AEROSPACE TESTING INTERNATIONAL

NOVEMBER/DECEMBER 2014

Scorpion update

The latest light fighter will cost just US$20m and operating costs will be minimal, but the test program is not cutting corners

FUEL THE FIRE

Inflight refueling (IFR) trials with an E-2D Advanced Hawkeye aircraft continue

GOING GREEN

Hydrogen fuel cells are a future emissions-free substitute for small gas turbine engines or APUs

HYPERSONICS

An integrated test and analysis of a hypersonic cruise vehicle has been completed at AEDC, Wind Tunnel 9

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PRODUCTS & SERVICES

REGULARS

Seconds after firing its rocket engine, Virgin Galactic's SpaceShipTwo (SS2) was breaking through the sound barrier, and traveled up to 50,000ft (10 miles above Earth). It was at this point, in the three disorienting seconds it took for the craft to climb from Mach 0.94 to Mach 1.02, that disaster struck.

It was the most ambitious test flight the craft had undertaken, and came with inevitable risks. "Our plan was to burn for a longer duration than we had in the past," said George Whitesides, a former NASA chief of staff, who joined Galactic in 2011.

The tragedy is now the subject of an investigation led by the US National Transportation Safety Board (NTSB) that could take the best part of a year. There has been some concern and anger following initial speculation that suggested that Michael Alsbury, the co-pilot who was killed, wrongly flicked a safety switch that controls the craft's folding wings, causing them to 'feather'. Both pilots would have been aware that unlocking the wings at near the sound barrier would have been disastrous. As objects reach this speed, the aerodynamic forces become unpredictable. So unpredictable that when test pilots first broke the sound barrier half a century ago, they lost total control of their aircraft with terrible consequences.

Apparently, SS2's engines were fired at 21 seconds past 10:07am. Nine seconds after ignition, a cockpit camera allegedly showed Alsbury pushing the lever to unlock the wings. It was then that the disaster literally unfolded.

However, it has also been noted that a second switch would have to be flicked, and a command given, suggesting mechanical failure.

SS2 was not equipped with ejector seats. It had a door immediately to the rear of the pilot station, and its emergency hatch was the middle passenger window on the right side. But it was only seconds between fault and catastrophic break-up. It appears that senior test pilot Peter Siebold was thrown clear and his parachute deployed, whereas Alsbury was trapped in the remains of the vehicle.

Virgin Galactic is understandably keen to minimize additional delays of its introduction into commercial service. But to press ahead with construction and perhaps even flight tests while the investigation is still underway could prove problematic. The tragedy will highlight any technical or potential human error faults and this can only improve safety in the future. The possibility of fatal accidents in commercial spaceflight has always been par for the course and acknowledged by anyone familiar with the difficulty it entails. Now that this has occurred, albeit perhaps sooner than some might have expected, prudence dictates a cautious response from all parties, including the public, that doesn't exacerbate the blow that the industry has already suffered.

Just to put things into perspective, the V-22 Osprey had 30 fatalities during testing, with four notable crashes. In the 1950s, one test pilot died each week on average. My research has found it difficult to pinpoint a number, but there have been at least 13 test-related fatalities directly linked to space travel – although the figure would, I'm sure, be far higher if Soviet numbers were released, and those of other nations.

I have seen Twitter comments vilifying the program and Sir Richard Branson for sacrificing life for commercial reasons. How wrong. Ever since the end of the Shuttle program (which had many fatalities of its own), taking humankind into space has stalled and relied on the Russian rocket programs. You could say that World War I moved aviation design into passenger travel and World War II into the jet age, both of which came at huge human cost.

Realizing the enormous expense of taking the next step into space, the US government backed away, so the commercial side has stepped in (with international support). Commercial space travel has to fill the void, and it needs to be tested.

A segment of the latest Virgin statement sums it up for me: "The support of our Future Astronaut community has been overwhelming. Their loyalty during this time confirms that there is a real and passionate belief in, and demand for, private space travel. The Spaceship Company's hangar is not empty: SpaceShipTwo serial 2, is already two-thirds complete. WhiteKnightTwo was unaffected by the accident and is in a flight-ready condition."

There will be more deaths, but test pilots know the potential cost. I have interviewed so many over the years and I have never talked to one who didn't think it was the greatest job in the world, and nearly all knew someone who perished in order to further aviation travel.

If I had an invitation to travel on one of the first flights, I would do 'one giant leap' at the drop of a space helmet.

Christopher Hounsfield, editor

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COVER IMAGE: MARTIN BAKER EJECTION SEAT TRIAL FOR SCORPIAN ATTACK AIRCRAFT

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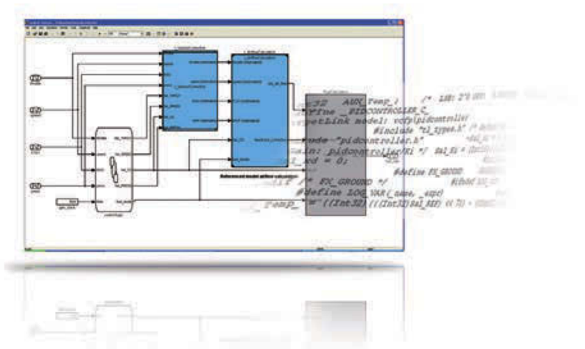

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WORLD TEST UPDATE

1 LIGHT COMBAT HELICOPTER MAKES MAIDEN FLIGHT

The Indian HAL Light Combat Helicopter (LCH) Technology Demonstrator TD-3 has completed its maiden flight. "Escorted by a Dhruv helicopter, the entire flight was flawless. It will be an effective weapon platform to deliver precision strikes at high altitude and we are confident it will meet the requirements of the IAF," said Dr R K Tyagi, chairman of HAL. "We are making all efforts to achieve initial operational clearance (IOC) by September next year," he added. In all, HAL is expected to produce/manufacture 179 LCHs for Indian Defence forces. The craft flew for 20 minutes. The scope of this project covers design and development of two technology demonstrators, one full-scale mock-up, one breakaway fuselage and IOC.

Bangalore, Karnataka, India

2 COUNTDOWN BEGINS FOR FIRST RECORD ATTEMPT WITH DESERT TRIAL

The Bloodhound Project has started the 12-month countdown to its first land speed record attempt, and celebrated Jaguar joining the program as innovation partner by staging a high-speed communications test at Hakskeen Pan, South Africa. These tests have confirmed that the project's entire radio infrastructure is now in place, ready for 2015 and the beginning of Bloodhound's high-speed campaign.

Hakskeen Pan, South Africa

3 REVOLUTIONARY SHAPE-CHANGING AIRCRAFT FLAP TRIAL

NASA's green aviation project is one step closer to developing technology that could make future airliners quieter and more fuel-efficient with the successful flight test of a wing surface that can change shape in flight. This past summer, researchers replaced an aircraft's conventional aluminum flaps with advanced, shape-changing assemblies that form seamless, bendable and twistable surfaces. Flight testing will determine whether flexible trailing-edge wing flaps are a viable approach to improve aerodynamic efficiency and reduce noise generated during take-off and landing.

Edwards, California

4 VIETJETAIR'S FIRST A320 COMPLETES FIRST FLIGHT

VietJetAir's first A320 on order from Airbus has reached a new production milestone, with the aircraft having successfully performed its first flight in Toulouse, France. Appearing in its colorful livery, the aircraft now enters the final acceptance phase, prior to delivery to VietJetAir by the end of 2014. This A320 is the first of up to 100 of the best-selling single-aisle aircraft that will be acquired by the airline under a deal that was finalized in February 2014.

Toulouse, France

5 TRIALS DEMONSTRATE ENHANCED AIR-TO-SURFACE CAPABILITY FOR TYPHOON

Working closely with the Royal Air Force and weapons manufacturer Raytheon UK, Typhoon have completed a series of flight trials culminating in the successful release of two Paveway IV precision-guided weapons simultaneously from a Typhoon aircraft. This is the first multiple release of the Paveway IV from an RAF Typhoon to multiple targets.

Essex, UK

6 ORION SPACECRAFT COMPLETED

NASA and Lockheed Martin have completed final assembly and testing of the Orion spacecraft. It will remain inside NASA's Launch Abort System Facility at Kennedy Space Center until it rolls to launchpad 37 this November. "An empty shell of a spacecraft arrived at Kennedy Space Center two years ago, and now we have a fully assembled Orion standing 72ft tall," said Michael Hawes, Orion program manager for Lockheed Martin. "We're ready to launch it into space and test every inch."

Kennedy Space Center, Florida

7 FIRST ARRESTED LANDING FOR F-35 ON CARRIER

The US Navy made aviation history when an F-35C Lightning II carrier variant Joint Strike Fighter conducted its first arrested landing aboard an aircraft carrier off the coast of San Diego. The arrested landing is part of initial at-sea developmental testing for the F-35C, which commenced November 3, 2014, and lasted two weeks.

San Diego, California, USA

8 AUSTRALIA'S FIRST F-35A TAKES TO THE SKIES

Australia's first F-35A Lightning II Joint Strike Fighter, known as AU-1, has made its inaugural flight, marking another significant milestone for the Australian F-35 program. "Australia's first aircraft AU-1 and AU-2 will undergo further flight testing in the lead-up to acceptance and transportation to Luke Air Force Base in 2015," said defense minister David Johnston.

Luke Richmond Air Force Base, Australia

14 BELL 505 JET RANGER X ACHIEVES SUCCESSFUL FIRST FLIGHT

Bell Helicopter has revealed the successful first flight of the Bell 505 Jet Ranger X helicopter. The maiden flight took place at the company's manufacturing facility in Mirabel, Quebec. "Bell Helicopter pioneered the short light single market, and here we are nearly 50 years later, changing the way the world flies once again," said Matt Hasik, senior vice president of commercial programs at Bell Helicopter. "We have seen tremendous response from the market for the Bell 505, and today's exciting flight marks another step toward delivering the high-performance, high-value aircraft our customers have been asking for."

Mirabel, Canada

15 REDUCED THRUST TAKE-OFF CERTIFICATION

Sukhoi Civil Aircraft has received a Supplemental Type Certificate, which allows Sukhoi Superjet 100 to perform reduced thrust take-off. In 'Operating' mode, with engines working and a reduced engine speed and lower turbine gas temperature, the aircraft's engine load is reduced, thus extending engine lifetime and, in turn, minimizing aircraft maintenance costs. Reduced thrust take-off mode on Sukhoi Superjet 100 aircraft can be used in airports with runways exceeding 2,000m in length.

Moscow, Russia

9 S-97 RAIDER UNVEILED

The first of two S-97 Raider helicopter prototypes has been unveiled by Sikorsky, signaling the start of activities in the program's test flight phase and a major step toward demonstrating the new – and first – armed reconnaissance rotorcraft featuring X2 Technology designed for military missions.

Stratford, Connecticut, USA

10 GROUNDBREAKER FOR LATEST COMPOSITE WING CENTER

Work has begun on the new 777X Composite Wing Center at the Boeing campus. Permission for the new 1,000,000ft² facility was granted seven weeks earlier than anticipated, allowing for an accelerated start to construction. Boeing is investing more than US$1bn in the Everett site for construction and outfitting of the new building.

Everett, Washington, USA

11 LEGACY 500 CERTIFICATION

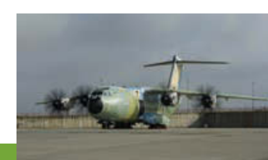
Embraer's Legacy 500 executive jet has been granted FAA certification during a ceremony at the National Business Aviation Association Conference and Exhibition, in Orlando, Florida. This approval allows entry into service of the aircraft in the USA and in countries that require such certification.

Orlando, Florida, USA

12 AIRBUS A350-900 RECEIVES EASA TYPE CERTIFICATION

The Airbus A350-900 has received Type Certification from the European Aviation Safety Agency (EASA). Rolls-Royce Trent XWB engines power the aircraft. FAA certification will follow shortly. "The A350-900 is now ready to fly from the nest and be enjoyed by airlines and passengers," said Fabrice Brégier, Airbus president and CEO.

Blagnac, France



13 ENGINE RUN FOR FIRST GERMAN AIR FORCE A400M

The first Airbus A400M new-generation airlifter for the German Air Force has begun final tests ahead of its delivery. The four engines on the aircraft were successfully run simultaneously for the first time on September 28, 2014 at the Airbus Defence and Space final assembly line.

Seville, Spain

A320NEO FLIGHT TRIALS

Little more than two months after its first flight, the Airbus A320neo has logged almost 100 hours in the air and the manufacturer is preparing to fly the second example of the re-engined variant in early 2015.

As Airbus continues preparations to fly the second Neo re-engined A320 in January 2015, it expects this month (December) to have initial analysis results of flight-test data from the first example, which performed its maiden flight on September 25. The Neo (New Engine Option) variant of the single-aisle twinjet is being offered with 33,000 lb-thrust Pratt & Whitney PW1100G-JM geared turbofan (GTF) engines, which power the first two machines, and the alternative CFM International Leap-1A powerplant that is scheduled to fly on the A320neo in mid-2015.

Analysis of results garnered from the first two months of

ENGINE APPROACH

By late November, Pratt & Whitney (P&W) had completed more than 96% of necessary work and analysis of the PW1100G-JM geared turbofan (GTF) during engine and rig testing, ahead of expected US certification (or airworthiness approval) by the year's end. Nevertheless, it declines to reveal progress. However, the GTF family has completed 12,000+ hours of testing, including 1,700 hours in flight, and more than 23,500 test cycles that have shown no 'issues'. Testing is claimed to have 'validated' a 16% reduction in fuel burn, a 30-50% reduction in regulated emissions, and a 75%-reduced noise footprint compared with current aircraft. P&W says next year will be busy, with GTF power-plants involved in "five active flight tests, three engine certifications, and two airplanes entering into service".

Competing manufacturer CFM International describes as "promising" results of initial Leap-1 turbofan testing that began in October aboard a Boeing 747-100 flying testbed, although it has not quantified the duration of tests. By mid-November, the Leap-1C variant – very similar to the A320neo's -1A model and destined to power China's Comac C919 – had flown for about 75 hours. "In terms of flight test, the two engines are similar and have the same fan size," says CFM International, which plans to have 20 test engines by year-end.

testing should provide the European manufacturer with a firmer understanding of the new variant's enhanced performance, compared with A320s powered by CFM International CFM56s or International Aero Engines V2500s. (Some A318s have PW6000 engines, but there is no A318neo.)

