing (BAAM). Where conventional 3-D printing can produce parts of only limited size, BAAM can manufacture large composite components.

The Cobra incorporates 500 lb. of printed parts made from 20% carbon fiber, which required 24 hr. of print time. BAAM was developed by ORNL, working with Lockheed Martin, which was interested in using the process to produce unmanned-aircraft wings. Recent improvements developed in partnership with machine builder Cincinnati Inc. include a smaller print-bead size for a smoother surface finish.

The first drivable 3-D-printed car, the Strati, was completed last September when Local Motors, working with Cincinnati and ORNL, built the vehicle over six days on the exhibition floor at the International Manufacturing Technology Show in Chicago. Additive manufacturing of the components using BAAM took 44 hr., followed by finish machining and assembly.

Local Motors, which specializes in crowd-sourced design of vehicles and operates a network of micro-factories to build them, says 3-D printing reduced the parts count to fewer than 50 from 25,000, and from design to drive took less than six months. ORNL says the speed of next-generation additive manufacturing offers new opportunities for automakers, particularly in prototyping. ☼



This Shelby Cobra replica was built using carbon-fiber additive manufacturing.

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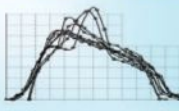
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- June 17—Commercial Aerospace Manufacturing Briefing, Paris.
- Oct. 13-15—MRO Europe, London.
- Nov. 3-5—MRO Asia, Singapore.
- Nov. 3-5—Aerospace Defense Chain, Scottsdale, Arizona.

Aerospace Calendar

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May 4—Association for Unmanned Vehicle Systems International's Unmanned Systems 2015. Georgia World Congress Center, Atlanta. See www.auvsi.org/events1/eventdescription/?CalendarEventKey=4b6a54a9-2072-463b-9398-67c2c462ec2e

May 6—American Institute of Aeronautics and Astronautics (AIAA) Spotlight Awards Gala. Washington. See www.aiaa.org/gala2015

May 11-14—33rd Annual Space Power Workshop, Manhattan Beach (California) Marriott. See www.event.com/d/n4qbdc

May 26-28—15th Annual Association of Old Crows' Electronic Warfare Europe, Stockholm. See www.eweuropa.com/page.cfm/Action=Form/FormID=6/t=m

May 26-29—Eighth Chaos Conference at Henri Poincare Institute, Paris.

See www.cmsim.org

June 1-5—University of Kansas Aerospace Short Course Program. Overland Park, Kansas. Also **June 15-19** in Montreal. Plus **Sept. 14-25** in San Diego. And **Nov. 16-20** in Orlando, Florida.

See www.aeroshortcourses.ku.edu

June 4—Aerospace Today . . . and Tomorrow—An Executive Symposium. Williamsburg, Virginia. See www.aiaa.org/ATT2015

June 22-26—AIAA Forum and Exposition. Dallas. See www.aiaa-aviation.org

June 27-29—AIAA Propulsion and Energy Forum and Exposition (Space 2015). Pasadena, California. See www.aiaa-space.org

Aug. 31-Sept. 2—Airports Council International Latin America-Caribbean World Annual General Assembly 2015. Panama City. See www.aci-waga2015.com

Oct. 8-12—Air Force Officer Candidate School Reunion. Montgomery, Alabama. Call Dave Mason at +1 (757) 820-3740 or blokemason@verizon.net

Nov. 10-12—International Aviation Women's Association's 27th Annual Conference, at Dubai air show. See www.iawa.org

Nov. 17-19—Aerospace Structural Dynamics International Conference. Seville, Spain. See www.asidconference.org

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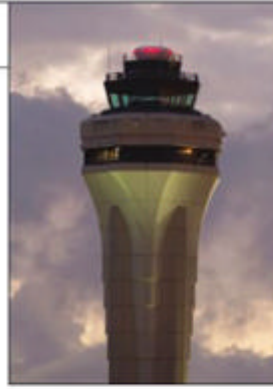
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Time To Reform Aviation Funding



JOEPRIESAVIATION.NET

Stephen D. Van Beek, Ph.D., is vice president of ICF International and a former member of the FAA Management Advisory Council.