The A320neo has been airborne about every two days (but sometimes twice a day), logging 22 flights in the test program's first eight weeks.

Testing is "going well and according to plan", says Airbus. By late November, it had added about 85 hours (equivalent to more than 40hr/month) to the 250 hours flying and related data and experience previously obtained with a standard A320 fitted with the manufacturer's more efficient "sharklet" wingtips now being fitted to current production aircraft. Some 300 hours of testing had been logged on ground and flying testbeds.

In the air, the A320neo "feels like an A320 – which is good news", explains Airbus experimental test pilot Etienne Miche de Malleray, who flew as co-pilot in the right-hand seat during September's first flight. Also on board was flight-test engineer Dr Sandra Bour-Schaeffer (pictured), who says, "We did a good job and opened quite a lot of the flight envelope. We flew in both 'normal' and 'direct' [flight control] law and up to 26,000ft."

During the flight, the new aircraft flew at speeds between minimum final-approach velocity (VLS) and about 280kts (320mph).

DATA MEASUREMENT

Following the September flight, Airbus would need "two or three months" to begin to fully understand the A320neo's performance, according to flight and integration tests senior vice-president Fernando Alonso, who has overseen initial operations of the past five Airbus projects: A380, A318, A350, and A320neo jetliners, and A400M military transport. The first few weeks' testing is "not just measuring cruise and climb performance, but also 'engine-out' behavior and everything else – and then asking 'What does it all mean?'".

Airbus hopes to receive airworthiness approval for the PW1100G-JM A320neo in December 2015 and the Leap-1A model by mid-2016 (see box, Engine approach). Alonso expects the test program will generate some 3,000 flight hours to achieve certification of all six planned variants. (A sub-variant – the A321neoLR – could yet emerge, with American Airlines saying it will be "evaluating economics, range and performance capabilities of the long-range version of the A321neo".)

Ultimately, the test fleet will involve eight aircraft: four A320neos, two A319neos, and a pair of A321neos, with engines split evenly between PW1100G-JMs and Leap-1As within each group. According to Alonso, all variants will undergo the same testing, but the necessary work will not be shared equally: "The bulk will be accomplished on the A320, which will identify most of the engine characteristics, then less on the others."

Around 1,600 hours, shared by both engines, will be flown with A320neos, says program senior vice-president Klaus Roewe. One PW1100G-JM A320neo is earmarked for high-altitude tests and flight in high and low temperatures, while a Leap-1A example is to be used to check autopilot functions, noise and extended-range operations.

Alonso confirms that it will not be necessary for the test campaign to go over any A320neo aspects, such as hydraulic and electrical systems, that are common to the current A320. Unshared areas of operation – aircraft handling and performance, for example – will be assessed for each airframe/engine combination, says Alonso. The full test program will also include around 300 hours of route proving.

To monitor and analyze performance and reliability, the A320neo team, led by experimental test pilot Philippe Pellerin, will operate the eight aircraft like a small airline – not only in flight, but also in aspects such as ground support, line and scheduled maintenance, and spares supply, according to Roewe.

Alonso expects that Airbus will deliver "probably all" of the A320neo test aircraft to customers, with the manufacturer retaining the initial aircraft if it follows established tradition. Meanwhile, Alonso's flight and integration test center team remains very busy: it is involved in six major tests or continuing development programs, flying 22 aircraft, and that second A320neo is set to arrive next month. ∎

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HELMET-MOUNTED DISPLAY DEMONSTRATION

Elbit's SkyVis helicopter helmet-mounted display has impressed in recent demonstration flights with Swiss emergency services operator Rega. Now the Israeli company is testing its compatibility with other enhanced vision systems and widening its application to further helicopter types.

In September, Elbit released details of a successful demonstration of its new SkyVis helmet-mounted display system for helicopter pilots, aboard a Rega AgustaWestland AW109. The air-ambulance provider flew the trials under demanding conditions and included landings on small pads with the pilot's natural vision deliberately obscured – a safety pilot flying as captain occupied the left-hand seat for safety assurance.

Elbit says, "SkyVis provides helicopter pilots with a conformal 'head out' view, displaying flight, vehicle and navigation symbology for day and night operation in poor weather conditions." It adds a monocle display to the standard pilot helmet and requires minimal modification to the aircraft's cockpit.

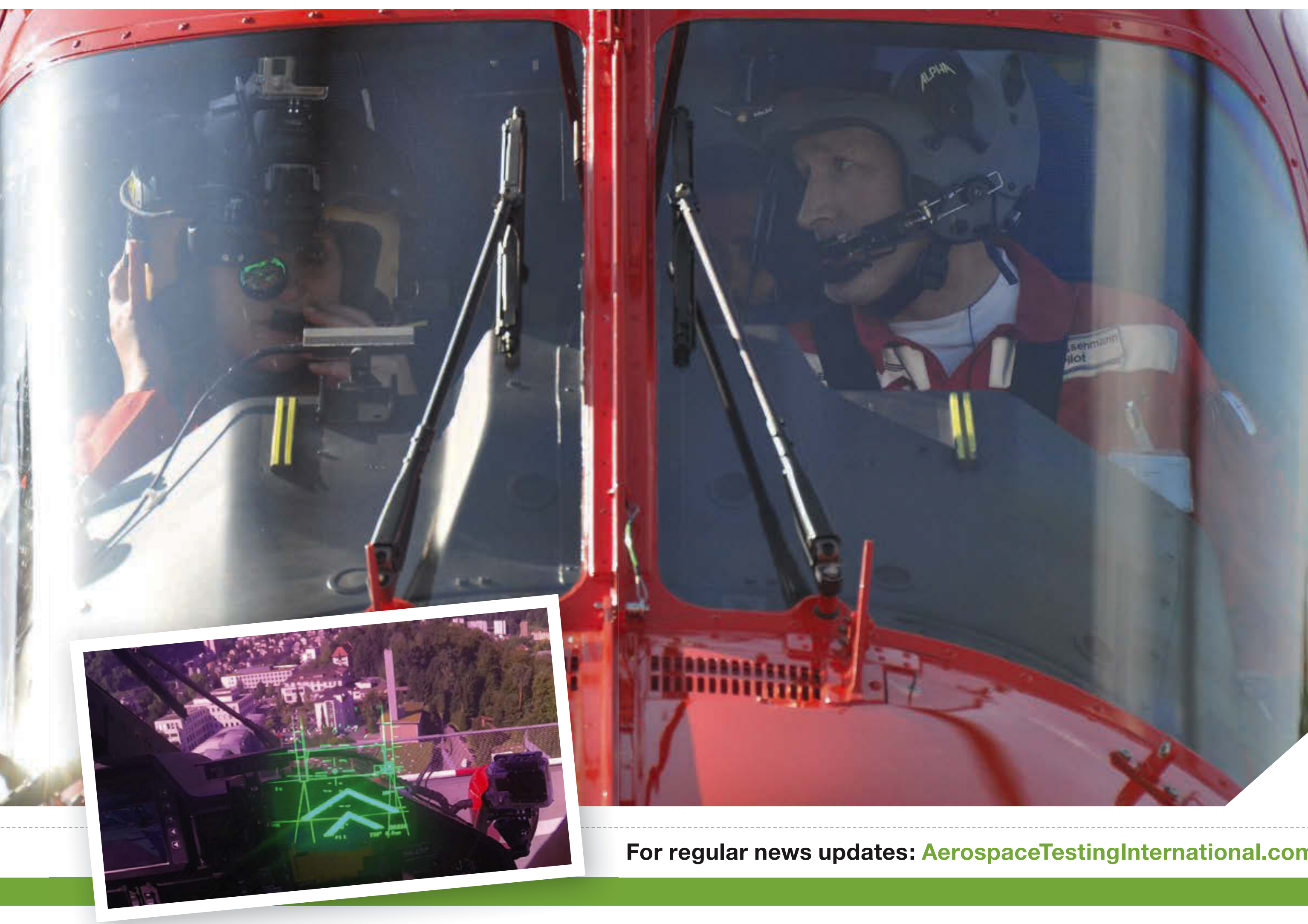
The display uses a regular NVG mount and weighs less than 400g. A head-tracking system ensures that information relevant to the pilot's direction of view is always supplied and the associated tracking component is "the size of a small pen". Installed in the instrument panel, the tracking unit interfaces with a processing unit that weighs around 5kg, and the entire system can be installed in less than a day.

Matching the data displayed in the monocle with the outside world, based on the head movements, avoids pilot disorientation. The display's horizon is always locked to the real horizon, with improvements in situational awareness, especially in darkness or impaired visibility from whiteout or brownout.

Monocle sighting systems are already in widespread use, and Elbit chose the configuration for SkyVis based on years of experience in developing head-up display (HUD) systems. It notes that the brain 'fuses' information from both eyes, so that the symbology presented over one eye is fused with the view from other eye, minimizing convergence problems. It is also low in cost and weight.

TEST CAMPAIGN

For its SkyVis test campaign, Elbit built a dedicated simulator, using it during the development phase before flight. Elbit's spokesperson explained, "It enables system integration with real avionics, an iterative process of symbology improvement and provides training for customers prior to first flight." The simulator was used alongside work in Elbit's SkyVis flight test helicopter prior to the Rega demonstration. Elbit has ensured that SkyVis is easily compatible



AEROSPACE TESTING INTERNATIONAL EXCLUSIVE

with flight simulators for future pilot training. The first live SkyVis flights were performed within Elbit Systems' internal test flight sessions, several weeks before the Rega demonstration, using a BO 105. The objectives were to test the system's usability and assess its technical stability, as well as gather pilot feedback.

Rega's crews underwent a carefully managed work-up process, as the spokesperson explains: "We designed a flight training syllabus that gradually built up to the AW109 flights. Rega pilots and engineers initially reviewed all the relevant information regarding the system and the flight plan in the classroom and on the aircraft, before the Rega flight sessions were conducted over the course of a week.

SYSTEM CAPABILITIES

"The SkyVis system requires only a brief period of crew training prior to flying and all the training was conducted during test flights. A Rega safety pilot, not wearing the system, monitored the trained pilot." Rega explored the system's capabilities in low visibility and for providing full situational awareness while flying with NVGs.

SkyVis relies on data from the helicopter's systems for flight and navigation data, and the SkyVis computer for terrain and obstacle data. It then presents the pilot with a precise view of the location of the chosen landing area and the helicopter's attitude. It creates symbology and artificial helipads that enable the pilot to land in a degraded visual environment, the system's aim being for the crew to reach minimum decision height with less workload and increased safety, while easing the transition between IFR and VFR. Elbit notes, "We also believe that together with FAA/EASA, we will be able to gain landing credit with the system, since it is designed for the highest level of safety," said the spokesperson. Compatibility with Elbit's HeliEVS also allows SkyVis to display video imagery.

Test and compatibility work is continuing. Over the next few months, Elbit expects to fly SkyVis on other helicopter types and points out that Skylens, its wearable HUD, tested on approximately six fixed-wing platforms, employs identical electronics and tracking systems to the SkyVis. It also plans to fly SkyVis alongside other tools from its range of situational awareness avionics. These include the ClearVision Synthetic Vision System and Combined Vision System, the latter combining data derived from an onboard database of airfields, obstacles and terrain with an ability to generate a detailed synthetic view outside, even if visibility is zero. ∎

GARNET RIDGWAY

PEER PRESSURE

Successful test flights are good advertising, but incidents in aerospace testing can propel organizations into the headlines worldwide for all the wrong reasons. Should such activities be locked away behind closed doors?

SOPHIE ROBINSON

Aerospace testing activities can be hugely complex and can feature large amounts of repetition. As such, they are likely to make poor entertainment for the casual viewer.

During any test program, the test team should be afforded a reasonable amount of independence from commercial or political pressures. This ensures that decisions, including those relating to test safety, can be based purely upon the cold, hard technical facts. The last thing test engineers need is

Garnet Ridgway has a PhD from the University of Liverpool. He has designed cockpit instruments for Airbus and currently works for a leading UK-based aircraft test and evaluation organization

a call from their program manager at an inopportune moment, or to be forced to change their plans to suit commercial activities. Such interference may be well intentioned or even subconscious, but can still have a negative impact on the safety of test activity. There may also be a reluctance to undertake the riskier or less palatable aspects of test activities, such as deliberate (and often valuable) testing to destruction due to the potential for bad publicity.

While encouraging public engagement in a product during the test phase can undoubtedly raise awareness, it also has the potential to invite unfair comparisons. For example, developmental items or vehicles are almost always not representative of the production version. Therefore, such items are unlikely to compare well to production versions of their competitors, or even their predecessors. Thus, an attempt to gain good publicity can in fact have completely the opposite effect; and any attempt to highlight the unfairness can be exploited. For example, the performance of the Lockheed Martin F-35 Joint Strike Fighter in an arguably unrepresentative combat simulation was jumped upon by its political opponents, with headlines reading “F35s clubbed like baby seals in combat”. Such sensational language sticks in the public memory much longer than any number of mundane but successful test flights.

In spite of the issues described above, it is possible to reap some of the benefits of public testing without surrendering control of the situation. Specific, targeted stakeholder engagement can play a key role in generating public and customer confidence. Indeed, limiting the amount of public access to a developmental product can enhance its appeal through the well-documented effects of artificial scarcity.

In summary, while shutting all aerospace testing activities away behind a closed door may not be appropriate, there should at least be a door (and a person who knows when to close it!).

After SpaceShipTwo’s recent tragic crash in the Mojave Desert, flight test activities have been thrust fully into the glare of the media spotlight.

SpaceShipTwo’s test program has been criticized for being overly ambitious, and Branson himself accused of showing “too much hucksterism and too much hubris” in pursuit of making his space tourism dream a reality. Faced with a virulent media backlash, many companies are re-examining the way they conduct flight test activities, particularly when they are in the public eye. It becomes increasingly tempting to shut all aerospace testing away from prying eyes, but there are still many benefits to publicizing our successes.

Testing in a manner that displays candor and openness may have its risks, but there are many positive sides to testing in this manner. It can foster a close relationship with customers and investors; they want to know that their cash is being spent wisely and it can help in de-risking future activities. Customers are also becoming increasingly knowledgeable and are less likely to be ‘turned off’ by unexpected results in testing too; they expect bumps in the road.

Publicizing the results of test activities can also have commercial benefits; building interest in new platforms and creating confidence among the intended users of your new product. Openness can also prevent negative rumors arising – these will cause financial and reputational damage if left to spread. While the idea that ‘there is no such thing as bad publicity’ may be a thing of the past in the current media climate, good publicity is still valuable.

Embracing publicity as part of your testing program can also open up opportunities for engagement with the wider community. Take, for example,

Sophie Robinson is currently finishing her PhD as part of the Flight Science and Technology Research Group within the Centre for Engineering Dynamics at Liverpool University. In the course of her research, Sophie regularly works with test pilots

the Bloodhound SSC project; billed as a ‘global engineering adventure’, this quest to build a car capable of achieving 1,000mph has actively embraced publicity in over 220 different countries in order to inspire and motivate the next generation of scientists, mathematicians and engineers.

The European Space Agency took a similar route by live-streaming the landing of Philae on a comet 317 million miles from Earth, and NASA regularly broadcasts spacewalks and launches live online; all are certainly high-risk activities, but with large reward. Sharing what we do can have a real impact on shaping the future of our industry by informing, educating and inspiring the next generation of engineers and testers, and we should endeavor to keep doing it wherever possible.


TV3

Sting on a budget

Textron AirLand Systems built the privately funded Scorpion jet on speculation to reverse the trend in expensive ISR/strike aircraft, and is planning a test program to satisfy customers

BY FRANK COLUCCI

"THE WHOLE DEVELOPMENT WAS DONE IN A FAIRLY SECRET WAY IN A SEPARATE FACILITY – THE GLASS HOUSE ON THE CESSNA CAMPUS"

LEFT: Ground testing prior to first flight included ejection of the Martin Baker Mk16 ejection seats from a Scorpion nose section (Photo: Textron AirLand LLC)

Leveraging proven materials and systems enabled Textron AirLand LLC – a joint venture of diversified industrial Textron Inc. and specialized defense proponent AirLand Enterprises – to begin flight tests of its Scorpion intelligence, surveillance, reconnaissance (ISR) and strike aircraft less than two years after the program started. The privately funded Scorpion first flew in December 2013. By early October 2014, the tandem-seat jet had logged just over 200 flight hours and had crossed the Atlantic in search of a launch customer.

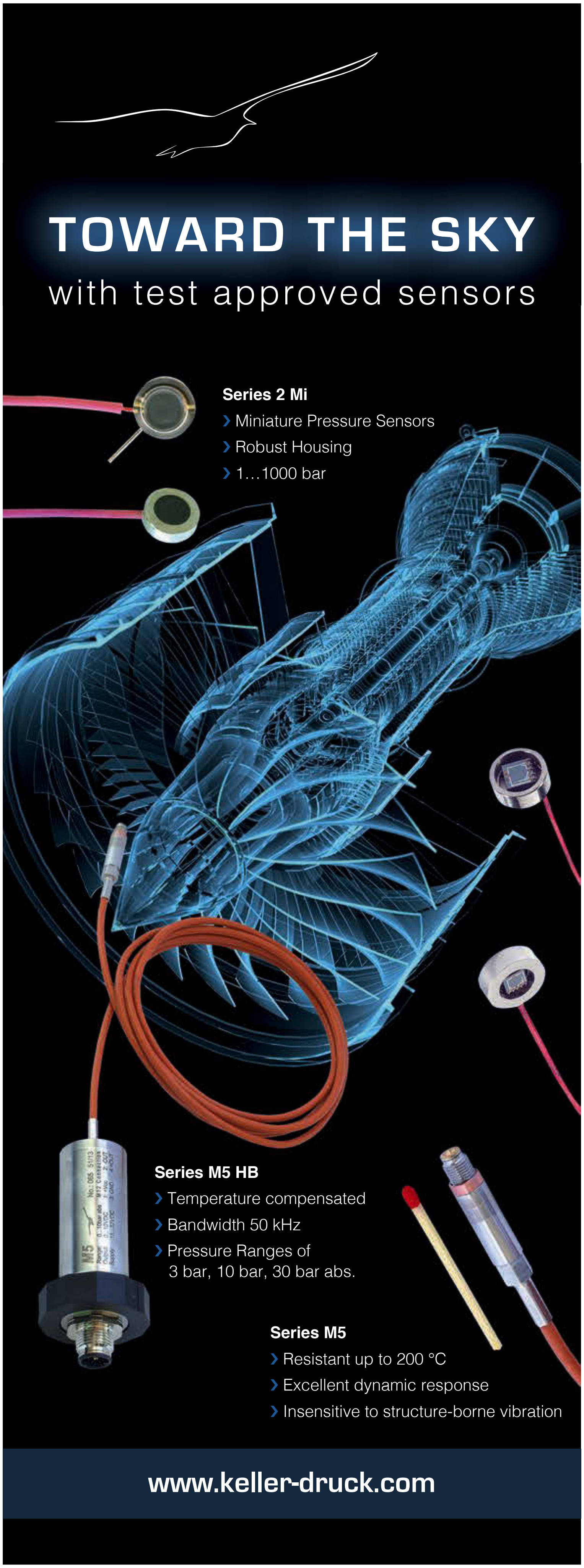
"I think we're looking to fly about 300 hours this year," says Textron AirLand's chief engineer, Dale Tutt. "Once we go into a certification program we would expect to need about 1,200 flight hours. A lot of that would be driven by specific customer requirements." Company president Bill Anderson adds, "We're going to work with the launch customer on the type of certification they desire."

The first Scorpion was built on speculation as a test aircraft and marketing demonstrator. The test program follows US MIL-Handbook 516 and FAA Part 23 airworthiness guidelines.

"Currently we're operating under an experimental R&D ticket with the FAA," says Tutt. "We're not yet a sponsored program through the US Air Force. That allows us to do a full evaluation of the aircraft performance, its handling characteristics, and how its systems operate." In October the FAA also granted Textron AirLand a marketing and promotional license for the Scorpion. "We flew a Royal Air Force test pilot," noted Anderson. "He was very complimentary."

Textron AirLand sees the straight-winged Scorpion, which has a top speed of 450kts and time-on-station up to five hours, filling roles in close support, counterinsurgency, maritime and airspace control, border security, counter-narcotics and tactical training. The demonstrator was displayed with ordnance at the Farnborough Air Show in July, and test plans call for a first weapon release late this year or early next. In dramatic contrast to modern combat aircraft, the 21,250 lb (9,639kg) Scorpion is meant to give air forces around the world a versatile ISR/strike platform for less than US$20m. Promised operating costs are less than US$3,000 per flight hour. "The calculation is fuel, parts and labor," summarizes Anderson.

Though not itself part of the joint venture, Textron Aviation, owner of the Cessna, Beechcraft and Hawker brands, did most Scorpion engineering and fabrication and provides metrics to validate operating costs. "Cessna has a very robust documentation system," observes Anderson. "It's been tried and proved year after year and we're using that process to document our cost-per-hour. On this particular airplane, even though it's our prototype, the cost-per-hour is extremely low. We're requiring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MUDFIGHTER IN COMPOSITES

The Textron AirLand Scorpion is not the first attempt to use composite structures and off-the-shelf systems to reverse the trend toward more expensive combat aircraft. The Agile Responsive Effective Support (ARES) demonstrator funded and built by Burt Rutan's Scaled Composites entered design in 1986 and first flew in February 1990. The 6,500 lb (2,948kg) ARES was a single-seat close support platform built around a commercial Pratt & Whitney JT15D-5 turbofan and a weapons bay big enough for a 25mm General Electric GAU-12/U rotary cannon with 220 rounds of ammunition.

The swept-wing canard design aimed at carefree low-speed/low altitude handling without a stability augmentation system. At low jinking speeds, the forward-swept canards provided a hard stall to drop the nose and keep the aft-swept main wing from stalling, to prevent departure from controlled flight. The ARES engine inlet was on the left-hand side of the fuselage and the gun muzzle on the right, to protect the engine from gun gas ingestion. To compensate for cannon recoil, the fuselage was offset on the wing 3in to the left. Fuel in the wing promised one hour endurance and 300 nautical miles from base.

The ARES demonstrator logged about 250 flight hours, but failed to find a customer.

very low maintenance and our availability has been better than 99%."

FROM A GLASS HOUSE

Speedy Scorpion development made use of familiar technology. The aircraft was designed, built and ground tested for Textron AirLand in Textron Aviation's rapid prototyping shop in Wichita, Kansas. According to Tutt, "The whole development was done in a fairly secret way in a separate facility – the Glass House on the Cessna Campus. That's where we do things that we want to keep out of the public eye.

"We produced over half of the composite parts in the Cessna facilities here. Most of the material system that we chose was because we had some understanding of it. We also did all the building-block tests – coupon testing, component testing – in preparation for the flight test program."

The Scorpion uses composite materials for load-bearing primary structures, and Cessna engineers proof-loaded the aircraft prior to first flight. "We really tried to use mature, non-developmental technology. In order for us to move in 23 months, we had to do that."

The Model E530 Scorpion prototype also borrows systems from existing aircraft. Flight controls are derived from those in the Model 750 Citation X business jet. The electrical, hydraulic, environmental control and ice protection systems come from the Model 525C Citation CJ 4. The wheels and brakes are from the Model 680 Sovereign. "Almost all the aircraft systems have a lineage on other aircraft," says Tutt.

The Scorpion avionics suite from Genesys Aerosystems is integrated around cockpit displays, air data and navigation sensors, engine/airframe data concentrators, and an autopilot flying on A109, S-61T and Mi-17 helicopters, Tucano and G120TP trainers and other platforms. According to Genesys Aerosystems' vice president, Gordon Pratt, "In various configurations these systems have been certified on over 740 aircraft types. All the products are FAA TSO'd [technical standard order] and meet most applicable MIL–STD requirements. OASIS [Open-Architecture System Integration Symbology] allows Genesys, the end user or even a third party to rapidly and cost-effectively interface with virtually any type of aircraft system or mission equipment while maintaining the integrity of Level-A software."

TOP: The Textron AirLand Scorpion ISR/strike made its first flight on December 13, 2013, beginning an engineering flight test and sales demonstration program in search of a launch customer – whose requirements will shape certification testing

LEFT: The Scorpion test article/ demonstrator was built in the Textron Aviation Cessna Glass House, a rapid prototyping shop near Wichita, Kansas

(Photos: Textron AirLand LLC)

EJECTION SEAT

Even the Scorpion's Martin Baker Mk16 ejection seats qualified for the US Air Force T-38C were ground-fired from a Scorpion cockpit. Tutt explains, "Even though we're using mature technologies, we wanted to mitigate the risk wherever possible before we tested in the air. There was a substantial amount of ground testing prior to first flight."

Textron AirLand worked with Cessna to conduct Scorpion flight testing under a service agreement between the two Textron business units. The Textron Aviation Test organization has just over 400 people responsible for planning, building, ground-testing, flying and maintaining the company's test aircraft and

23	Number of months it took from concept to first flight
450	Top speed on test flight in knots
518	Maximum speed in mph
21,250	Target aircraft weight in pounds
3,000	operating costs per hour in US dollars
45,000	Ceiling in feet

analyzing test data. According to Tutt, the engineering flight-test portion of the organization includes 38 aircrew and 59 flight-test engineers and support personnel. Some of the pilots have military experience and many of those have formal military test pilot training. In addition, Textron Aviation develops civilian test pilots with a mix of in-house and contracted training.

The current mix of Textron Aviation test pilots is approximately 42% military and 58% civilian-trained. "All our pilots are Cessna – and now Textron Aviation – experimental flight test pilots," says Tutt. "As we expand the team we'll look at other people as well."

FLY AND RECORD

Most Scorpion test flights have been launched from McConnell Air Force Base and stretched across Kansas and surrounding states within telemetry range of Wichita. Additional test hours were logged during the demonstrator's transatlantic flight to the Farnborough Air Show in July 2014, and in the course of the Vigilant Guard disaster response exercise in August 2014. This exercise with the Kansas National Guard saw the Scorpion integrated with an L-3 WESCAM MX-15 multisensor gimbal in the 83ft^3 (2.35m^3) mid-fuselage bay to downlink color and infrared video to first responders answering simulated emergencies. A helmet-mounted cueing system enabled the Scorpion back-seater to keep eyes-on-target while managing the sensor turret.

The Scorpion is designed to interface through MIL-STD-1553, ARINC 429, Ethernet and video databuses with payloads up to 3,000 lb (1,361kg) housed in its nose and fuselage bays. Flight testers fill the fuselage bay with instrumentation, as Tutt explains: "Mission sensors go on a pallet covered by the aircraft skin. We have done exactly the same thing with the flight test instrumentation."

Sensors and recorders are typically bought from outside sources and installed and integrated on test aircraft by Textron Aviation. On the Scorpion, 1,200 lb of instrumentation taps 3,200 sensors to record and telemeter flight test data. "We're measuring everything," notes Tutt. "We have strain gauges to measure flight loads on the airplane, pressure transducers to measure bleed air on the hydraulics, and position sensors on the control surfaces."

The Honeywell TFE731-40AR engines on the Scorpion demonstrator make their own contribution. "The engines have digital electronic engine controls on them. We take the data off the built-in engine sensors through the built-in databus. We also installed some of our sensors on the engines to measure temperatures, vibrations and bleed-air pressures. It's not so much what's on the engine as what's coming out. It's an off-the-shelf engine, so it's pretty well understood," says Tutt. Scorpion test data flows with attitude and heading reference system data and other flight parameters through the ARINC 429 avionics bus.