For the first time in at least 25 years, a policy reform breeze is blowing in Washington. Attend any major aviation meeting, such as the recent Chamber of Commerce Aviation Summit, and you will hear political and aviation leaders express support for changing the way we organize, fund and deliver the services and infrastructure so vital to our aviation system.

Support is emerging for using this year's FAA reauthorization to address two pressing needs. First, where possible, remove the FAA's services from the federal budget process, where they are vulnerable to interruption. Second, modernize the provision of air traffic control and other services by separating them from the FAA, allowing the agency to focus on its key regulatory mission. Passage of an FAA reform effort would be the most sweeping and significant aviation policy reforms since 1978—when the Airline Deregulation Act became law.

Leading the charge is House Transportation and Infrastructure Committee Chairman Bill Shuster (R-Penn.),

“Stakeholders are frustrated with unmet promises for the ATC system, an outmoded and unfair tax system and airport infrastructure shortfalls.”

who declares that he will try for “bold and transformational reform.” He has urged stakeholders—including airlines, airports, general aviation and labor—to put their parochial, and sometimes petty, disagreements aside in favor of the interests they have in common. Now that he has begun deliberations on the bill, aviation interests appear to be listening.

Why? Stakeholders are frustrated with unmet promises for the air traffic control system, an outmoded and unfair tax system that does little to incentivize efficient use of scarce resources and airport infrastructure shortfalls. Most of all is the shared experience of living through a series of embarrassing budgetary train wrecks, including sequestration, debt-limit fights, 23 short-term extensions of authorization and lapsed appropriations.

Over the past several years, each of these at one time or another forced the FAA to triage its operations and infrastructure investments, causing dislocations to travelers as well as the FAA, airlines, airports and the employees who work for them. For many, the biggest priority is to avoid a second round of sequestration in fiscal 2016,

which begins Oct. 1. Many remember the damage caused by the first round, including controller furloughs, closure of the FAA academy, suspension of airport safety and capacity projects and delays in certifying new aircraft, parts and procedures.

Working behind the scenes over the past four years, two separate FAA Management Advisory Councils (MACs) have put together a set of consensus-based reform principles that would address FAA financial stability and improve air traffic control. As MACs first deliberated and then released their principles, groups such as the Business Roundtable and the Eno Transportation Foundation offered their own proposals vetted with significant segments of the industry. Chairman Shuster and committee members have a good base from which to work.

These efforts share three key ideas:

- Insulate the FAA and aviation services. Remove major FAA programs from the federal budget. Where possible, shift air traffic services, the funding of airport infrastructure and certification to cost-recovery, user-pay systems. Make sure safety, research and the needs of smaller community airports—where it is challenging to recover costs—have stable and sustainable funding mechanisms.
- Change the ATC governance model: The U.S. is virtually alone in operating its air traffic system through a bureaucratic agency funded by ticket taxes and taxpayers. Other nations and the International Civil Aviation Organization recognize that national regulatory agencies should focus on the provision of public goods such as regulation and safety, not delivering user services. These systems typically separate the air traffic provider from the regulator, protecting the interests of the public while enabling the efficiencies and access to capital of a commercialized provider. They also use governing boards made up of customers and aviation professionals that set goals, develop business strategies and hold their leadership accountable for performance.
- Shift to cost-recovery and eliminate ticket taxes: Taxes collected today are a hodgepodge series of charges unrelated to the costs of providing services. The per-passenger return from taxes is declining as ticketing practices have reduced the revenues that support FAA services. Far better, where possible, is to shift to a system under which air traffic, airport and certification services are paid directly as “business to business” transactions that flow to the balance sheet of users, protecting services and encouraging efficient use (alternatives are available for users who would like to pay through other methods).

Historic reform is always hard. However, enough unmet needs, broken promises and policy failures have convinced a core group of farsighted leaders and stakeholders that our system deserves better. Now is the time. ☐

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