"THE ENGINES HAVE DIGITAL ELECTRONIC ENGINE CONTROLS ON THEM. WE TAKE THE DATA OFF THE BUILT-IN ENGINE SENSORS THROUGH THE BUILT-IN DATABUS"

TOP: **Textron AirLand offers potential Scorpion customers a versatile platform for maritime, counterinsurgency or border control, or tactical training tasks for less than US$20m per aircraft, with operating costs about US$3,000 per flight hour (Photo: Textron AirLand LLC)**

ABOVE: **The Scorpion payload bay has been filled with 1,200 lb of test instrumentation**

The Scorpion records flight test data on board and telemeters data to the ground. The Textron Aviation Test Organization operates telemetry facilities in Wichita that can monitor three flight activities simultaneously and receive data from aircraft 200 miles away. "We get all the aircraft parameters through telemetry," says Tutt, "but we look at only a selected set of data depending on what we need from that flight." The customized ground systems are based on commercially available equipment and have been updated by Textron Aviation personnel to automate processing of flight data and receive video.

The first Scorpion has achieved 455kts airspeed. "We're very pleased with the progress of the flight test program. As we evaluate the airplane, its performance has been meeting or exceeding expectations," notes Tutt. "The aircraft we're flying today is the only one we have flying now. We're using it to do evaluation, development of systems and static displays. Once we enter into a full flight-test program, we're looking at two additional aircraft, fully conforming to a production standard for certification testing." ■

Frank Colucci specializes in writing about rotorcraft design, civil and military operations, test programs and material and avionics integration

ANNOUNCEMENT

1st CAE-DNW Workshop on CFD-Wind Tunnel Correlation Study

The dual purpose model CAE-AVM is tested in DNW-HST both for aerodynamic performance and CAE Aviation CFD codes validation. Before and after the wind tunnel tests, CAE performed detailed CFD investigations. It is found that to effectively compare CFD and wind tunnel data, typical test related phenomena (e.g. sting interference, model deformation) would have to be taken into account. The geometry represented an airplane with slender swept wings and fuselage mounted engines.

The goal of this workshop will be to discuss the interference of the model deformation and sting in the CFD-wind tunnel correlation. This will give participants a unique chance to use their own CFD codes to calculate the CAE-AVM model geometry with and without wing deformation and related wind tunnel sting geometry, evaluate the adequacy of their methods, meanwhile to provide their observations of CFD-wind tunnel comparison. During the workshop parties can present their results, and jointly compare with the wind tunnel test data.

The workshop is to be held in 2015. Detailed information of the organization will be made available at the beginning of 2015 in the CAE and DNW websites.

German-Dutch Wind Tunnels

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Hawkeye IFR: the story

It has taken nearly a decade to get as far as initial design capability for the IFR system for the E-2D Advanced Hawkeye. When the complex system is finally installed, it will double the time an aircraft can spend in the air

BY THOMAS NEWDICK

Northrop Grumman is working on the development of an inflight refueling (IFR) capability for its E-2D Advanced Hawkeye, the US Navy's carrier-based airborne early warning and control (AEW&C) aircraft. For previous generations of the Hawkeye, the need to refuel during missions was not considered necessary.

The US Navy declared initial operational capability for the E-2D Advanced Hawkeye aircraft on October 27, 2014. The first five aircraft are expected to deploy in 2015.

On September 3, 2014, Northrop Grumman announced that it had successfully completed the preliminary design review for the E-2D aerial refueling system in partnership with the US Navy. Completion of the preliminary design review means the manufacturer can embark on the next stage in the program – the critical design review. This will pave the way toward eventual manufacture of the IFR system and its installation on the US Navy's E-2D fleet.

As well as being included on new-build Advanced Hawkeyes that roll off the Northrop Grumman production line at St Augustine, Florida, the kit can also be retrofitted to E-2Ds previously delivered to the US Navy, providing fleet-wide commonality.

The US Navy program of record is for 75 E-2Ds that will progressively replace a fleet of 62 E-2Cs currently operated. Under US Navy plans, all 75 E-2Ds will receive an IFR capability and the system should attain initial operational capability in 2020.

A further 28 E-2Cs are operated by Egypt, France, Japan and Taiwan, of which only the French Navy examples are carrier-based. There exists the potential to retrofit the E-2D's IFR capability on these 'legacy' aircraft should a customer require it. In November 2014, Japan announced selection of the E-2D to meet its requirement for a new-generation AEW&C aircraft.

In the early 1980s, the US Navy installed a refueling boom on a Grumman C-2A Greyhound carrier onboard delivery (COD) aircraft, a derivative of the Hawkeye. The modified Greyhound deployed to the Indian Ocean on board the carrier

USS America, but it appears the aircraft was never actually used on that deployment.

The first refueling tests involving the US Navy E-2 were executed with limited onboard instrumentation and without actually using a probe. Instead, test goals were achieved by simulating the refueling pre-contact position behind the basket trailed by the tanker.

PROBE TESTS

Next, testing of an aerial refueling system was undertaken using an E-2C fitted with a dummy probe in 2005 and 2006.

This round of flight test saw the integrated test team at the US Navy's Air Test and Evaluation Squadron (VX-20) run a check on potential points of risk for an IFR-capable Hawkeye. The team sought to identify the aircraft's handling qualities, pilot field-of-view for tanking maneuvering, structural impacts and crew system impacts. Test results would then be examined to determine whether launch of a full-scale testing program was beneficial.

Described by Northrop Grumman as 'limited-scope test flights', unlike the previous tests, this program saw crews use an E-2 equipped with testing instrumentation. Furthermore, the team attached photo-calibration markings to the E-2's airframe to help photographically measure aircraft position, while recording temperatures and pressures and other test indicators of interest to the team.

The first demonstrations of the US Navy Hawkeye's potential to refuel in flight were conducted in December 2005 and early January 2006. Simulated refueling was achieved by the E-2/C-2 Airborne Tactical Data System Program Office (PMA-231) over the Patuxent River using the appropriately 'probed' E-2C and US Navy Lockheed Martin KC-130 Hercules and Boeing F/A-18E Super Hornet tankers.

"In situations where there is a need to be there, it is always better to be able to stay there," remarked E-2 pilot Lt Cdr Hugh Winkel at the time. During the tests, the Hawkeye plugged into the basket as it would during the normal process of transferring fuel. Among the specific parameters under test were

ABOVE: An E-2C of the test and evaluation squadron VX-20, tests the aircraft's potential for inflight refueling with an F/A-18E of VX-23 over the skies of Naval Air Station Patuxent River, Maryland (Photo: US Navy)

> **"OUR TASK WILL BE TO HELP DEVELOP THE TRAINING CURRICULUM FOR THE FLEET READINESS SQUADRON ONCE TESTING HAS CONCLUDED"**

ABOVE: VX-20's IFR testbed, E-2C BuNo 165294, complete with calibration markings for flight testing (Photo: Arie Church)

RIGHT: An F/A-18 Hornet provides inflight refueling to a modified E-2C Hawkeye during the second round of IFR testing at NAS Patuxent River in summer 2009 (Photo: US Navy)

noise on the flight deck, and movement of the basket. After 16 successful connections with a KC-130 in December 2005, a first connection with a Super Hornet from VX-23 was made during a flight that lasted a little over an hour on January 5, 2006.

Dry hook-ups were made with the F/A-18E equipped with a 'buddy' refueling pod on the standard center-line position. Use of the Super Hornet as tanker in the tests will be of benefit for future E-2D IFR operations, since the type is responsible for providing all US Navy carrier-based tanking.

THE NEXT ROUND

A subsequent round of flight testing took place with VX-20 at Naval Air Station Patuxent River, Maryland, in 2009. This testing served two purposes: first, to identify and develop the techniques required for Hawkeye IFR; and second, to bring to light any problems related to the aircraft's rotodome – the fuselage-mounted housing for the primary radar antenna(s). Further test points included evaluation of performance during unusual or difficult operations. As a result, tests also took place in less-than-ideal weather conditions.

"The Hawkeye was not initially designed for inflight refueling," explains Diane Wathen, Hawkeye Greyhound program office (PMA-231), IFR lead. "However, there is a proven need for it and it is up to us to figure out what works and what doesn't, so we can incorporate these capabilities into fleet aircraft."

"A major concern being addressed during this period of testing is crew fatigue," adds Chris Gay, Hawkeye integrated test team lead flight-test engineer. "We are assessing compatible envelopes between the E-2C and the available tankers, as well as how to reduce fatigue during extended flights."

According to Naval Air Systems Command (NAVAIR), the overall testing was conducted according to a 'build-up' process. At first, the focus was on identifying low-risk obstacles, before identifying high-risk areas. During test flights, the aircrew evaluated different airspeeds and altitudes to determine the best method for the Hawkeye to plug its refueling probe into the tanker's trailing drogue.

The test work undertaken by VX-20 did not just serve to prove the potential of the E-2's IFR capability, and to address any possible risks. Once all testing requirements were completed, VX-20's IFR project officer, Lt. Wes Turbeville, then began to train Hawkeye instructors at the Fleet Readiness Squadron, Carrier Airborne Early Warning Squadron 120 (VAW-120) at Naval Air Station Norfolk, Virginia. This is the unit responsible for training all naval aviators, naval flight officers and naval aircrew to safely and effectively operate E-2 and C-2 aircraft. As a result, current and future-generation Hawkeye crew now learn IFR procedures before they are posted to frontline squadrons.

"Our task will be to help develop the training curriculum for the Fleet Readiness Squadron once testing has concluded," said VX-20 test pilot, Lt Cdr Mike Newton, at the time. "What we learn during this assessment will have a direct impact on how the fleet will maneuver a refueling Hawkeye."

Neither of the two initial flight-test phases involved the transfer of fuel from tanker to receiver. Instead, the trials aircraft had a non-functional IFR probe attached above the E-2C's cockpit.

On the basis of this testing, a number of modifications were made to the airframe and to the flight control system in order to address changes to the handling qualities. Among the changes made to the aircraft are new seats to improve the pilot's field-of-view and reduce crew fatigue; formation lights in order to ensure tanker and receiver can visualize one another and ensure safe airspace orientation at night; and enhanced software in the Standard Automatic Flight Control System to give the pilots the handling

RIGHT: The 'flight test only' status of the non-functional cockpit-mounted refueling probe is evident on this VX-20 E-2C seen on September 4, 2011, at the NAS Patuxent River Open House (Photo: Arie Church)

qualities needed for refueling. The problem of crew fatigue becomes more important as the mission's maximum endurance is extended.

Normally, crew members are confined to their stations, and the only option for stretching is in a crouching position. This has now been addressed through the addition of improved seats and cushions.

In September 2013, US Naval Air Systems Command awarded Northrop Grumman an engineering, manufacturing and development contract worth US$226.7m, under which the company designed the various new systems required by the E-2D to add an IFR capability.

360°	The total radar coverage in all weather for the E-2D
9 hours	New mission duration with IFR, up from 4.5
170	The number of suppliers providing products to the E-2D program
1923	The year of the first air-to-air refuel between two Airco biplanes
27	The number of days spent in the air for the longest-ever aerial refuel

THE ROAD AHEAD

Cmdr. Keith 'Brownie' Hash, a deputy program manager with PMA-231, explains what will happen as the program moves from the preliminary design review (PDR) to the critical design review (CDR) phase: "The preliminary design review is the first time that we get an in-depth look at the detailed drawings made by Northrop Grumman. It gives us a chance to offer direction and feedback." Hash states that the PDR is very important because "we have to make sure the initial design meets our requirements".

"Current planning has the CDR finishing at the end of this year, with the first modified E-2D completing testing in 2017," says Hash. "The CDR event, once completed, freezes the design. Right now the company [Northrop Grumman] is working diligently on our comments and suggestions to come up with the final design. The CDR is a culminating event where we go through a formal review with the vendor to make sure the design meets our requirements," Hash explains.

Currently, VX-20 has no E-2Ds with an aerial refueling probe, but in 2017, they will receive the first aircraft modified after the CDR. Testing will then begin to ensure the new design works properly. Speaking after successful completion of the preliminary design review this autumn, Capt. John Lemmon, program manager, E-2/C-2 Airborne Tactical Data System Program Office (PMA-231) said, "I'm very pleased with the progress the team has made. Adding an aerial refueling capability to the E-2D Advanced Hawkeye will extend its critical mission of providing continuous information to the warfighter that depends on it."

BELOW: The US Navy's latest E-2D Hawkeye over Naval Station Norfolk, Virginia, in March 2014. The aircraft is signed to the first frontline operator, Carrier Airborne Early Warning Squadron 125 (VAW-125), scheduled to deploy in 2015 aboard the carrier USS Theodore Roosevelt (Photo: US Navy)

Extending the mission duration of the Hawkeye is seen as critical for its increasingly busy mission brief, which now includes overland surveillance, as well as operations over the expanses of the Asia-Pacific region, where the US military plans to concentrate resources as part of the so-called 'pivot' away from the Middle East. The IFR capability should increase mission duration to between eight and nine hours, compared with around 4.5 hours for an E-2D on its own fuel.

"The greater endurance provided by IFR provides the warfighter with enhanced surveillance and targeting capability and the persistence needed to accomplish this more effectively," says Bart LaGrone, vice president, E-2/C-2 programs, Northrop Grumman Aerospace Systems. "This translates into an advanced airborne early warning system that yields greater surveillance for a longer period of time at a greater distance than presently available.

"The level of information provided to the warfighter will increase exponentially with the extended range and endurance of the E-2D Advanced Hawkeye fleet with aerial refueling," LaGrone adds. ▮

Thomas Newdick is an aviation and defense writer based in Berlin. *Acknowledgements: With thanks to Rick Burgess/Seapower & James Deboer*

Wing and a prayer

Composite wings offer savings in weight, assembly effort and maintenance, but their novelty means they are subjected to a far more rigorous test regime than conventional metal airfoils

BY BERNARD FITZSIMONS

Like the Boeing 787 and Airbus A350, Bombardier's in-development CSeries airliner has a composite wing. Made at the manufacturer's new factory in Belfast using the company-developed resin transfer infusion process, it helps reduce weight and so contributes to a fuel burn 20% lower than those of competing aircraft.

Automated manufacture and corrosion-free materials mean the wing should also be less labor-intensive, both to build and to maintain than a metal wing. But the testing required for airworthiness certification is far more onerous, says Colin Elliott, vice president of engineering at Bombardier Belfast.

Over the last 20 years, he says, the certification authorities have developed a five-level building-block approach to certification of composite airframe structures. It starts with testing coupons – small samples of the materials used – to characterize their basic mechanical and physical properties.

Level 3 testing looks at elements. "You're testing things like mechanical joints between different components within the structure," Elliott says. Level 4 examines subcomponents: "These would be bench tests using fairly large specimens up to 3m or 4m in length representing, for example, spars in the wing. And eventually you get up to Level 5 testing of the complete structure, which includes the complete wing."

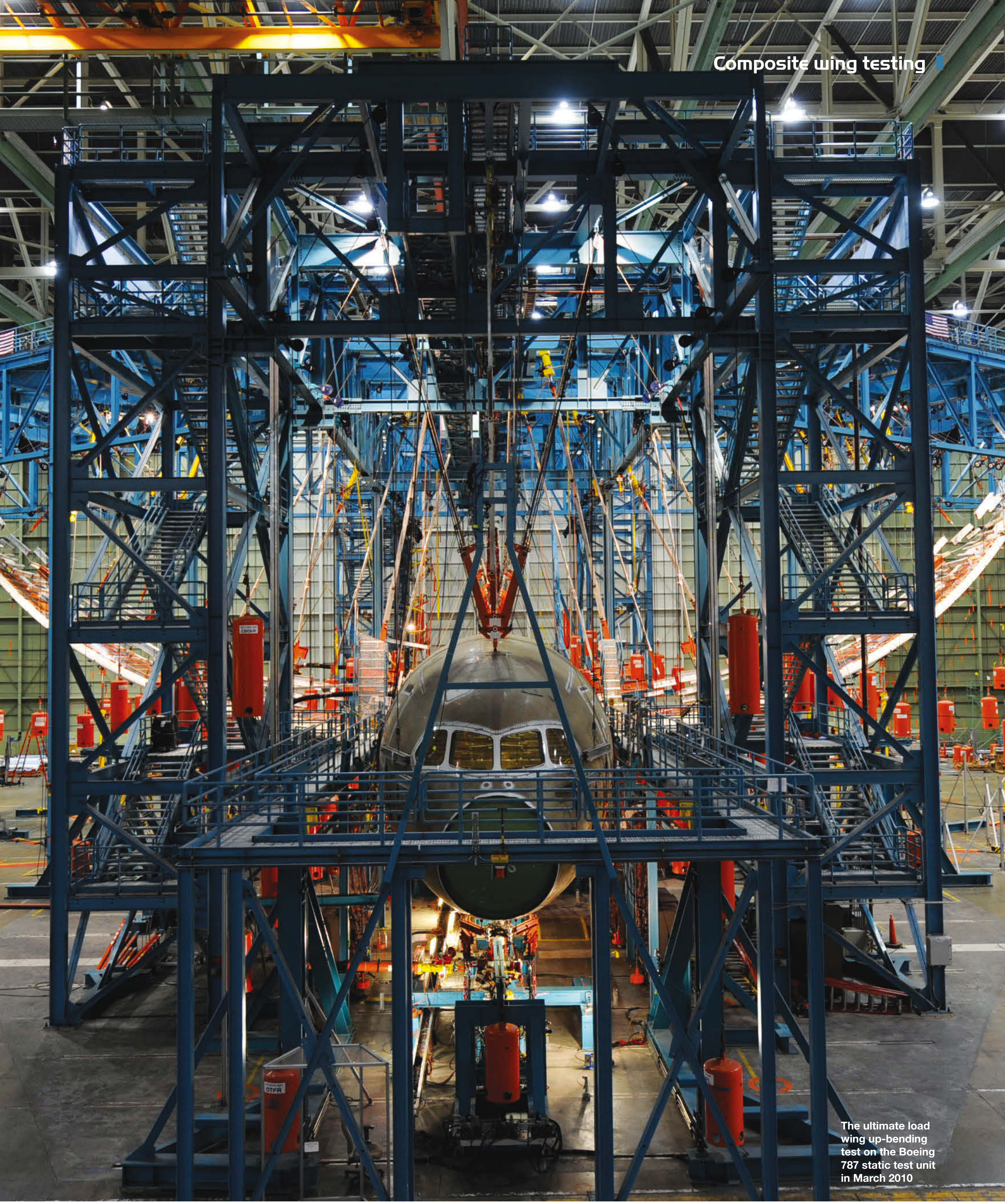
This all adds up to "a very laborious, very expensive, very time-consuming way of doing things", Elliott comments. "The industry has been doing metallics for very much longer. There's a much greater database available, so unless there's something very peculiar or very unique in the design, we would design the metallic structure purely by analysis and finite element modeling, and then go straight to static and durability testing."

The first four levels represent an additional burden for composite structures, although Elliott expects that to diminish: "As time goes on and the manufacturers and certification authorities become more comfortable and more confident with the materials and with our methodologies for finite element modeling and analysis, we should be able to start reducing the amount of testing at those sub-levels."

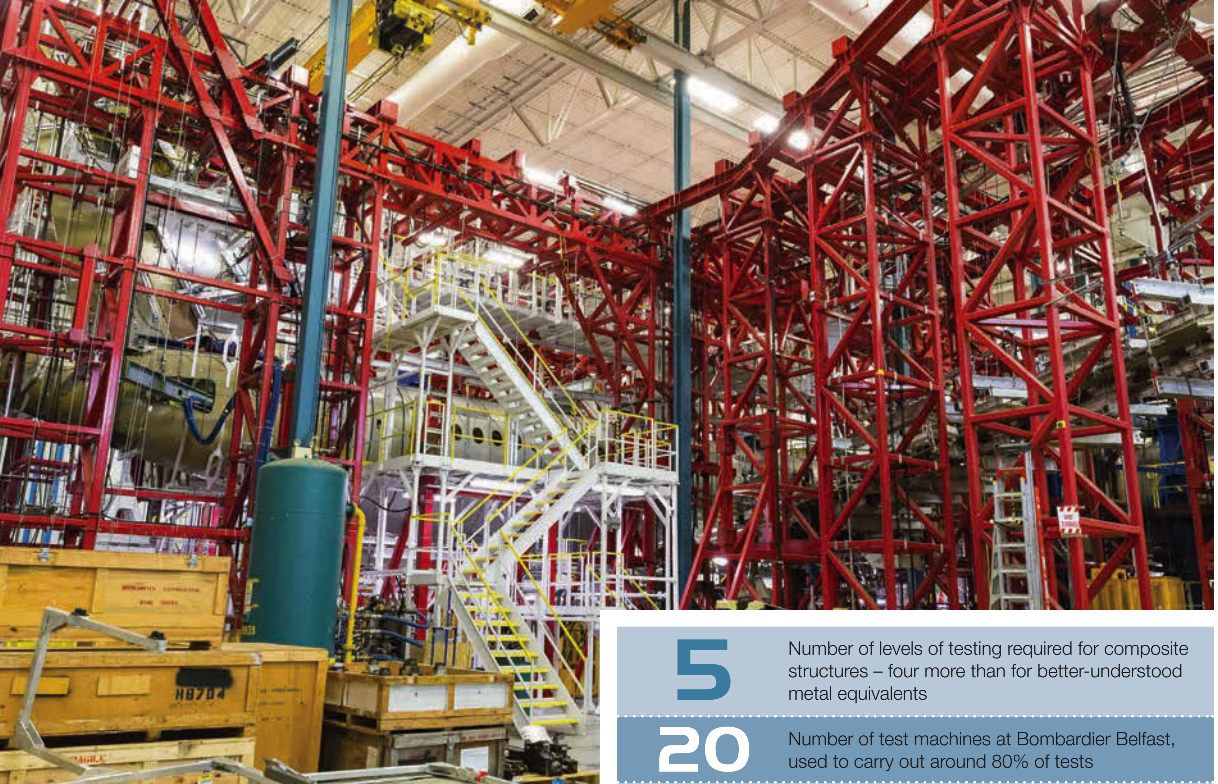
For now, though, the additional testing is a significant burden in terms of cost and time: "You have to start that testing from day one of the development program, build up your database, and keep the certification authorities involved and informed of the test program and the correlation between your predicted results and the actual results," Elliott says. "It's vital to keep communication going throughout the development cycle so the authorities know what we're doing."

CERTIFICATION AUTHORITIES

The authorities, he says, will want to view all the test plans, and the entire strategy for demonstrating compliance with the regulations. "As you put more detail around that and determine exactly what you're going to test – and we're talking about thousands of test specimens here – they will review those test plans and decide what is their level of involvement." That may involve viewing the test plans and



The ultimate load wing up-bending test on the Boeing 787 static test unit in March 2010



5	Number of levels of testing required for composite structures – four more than for better-understood metal equivalents
20	Number of test machines at Bombardier Belfast, used to carry out around 80% of tests
6,000+	Number of individual test pieces manufactured and assembled for various types of testing
180,000	Number of flight cycles replicated in fatigue test program – three times the 60,000 cycle design life

ABOVE: The CSeries complete aircraft static test article (CAST) under test at Bombardier's Montreal Mirabel facility

drawings, watching the specimen being manufactured or assembled, and/or being present for the actual testing. The US FAA, Europe's EASA and Transport Canada are all involved in the CSeries certification process. "They all have different interests," says Elliott. "Sometimes they demand to witness the same tests, other times they have particular areas of interest that they want to come and see."

There are other tests, such as the ability to withstand bird strikes and impacts from runway or tire-burst debris. Fuel tank ignition prevention is another major concern, and one with added complications for non-conductive composite structures: "In a metallic structure, a lightning strike attaches to wherever it happens to hit, flows through the structure and departs the aircraft, usually from the trailing edge or the wingtip. So the intent is to make sure that there's nothing in there that's going to cause the current to jump across from one component to another component and cause a spark that could ignite the fuel."

All aircraft have to be certified with inert gas systems to ensure that the level of fuel vapor in the free space within the wing is low enough not to ignite, even if there is a spark. Bombardier also uses isolators to create an electrical barrier between system components, such as electrical harnesses and fuel or hydraulic pipes, and the wing structure, to prevent sparking or arcing. "That's all the result of new regulations that have come into force within the last three or four years," says Elliott. "Again, that entails an awful lot of testing." Samples from small flat panels, right up through subsystems representative of the structure and installed systems, are sent to specialist test facilities such as Cobham Technical Services to have lightning strikes induced onto them. And there is further testing to demonstrate the structure's ability to withstand a post-crash fire.

The five levels of testing involve the manufacture and assembly of more than 6,000 individual test pieces. Bombardier has around 20 test machines at its Belfast plant to test them both statically and in fatigue, Elliott says, "You're putting them through literally hundreds of thousands of fatigue cycles to make sure that they retain their mechanical properties over the life of the project."

The test specimens incorporate imperfections of the kind that may arise during manufacture and the sort of damage that might go undetected in service to ensure that worst-case scenarios are covered. And even with so many machines of its own, Bombardier still needs to subcontract about 20% of the testing to specialist test houses, laboratories and universities.

FULL-SCALE TESTING

For full-scale testing, Bombardier Belfast has a team of people in its ground test and experimental department who design and manufacture the test rigs and set up the hydraulic and controlled loading systems. "We have three separate full-scale test articles to make sure that we understand the behavior of the airframe, including the wing, and that we can meet all the regulatory requirements," Elliott says.

In Montreal, there is the complete aircraft static test article (CAST), an entire airframe that is put through hundreds of load cases to mimic all the conditions that the aircraft is going to encounter in service, such as high-speed maneuver, up-gust and down-gust wing bending, landing, ground maneuver and take-off.

For each condition there is a limit load representing the maximum load that the aircraft will see once in its life: "For up-gust cases, for example, we take the extreme, the absolutely worst case for an up-gust of wind which is going to bend the wings upward and load not just the wings but the fuselage attachments as well," Elliott says. "Then to meet the certification requirements, we apply a 50% factor on top of that, so we test at 1.5 times that limit load for every one of those static cases."

Then there is a full-scale test article for each of the major structural components. "We have a full-scale wing test article here in Belfast," says Elliott. "On that article, we're applying fatigue and damage-tolerance cycles. If the aircraft is designed to meet, for example, 60,000 cycles during its life, then we would test it to 60,000 times three, and again we go through all the different regimes from take-off, climb, cruise, with all the incidents or up-gust, down-gust, maneuver, whatever else may happen during the cruise, then coming in to land and landing. We take a complete spectrum of all the loads from that complete flight from take-off to landing and we come up with a fatigue spectrum."

The fatigue spectrum is a statistics-based model. "Obviously you don't want to assume that the aircraft will see all of those worst-case events on every single flight," Elliott explains. "So we go through a statistical process to come up with a model that says the life of that aircraft over those 60,000 cycles

BELOW: The Airbus A350 static test airframe passed its ultimate load test, withstanding loads up to 1.5 times the maximum it might encounter in service, in December 2013

is going to see so many of these cycle types or load patterns induced." They are then compiled into a computer program, and over time the test installation replicates the 180,000 flight cycles with all the bending and twisting, and all the different types of loads.

"It's a very dynamic case," says Elliott. "You can literally stand back and watch the wing being bent upward and downward and twisted and put through its paces, replicating all those different elements of the typical and non-typical flights, and other flights with these extraordinary events in them from time to time."

There is a complication, however. "The wing or any other composite structure is not entirely composite," Elliott points out. "You will have metallic components in there. The environmental knock-down factor means the metallic components within that structure are actually seeing loads that they were never designed for. We don't design for environmental degradation in the metal components because they don't degrade over time. We're actually penalizing the metallic elements of the structure by putting them through that test program."

Accordingly, there is another full-scale test article at IABG in Germany: "They put it through metallic fatigue and damage-tolerance testing," Elliott says. "They take basically the same load envelope, the same fatigue spectrum, but they don't apply the same factors to it. So they're testing all the metallic elements of the airframe in Germany and we're specifically testing the composite elements of the wing here in Belfast."

FATIGUE TESTING

For the metallic fatigue testing, Elliott says a number of cycles agreed with the authorities, possibly a complete lifetime of 60,000 cycles, is carried out with pristine structure with little or no deliberately induced damage: "After we've completed 60,000 cycles, we'd go in and start adding local impact damage, literally firing metallic ball bearings at the structure to induce delaminations in the structure, and we test for another lifetime. And just to make sure, we would go in then and scan the structure on a regular basis, to ensure that the delaminations that we have induced with the initial impact are not growing to the point where they might reduce the load capability of the structure."

After the second lifetime of testing, there is a thorough inspection of the test article to see if any cracks have started in the metallic structure. "If there are none, then we'll start inducing cracks by putting little saw cuts into the structure in what we believe are the most highly loaded areas and then continue the testing by a few thousand more cycles and watch each of those crack sites to see whether the crack is growing at all, and if it is growing, how fast is it growing and therefore what the in-service inspection intervals would need to be."

All this testing represents a significant additional burden, Elliott says, "Typically we talk about the weight advantage for composites. In some cases there can be a recurring cost advantage, because you're making bigger components and therefore you can reduce the number of man-hours required to assemble those larger components. But you also have to take into account all this testing, which can cost tens of millions of dollars. That's all part of the equation that determines whether or not going with a composite structure is a good idea or you just want to stick with the metallic structure."

ABOVE: Composite durability and damage tolerance test (CADTT) article for the CSeries wing under test at Bombardier Belfast

INSET: Preparing to test skin to stringer tension on a section of CSeries wing

Metals and composites have dissimilar failure modes. Metallic structures tend to buckle and stretch. Elliott says, "You get a certain amount of yielding of the metallic materials. In tension, they stretch a certain amount before they break, or on the upper surfaces of the wing with the wing bending up you can see the metallic structure beginning to buckle." But they can continue to carry load and remain safe despite this buckling and yielding.

Composites behave differently: "It's just an instantaneous failure, it absorbs so much energy, so much load, and then it will just go, usually with a very loud bang. You don't get any of that yielding or pre-failure activity; it's either working or it's not working."

The test burden should ease as understanding of composites grows, Elliott adds. "The industry is getting much better at predicting the behavior of composite structures. On the full-scale static article, obviously the specimens are covered with hundreds of strain gauges, so we can measure exactly what load and what strain is going on in every element of the structure. So we do a correlation between what the finite model is telling us and what we're actually seeing in the structure."

The industry as a whole is getting very good at being able to predict those strain levels, he says. "That's all part of building up confidence with the industry and the certification authorities so that over time we can reduce the number of specimens that we have to test and the number of different specific tests that have to be done."

Bernard Fitzsimons is a journalist specializing in air transport business, technology and operations

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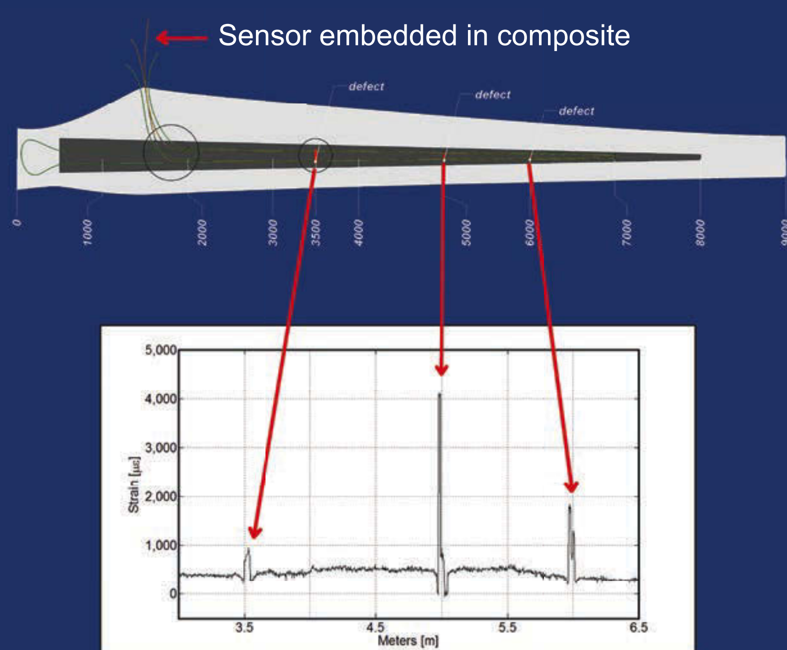

Pedrazzani, J.R., et al, 2012 SAMPE Technical Conference Proceedings, Baltimore, MD, May 21-24, 2012; US Dept. of Energy-funded program "Effects of Defects" in collaboration with the University of Massachusetts, Lowell; TPI Composites, Inc.

DEFYING IMPOSSIBLE.

Lighter fuel

Airbus believes hydrogen fuel cells could replace current onboard equipment to power systems, start engines and provide emergency back-up – and reduce weight. It has now established a partnership with a research center to examine their potential

BY IAN GOOLD

1	The atomic number of hydrogen, the lightest of all elements on the periodic table
100	The amount of electricity the system can provide in kW
23	The time in hours the US National Laboratory's Tiger flew using a fuel cell in 2009
13	Percentage use of fossil fuels that aviation uses across all global transport systems
25,000	Height in feet where Airbus and DLR conducted fuel cell tests on board an A320 research aircraft in 2008

Airbus and South Africa's National Aerospace Centre (NAC) are embarking on three years of jointly funded research into the potential application of fuel cells on commercial aircraft as part of the European manufacturer's efforts to improve jetliner environmental and economical sustainability. "The dual factors of high fuel costs and industry commitments to halve 2005 CO_2 emissions by 2050 are driving the search for alternative solutions to fossil-fuel-based propulsion and energy sources," says Airbus.

The company thinks that, ultimately, hydrogen fuel cells could replace current auxiliary power unit (APU) technology to power aircraft systems, start engines, and provide standby energy resources for emergency back-up – as an alternative to ram air turbines (RATs) used for minimum flight instrumentation and essential control systems. The technology could also replace airport ground power units. Initially, the partnership will share sponsorship of a Hydrogen South Africa (HySA) program to be undertaken by the organization's systems division competence center at the University of the Western Cape.

"This fuel cell project with HySA Systems and NAC is part of an Airbus research and technology initiative with South Africa, which was launched in 2006 and involves collaboration with several universities and research institutes," says Airbus emerging technologies and concepts senior manager Dale King. According to HySA Systems director Prof. Bruno Pollet, fuel cell technology for land vehicles has rapidly matured, but this new research is "aimed at understanding how hydrogen fuel cells could perform over an aircraft's life while subjected to harsh and rapidly changing climatic and environmental regimes".

Representing the third element of the partnership, NAC director Philip Haupt sees hydrogen fuel cells technology becoming "a game-changer in aerospace and other fields". Described as a "PhD research and technology project", the work is co-funded equally by Airbus and NAC.

The fuel cell research will involve HySA Systems' own laboratory-based work, with the resulting data and findings being shared with the Airbus fuel cell team. The manufacturer says the project "will form part of the body of knowledge" supporting work by Airbus and its established fuel-cell technology partners.

PREVIOUS DEVELOPMENT

Airbus has performed previous test flights involving fuel cells to power individual emergency power systems, but does not yet have the knowledge and technology for the complete replacement of aircraft electrical systems with a multifunctional fuel cell. It expects that this postgraduate level project with the HySA Systems competence center "will go some way to closing that gap and will identify the factors influencing fuel cell performance, aging and monitoring, and consider how these could be adopted for use in aircraft".

The manufacturer very much sees hydrogen fuel cells as a future, emissions-free substitute for small gas

ABOVE: ILA Berlin 2008 – the fuel cell unit attracted many questions from interested visitors

FUEL CELLS SIMPLIFIED

Airbus describes fuel cells as devices that "transform the energy in hydrogen and oxygen into electricity through a direct chemical conversion at a low temperature level without moving parts". The exhaust product is water and, in the case of an air-breathing system, oxygen-depleted air. "The electricity produced by fuel cells is cleaner and more efficient than combustion engines. In addition, the water and the oxygen-depleted air (inert gas) can be used on the airplane to substitute the water and inerting systems," concludes the manufacturer.

LEFT: HySA Systems has developed hydrogen and fuel cell systems

BELOW: Airbus presented for the first time its fuel cell activities on board an A320 research aircraft at the 2014 ILA Berlin Air Show in May

turbine APUs used to generate onboard electrical power and heating while aircraft are on the ground. "Replacing the fossil-fuel powered APUs with hydrogen fuel cells would help achieve the goals of emission-free and low-noise aircraft operation," says Airbus.

Will this research lead to development, prototyping, testing and commissioning of new fuel cell technologies? "Little research in fuel cells has focused on aviation applications, compared with automotive applications," according to Pollet. "The research will open new areas in fuel cell systems and material-related technologies."

Besides emission-free and low-noise aircraft operation, fuel cells would reduce the overall weight of aircraft, leading to lower fuel burn and operating costs, together with further reduced carbon emissions during flight, says Airbus. "Hydrogen fuel cells could enable aircraft to generate their own water supplies. They would also have a safety benefit through their ability to generate inerting gas used to reduce flammability levels in aircraft fuel tanks and for suppressing any cargo hold fires," says Pollet.

Because they do not have any moving parts, fuel cells are less maintenance-intensive than the more conventional APUs. The units also could replace heavy aircraft batteries and conventional fuel tank inerting systems, says Airbus. "In doing so, they would reduce weight and fuel consumption."

The manufacturer reports that a principal area of testing to be conducted by HySA Systems involves materials. "The purpose of the project is to develop a better understanding of the behavioral properties of the various materials used in the manufacture of hydrogen fuel cells," says Pollet. "The range of materials includes various polymers, stainless steel grades, titanium alloys, aluminum, and carbon-based materials." He tells *Aerospace Testing International* that these materials' desirable behavioral properties are "fairly well understood at ground-level applications, but not at high altitudes".

What laboratory testing and research is planned to improve such understanding of material behavior? "Testing of materials, systems in climatic chambers, and in 'real' conditions (with smaller aircraft, such as unmanned aerial vehicles) using international and industry standards," says Pollet.

Airbus confirms that flight tests "are not contemplated as part of the HySA PhD project, which does not relate to any specific fuel cell design and therefore there is no need to contemplate flight tests". But asked directly about likely or potential "real conditions" testing with small aircraft, the manufacturer says that there are programs running at Airbus Group Innovations – its network of research facilities, scientists, engineers and partnerships through which the

CASE STUDIES

Airbus performed the first flight test on an airliner using a fuel cell system to power back-up systems in 2008 with partner DLR, the German aerospace center. To explore the technology's potential as an electric power source in ground operation, DLR subsequently designed and installed a demonstrator in its own A320 fuel cell test aircraft three years later. The unit comprises a fuel cell powering an electric motor that drives the nosewheels, allowing the aircraft to taxi autonomously. Airbus was responsible for overall system architecture and technology integration, while DLR provided basic research activities.

Also in 2011, the aircraft manufacturer partnered with US equipment provider Parker Aerospace, an established Airbus supplier with special competencies in multifunctional system integration. With Airbus again responsible for system architecture and technology integration, and Parker supplying the multifunctional fuel cell system and managing subsystem suppliers, the partners aim to develop a technology demonstrator and conduct a joint flight test campaign, including operational and infrastructural tests.

NATIONAL AEROSPACE CENTRE

South Africa's National Aerospace Centre (NAC) was set up by the country's Department of Trade and Industry in 2006 to "engage with government, industry, academia and research institutions, locally and internationally, to promote competitiveness through research in South Africa's aerospace sector". Hosted at the University of the Witwatersrand, the NAC also aims to develop skills and talent within the industry. The NAC and Airbus co-fund postgraduate scholarships for Master's and doctoral studies in areas relevant to local aerospace and academia, and to the future Airbus business. NAC director Philip Haupt says, "This has been happening for eight years and there are six local universities receiving support." NAC contributes 50% of the funding, as well as the provision of joint supervision and access to linkages into the domestic academic, industrial and governmental networks. The NAC represents all local universities that have engineering and related sciences, provides bursaries and scholarships, and funds focused research and development in specific areas such as manufacturing and materials, dynamics and control, and firm level competitiveness.

company aims to foster "technological excellence and business orientation" through sharing group competencies and establishing partnerships with research centers, universities and schools. "Furthermore, tests at the German aerospace center, DLR, have been performed in the past. There are no flight tests necessary or planned for the next few years."

ENVIRONMENTAL RESEARCH

Research will specifically relate to how the various constituent materials will withstand "the harsh climatic, physical and operating environment that characterizes jet airline transport", says Airbus. The research will be "in particular looking at the materials' behavior in response to rapid and dramatic changes in temperature and air pressure, and gravitational and centrifugal forces".

What factors influence the materials' tolerance of such an environment? Pollet lists many things that will impinge on performance, including pressure differences during operation, fluctuations in relative humidity, and vibrational and gravitational (*g*) forces. Other factors are the effects of harsh climatic, physical and operating environments; fuel chemistry, purity and delivery; and oxygen starvation. He also points out that the effects of climatic changes on the chemical composition of the fuel cell water exhaust will need to be examined to investigate degradation mechanisms. Pollet emphasizes that current knowledge relates to ground applications for fuel cells and says that the materials' tolerance of a high-altitude environment could be "greatly affected" by exposure to temperature and pressure changes, and other gravitational factors.

Until the South African research and testing program has yielded results, the European aircraft manufacturer remains optimistic that this emerging technology is the way forward. "In the very long term, Airbus foresees a potential application of hydrogen fuel cells as a substitute for APUs, providing ground power for commercial aircraft cabin and cockpit systems, start power for the main engines, and as an alternative to RATs used to generate standby emergency electrical back-up power for flight instruments and essential controls," says Pollet.

ABOVE LEFT: **Fuel cell powered nose landing gear test**

ABOVE RIGHT: **The fuel cell system on the Airbus A320 ATRA research aircraft was built by DLR with Airbus project leader Jens Dietrich Kurre**

THE FUTURE

Pollet declines when asked if he would like to suggest a likely timeframe in which there could be an initial application of fuel cell technology entering airline service: "This depends on the Airbus product strategy in the next 10-20 years."

Beyond replacement of APUs and RATs, what other areas of aircraft power requirements has Airbus identified for future fuel cell application? The manufacturer is unequivocal: "Sorry, but the Airbus fuel cell strategy is highly confidential. We are looking for various applications in a step-by-step approach for future and existing aircraft programs."

Asked if fuel cells could become a more frequently used source of onboard power in the air, Pollet points to proton exchange membrane fuel cell technologies. Is this a 'yes', a 'no', or a 'maybe'? It is "a clear 'yes' and 'maybe' – but there is still a lot of work ahead. We need to show that this technology is mature and safe," indicates the professor. ∎

Ian Goold is a UK-based writer specializing in the civilian aviation industry

HYSA SYSTEMS

As part of an effort to increase South Africa's research efforts in hydrogen and fuel cell technologies, and to create job opportunities as well as intellectual property rights, the country's Department of Science and Technology (DST) developed the National Hydrogen and Fuel Cells Research, Development and Innovation Strategy (branded Hydrogen South Africa (HySA)) under a 15-year program that was approved in May 2007. The DST has set up three HySA centers of competence, hosted by universities and science councils. The University of the Western Cape is host to the HySA Systems integration and technology validation center of competence at the South African Institute for Advanced Materials Chemistry.

As part of the US-German cooperative program known as Hypersonic International Flight Experimentation (HIFEX), an integrated aerodynamic and aerothermal test and analysis of a hypersonic cruise vehicle was recently completed in the AEDC Hypervelocity Wind Tunnel 9

Equal measures

AEDC partners with AFRL to advance the latest hypersonic technology

BY DEIDRE ORTIZ

Through its growing partnership with the US Air Force Research Laboratory (AFRL), Arnold Engineering Development Complex (AEDC) continues to make advances in hypersonic flight and weapon systems development. AEDC has played a role in testing high-performance aircraft, missile and ordnance used by the US military today, with hypersonic aerodynamics testing being one of the main capabilities offered to test customers for several decades.

In the past, the focus has been more on vehicles that briefly move through the atmosphere at high speed, but current work is concentrated on operating systems for sustained periods in the hypersonic regime.

Over the past few years much of AEDC's hypersonic testing and research has taken place at Hypervelocity Wind Tunnel 9, in White Oak, Maryland. Tunnel 9 is a blow-down facility capable of subjecting test articles to speeds as high as Mach 14 for up to 15 seconds.

AEDC's hypersonic wind tunnel capabilities also include the von Kármán Gas Dynamics facilities, which can run continuously from Mach 4 to Mach 10. Currently these wind tunnels are busy characterizing the aerodynamic performance of high-speed cruise missile concepts and are also expected to be heavily used in technology development.

AFRL has sponsored many of the hypersonic tests completed at the White Oak facility, including the testing conducted at Tunnel 9 as part of the Falcon program. This program, a joint Defense Advanced Research Projects Agency (DARPA) and US Air Force program, has developed and demonstrated hypersonic technologies that enable the execution of prompt global reach missions. AFRL assisted in providing technical guidance for the Falcon program to DARPA.

Aerothermal and aerodynamic data at Mach 10 and Mach 14 were obtained during the Hypersonic Technology Vehicle 1 (HTV-1) entry in 2005 to validate the aerodynamic database at two important flight points prior to the critical design review. Additional data sets were taken on the next-generation glider, the HTV-2, including critical data leading to understanding anomalies in flight. "This data set was critical in helping us satisfy the stringent return to flight criteria," explains Dr Peter Erbland, Falcon HTV project manager.

In 2010, a Mach 10 scramjet-powered vehicle configuration underwent testing at Tunnel 9 to characterize vehicle stability and control characteristics for different inlet operating conditions. These inlet operating conditions were correlated to scramjet engine operability data.

Tunnel 9 test teams then partnered with AFRL and universities to attempt to improve the understanding of hypersonic boundary layer transition in testing and evaluation (T&E) facilities. These tests, performed in 2013, were made possible under the Test Resource Management Center (TRMC) and the Air Force Office of Scientific Research (AFOSR) funded Hypersonic Center of Testing Excellence (CoTE).

High-fidelity measurements were required to make better flight predictions based on wind tunnel measurements and to validate boundary layer stability computations. Such computations will be essential to reduce the developmental risks of new hypersonic systems. Previous measurements in large-scale hypersonic T&E facilities were mostly limited to the determination of the transition location and provided limited insight into the physics of the transition process.


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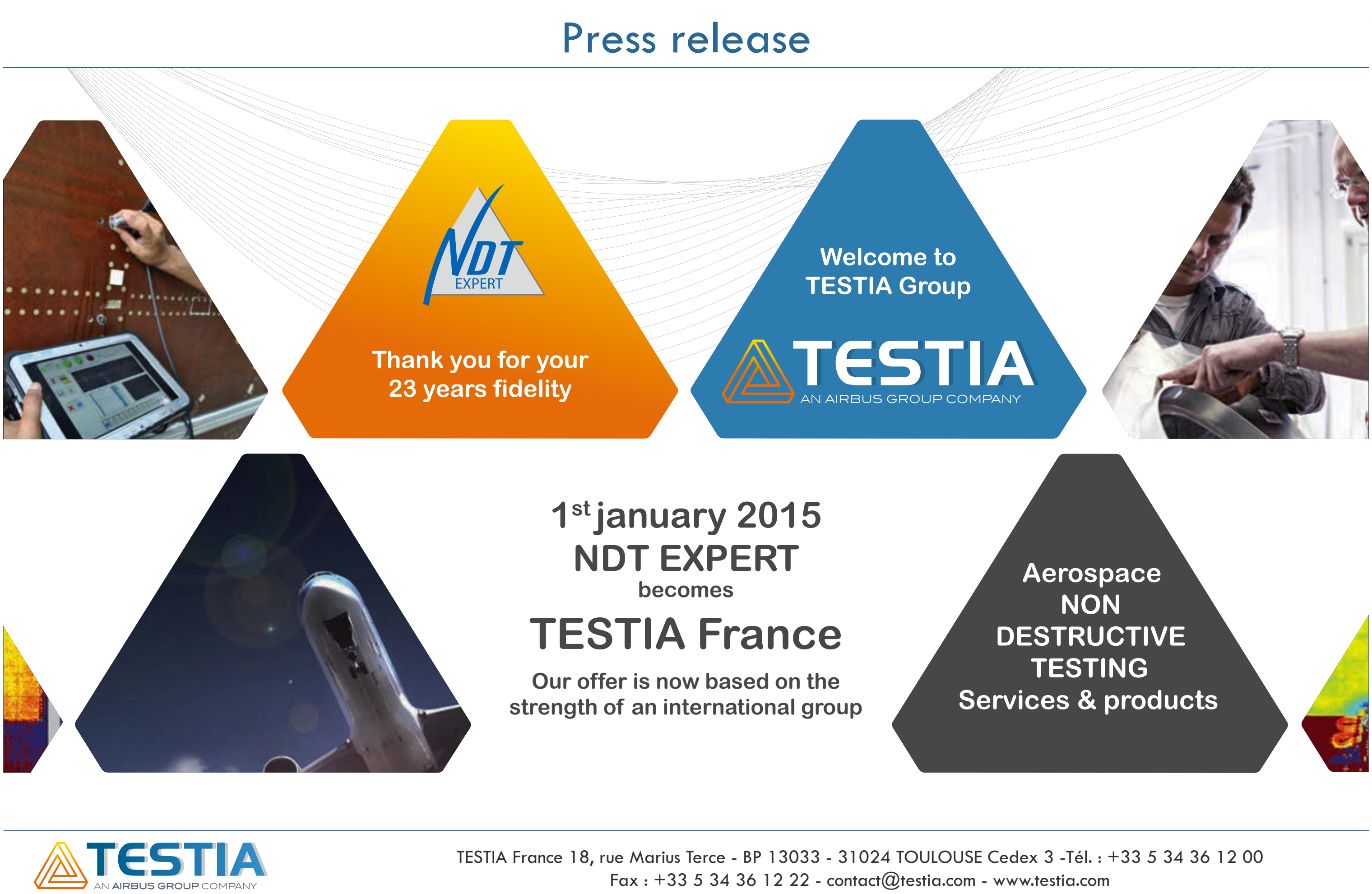
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TOP LEFT: Scramjet-powered vehicle

TOP RIGHT: Test engineer Joe Norris and Tunnel 9 technical director John Lafferty ready a Hypersonic Technology Vehicle-1 model prior to a Hypervelocity Wind Tunnel 9 operation completed in 2005

TUNNEL 9 SUPPORTS HIFEX

Most recently a successful integrated aerodynamic and aerothermal test and analysis of a twin scramjet-powered hypersonic cruise vehicle was completed at Tunnel 9. Researchers and engineers from AEDC and AFRL conducted the testing as part of a scientific research effort called Hypersonic International Flight Experimentation (HIFEX).

HIFEX is a joint collaborative effort between AFRL and the German Ministry of Defense, executed by the German Aerospace Centre (DLR) under the authority of a Defense Level Project Agreement. It was created to advance the maturity of technologies deemed to promote the realization of a next generation of hypersonic aerospace systems. The program's goal is to investigate fundamental hypersonic phenomena and characterize the effectiveness of key technologies in a relevant hypersonic environment. Investigations to date have addressed aerodynamics and aeroheating, scramjet aeropropulsion integration, structures and materials for operation in extremely high thermal and erosive environments, and adaptive guidance and control methodologies.

Douglas Dolvin, AFRL program manager of HIFEX, explains that hypersonic aerospace systems may enable a full spectrum aerospace force with the capability to perform seamless operations that transcend the continuum of the air and space domains. Transformational missions currently envisioned include prompt call up and global reach, responsive precision strike and flexible maneuver through anti-access aerial denied regions. "The research efforts also seek to advance the state-of-the-art in measurements and diagnostic instrumentation," he says. "This has culminated with the recent aerodynamic testing of the twin scramjet-powered hypersonic cruise vehicle in the Tunnel 9 facility."

The recent HIFEX test was the first time the effects of asymmetric engine unstart on vehicle stability and aerodynamic heating of a complex hypersonic vehicle design were experimentally evaluated.

AEDC staff were commended for playing an integral role in the testing process, from beginning to end. "The scientific and test communities worked hand-in-glove like a highly synchronized team," comments Dolvin. "The AEDC test component was fully engaged with our HIFEX science component from the early conceptual level definition of the flight vehicle configuration through the development and test of the research model. The test director communicated often and effectively with AFRL's principal investigator, Heidi Wilkin. Together they formulated a test manifest that was comprehensive enough to capture the most critical aerodynamic phenomena yet responsive to constraints on time and costs."

Dolvin adds that AEDC's team was there to provide critical support whenever challenges arose: "They were receptive to input from our scientific leads and responsive to the concerns of our on-site representatives," he notes. "The high-quality optical instruments and the measurement technologies employed, including extensive use of temperature-sensitive paints, proved to be instrumental in capturing unsteady aerodynamic phenomena that have never been characterized before, and in formulating an understanding of complex interactions."

In addition to HIFEX, AEDC has partnered with AFRL to identify, develop and execute several advanced technology programs, such as the Asymmetric Scramjet Engine Test (ASET) and Hypersonic International Flight Research Experimentation (HIFiRE) programs.

WIDE RANGE OF CAPABILITIES

Military and commercial customers also take advantage of the capabilities available at its other test facilities at Arnold Air Force Base, some of which are unique in the world.

The complex has high-enthalpy arc-heated facilities that play an important role in hypersonic research and

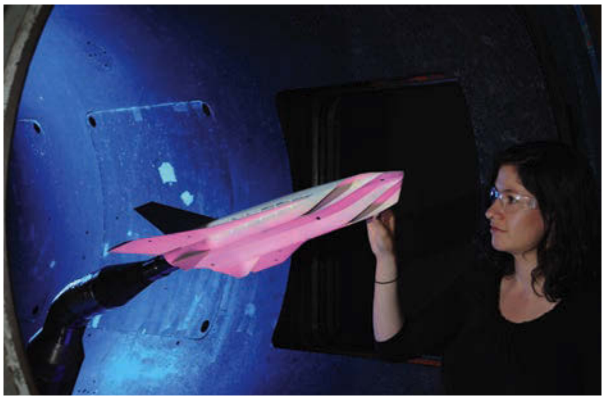
HYPERSONIC PROGRAMS SUPPORTED BY AEDC TEST FACILITIES

Falcon program
- Mission-critical testing of Hypersonic Technology Vehicles (HTVs)
- Tunnel 9 teams tested HTV-1 at Mach 10 and Mach 14 in 2005

Axisymmetric Scramjet Engine Technology (ASET) program
- Joint effort between AFRL, DARPA and AEDC, which founded the relationship between AEDC Tunnel 9 and AFRL

Hypersonic International Flight Experimentation (HIFEX) program
- Collaboration between AFRL and the German Ministry of Defense
- Recent testing of twin scramjet-powered hypersonic cruise vehicle
- Possible missions include prompt call up and global reach, responsive precision strike, and flexible maneuver through anti-access aerial denied regions

Medium Scale Critical Components (MSCC) program
- Direct-connect test program exploring first generation of larger scale scramjet engine characteristics
- Engines expected to have 10 times the airflow rate of the X-51A Waverider



ABOVE: Inna Kurits, AEDC Tunnel 9 test engineer, checks the US Air Force HIFEX vehicle geometry for final readiness before testing in the AEDC Hypervelocity Wind Tunnel 9

development. These facilities are unique in their ability to reproduce thermal environments simulating flight from Mach 8 to Mach 20 for the long exposure periods required to validate thermostructural performance and survivability of materials and components. Arc heaters have had widespread use in the development of high-speed vehicles, including hypersonic missiles, reentry vehicles, high-speed transports, space transportation and space access vehicles, and ordnance and munitions systems.

The Aerodynamic and Propulsion Test Unit (APTU), a hypersonic blowdown freejet test facility, is currently being upgraded to make the first-ever direct-connect tests of a larger scale scramjet engine class.

Once upgrades are complete, APTU will be fully capable of supporting AFRL's Medium Scale Critical Components (MSCC) direct-connect test program, which was started in 2011 to explore the first generation of larger scale scramjet engine characteristics. It's anticipated that the engines tested as part of the program will have 10 times the airflow rate of an X-51A Waverider.

As hypersonic system technologies mature, AEDC stands ready to evaluate the lethality and survivability in the G-Range ballistic range, where scaled test articles are accelerated to hypervelocity speeds to understand impact lethality. Plus, these systems will employ sensors and rocket propulsion, requiring testing in AEDC's large rocket cells and space environmental chambers.

NEW HYPERSONIC BRANCH AT AEDC

As a way of further progressing hypersonic research and testing, AEDC has extended its partnership with AFRL by starting a High Speed Experimentation Branch, now on-site at Arnold AFB. Glenn Liston, chief of the branch, explained that the objective of the office will be to conceive, develop and execute high-speed experimental research in the nation's premiere wind tunnel facilities. "AFRL is excited to grow our partnership with AEDC," he says. "This new branch will leverage our long-standing relationship."

Tunnel 9 director Dan Marren believes that the collaboration, which has been in the works since early 2014, will create a center for hypersonic research that's unlike any other.

"I am thrilled that the new hypersonic branch at AEDC can take the pilot activity we began at White Oak to a new level, bringing in several hypersonic disciplines and forming the basis for what we do across our hypersonic test enterprise."

All involved look forward to watching what the future holds for hypersonic research as a result of this new development: "Having Glenn Liston from AFRL, Dr John Schmisseur at University of Tennessee Space Institute and the multidisciplinary test facilities and teams at AEDC, will give the US Air Force the advantage of having everything to move hypersonics to the warfighter co-located and moving in one direction," Marren explains.

Liston explains the team's mission will be to conduct foundational and systems research in propulsion, aeronautics and structural applications providing technology maturation related to the hypersonic flight regime: "For AFRL's benefit, the branch will use the AEDC facilities and expertise to conduct research at larger scales than we can typically handle in the facilities at Wright-Patterson AFB," he says. "A benefit to AEDC will be the ability to engage the T&E [testing and evaluation] workforce in the research process, generating new knowledge for hypersonic systems while improving their capability to test revolutionary new flight systems."

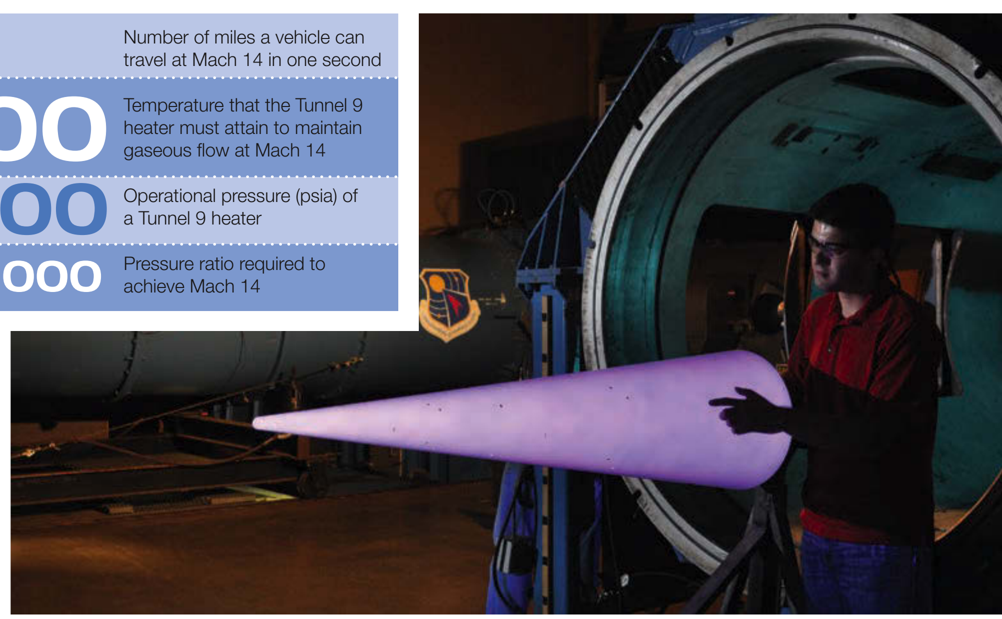
The branch will focus on research for high speed and hypersonic flight in the atmosphere. "Our research thrust will include aerodynamics and aerothermodynamics, integration of high-temperature structures, efficient airframe-propulsion integration and the development of instrumentation, diagnostics and test techniques," Liston continues. "We will tackle some of the most challenging problems in hypersonic aerodynamics, structures, propulsion and integration. We will be working with AEDC to develop new diagnostic techniques that will be essential for both S&T [science and technology] and T&E."

Space access is one application that Liston says could benefit from hypersonic technology: "If we can use hypersonic S&T to develop space launch systems that are fully reusable and highly responsive, then we can transform military and commercial space launch." He foresees using the strengths of traditional S&T and the T&E communities to develop the next hypersonic systems. "Together we will advance hypersonic capabilities from missile-size vehicles like the X-51 to future platforms that can revolutionize how the Air Force flies and fights."

The High Speed Experimentation Branch is expected to reach full capability by September 2015. ∎

Deidre Ortiz is a technical writer at Arnold Engineering Development Complex, USA

3	Number of miles a vehicle can travel at Mach 14 in one second
3,500	Temperature that the Tunnel 9 heater must attain to maintain gaseous flow at Mach 14
30,000	Operational pressure (psia) of a Tunnel 9 heater
1:1,000,000	Pressure ratio required to achieve Mach 14



RIGHT: An Air Force project engineer examines the illuminated temperature sensitive paint coating on the large, 7° cone prior to testing (Photo: Mike Smith)

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INVESTIGATION: TEST SITE

In this latest installment of our in-depth look at test sites, *Aerospace Testing International* gains exclusive access to commercial airliner test sites. Our reporters talk to the people who run some of the leading civil test locations around the world: Airbus, Boeing, Embraer, Sukhoi and Bombardier.

- Boeing Field, opened in 1928, was where the B-17 and B-29 were tested during World War II; an aircraft was completed every two days
- Bombardier has prime test sites in Canada and the USA, employing 1,000 specialist staff in total
- Sukhoi now has to fulfill 320 orders for its SJJ100, and then begin tests on the SJJ130 NG
- Embraer boasts the longest runway in the southern hemisphere – it is 5,000m in length
- The A350 XWB completed 2,600 flight test hours, which included route-proving to 14 international airports

AEROSPACE TESTING INTERNATIONAL EXCLUSIVE

Toulouse-Blagnac Airport is alive with activity as the five A350 XWB test aircraft are prepared for their formation flight on September 29, 2014

Airbus, flight test center

Location: final assembly facility, Toulouse, France

Coordinates
Latitude: 43.61227
Longitude: 1.368326
Elevation: 154m

Commercial airliner production is at the heart of the activity of the Airbus Group (formerly EADS), Europe's largest aerospace and defense company, which now operates in more than 170 locations worldwide. The Airbus commercial product line includes airliners with 100 to more than 500 seats, from the single-aisle A320 family to the double-deck A380. Globally, Airbus secures around half of all commercial airliner orders.

Reflecting the multinational nature of the company and its global footprint, developmental, integration and flight test work for the Airbus commercial range is distributed across three of the main European partner nations, as well as alongside aircraft final assembly lines in Tianjin, China and Mobile, Alabama.

Fernando Alonso is senior vice president, flight and integration tests, a position he assumed in 2007 after a previous role as head of flight operations. He is responsible for overseeing developmental flight testing of new models as well as pre-delivery flight testing of all production aircraft as they leave their assembly facilities. An increasing proportion of test work is now conducted prior to an airliner's first flight, and as such Alonso also heads up the systems integration test effort.

Alonso's department includes around 1,700 people, including sub-contractors. Flight test activity is supported by a team of 43 pilots and 58 flight test engineers. In all, around 150 personnel are dedicated to flight test activity, with the remainder of the department assigned to ground testing in France, Germany and the UK.

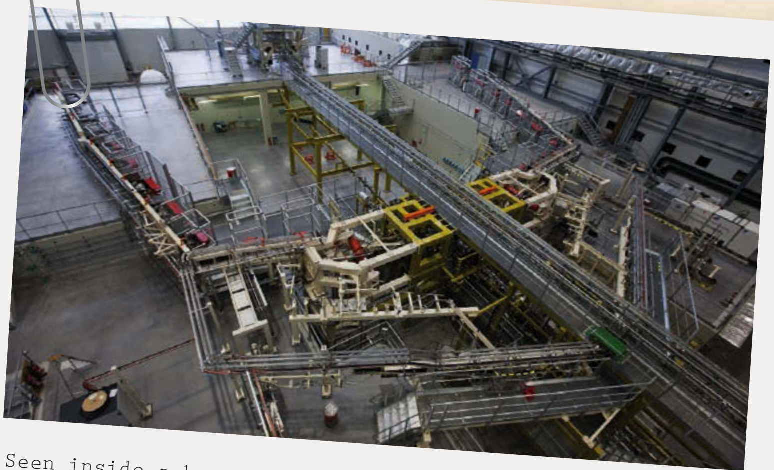
In order to validate production aircraft as they roll off the line, dedicated test teams are found in Toulouse, Hamburg and Tianjin, and from 2016, similar activity will also take place in Mobile. As well as the first flights of each new airframe, these teams are responsible for the actual delivery of the aircraft to their customers.

In terms of development flight testing as distinguished from production flight testing, the team's recent key projects have included the testing and type certification (EASA and FAA) of the A350-900, which was completed in 2014, and the start of the development flight testing for the A320neo with Pratt & Whitney engines, which will continue in 2015 for the entire single-aisle NEO (New Engine Option) line, comprising the A319neo, A320neo and A321neo with either CFM International or Pratt & Whitney powerplants. From 2016 the development effort will begin to focus on the A350-1000, the larger member of the A350 XWB family that will enter airline service in 2017. 2017 will see similar development work begin on the A330neo, one of two new members of the Airbus widebody family. While 2014 saw a total of 22 aircraft in testing (including major development programs like the A350 and NEO), this will fall off somewhat to 16 aircraft in 2015, before climbing back to 19 for 2016.

GLOBAL FACILITIES

The company's ground test sites in Toulouse, Hamburg, Bremen and in Filton in the UK are concerned with developing and proving inflight systems before bringing them together as a functioning whole in the integration phase. At each location, functional integration benches are provided to test individual functions, as well as much larger integration rigs, which serve to validate all related systems working in unison, as on the aircraft itself.

Looking at the ground test sites in turn, Filton handles landing gear and fuels systems work, and is equipped with functional integration benches and a landing gear 'zero rig', a replica of the undercarriage that is used to test the whole subsystem, including interfaces. The fuel test facility is equipped to verify



Seen inside a hangar at Toulouse, the 'iron bird' is a ground-based systems integration test bench

KEY FACTS

Ground fatigue testing for the A380 alone included a total of 47,500 flight cycles – 2.5 times the number of flights that an A380 would make in 25 years of operation.

Airbus's central telemetry room receives real-time data from aircraft at a rate of 5.3MBps.

As part of its certification, the developmental A350 XWB fleet completed over 2,600 flight-test hours worldwide, including a global route-proving tour of 14 major airports.

Beginning with a maiden flight in September 2014, the NEO flight test and certification program will include 3,000 flight-hours across eight aircraft – two A320neos, one A321neo and one A319neo for each of the two engine types.

functions of fluids on board the aircraft, and is similarly provided with a functional integration bench and a zero rig. The latter has the ability to replicate heating or cooling of the fuel involved, as well as its feed and transfer, and the actions of pipes, pumps, vents and other components. It is, says Alonso, "a powerful capability".

In Bremen, work focuses on flaps and slats, and again the test objectives are divided into two components, as functional integration benches and zero rig. Here, the zero rig is based on a complete physical airframe assembly, to provide what Alonso describes as "an end-to-end validation".

Ground test work at Hamburg includes functional integration benches and the cabin zero, and here all cabin equipment is put through its paces. With the increasing importance of in-flight entertainment, wireless networks and other onboard innovations, cabin test work is becoming an increasingly complex affair. To this end, the Hamburg team operates cabin zero, a complete replica of the cabin, including galley and toilets, which can also be used for ground tests of the ventilation system.

Toulouse is home to the functional integration benches for hydraulic, electrical, navigation and powerplant systems, and is the largest of the test facilities. Once subsystems have been checked on the benches, all are brought together for final tests before installation, using the 'iron bird'. This geometrically representative rig includes all aircraft systems down to exact replicas of the wiring system and harnesses.

After the subsystems and have been proved at these sites and ground testing is complete, work moves on to developmental flight test, all of which is undertaken at Toulouse. The facility is appropriately equipped with telemetry equipment and can send collected flight test data to a ground station in real time, using a satellite link. The test effort includes in-house development aircraft, such as the A320 that first tested Sharklet wingtip aerodynamic devices from Toulouse in 2011.

From a production flight test point of view, such work is conducted at Toulouse as well as the company's other two final assembly centers at Hamburg and Tianjin. Family production across the final assembly lines is assigned as follows: Toulouse builds A320s; Hamburg has responsibility for the A318, A319, A320 and A321; Tianjin assembles A319s and A320s; and the new US facility at Mobile will produce A319s, A320s and A321s.

GLOBAL TEST SITES

Additional sites around the world are used by Airbus for particularly challenging elements of the flight test campaigns. Systems and aircraft are required to be demonstrated in extreme conditions, including at high altitude, for which La Paz, Bolivia, with its elevation of 4,000m (13,000ft) is regularly employed. Very cold weather trials are conducted in northern Canada and Siberia, while hot weather work can see flight test teams deployed to the United Arab Emirates, and for hot and humid, Hong Kong or Singapore. The A350 XWB program is additionally making use of the US government's McKinley Climatic Laboratory in Florida. In the McKinley hangar, as Alonso points out, an airliner "can be exposed to 40°C on one day and -40°C the day after. It is a very powerful facility offering a uniquely controlled test environment."

In terms of testing, the company's key strategic objective is to reduce the lead time involved in the certification of a new aircraft, and improving the maturity of that aircraft at the time of its service entry. Alonso recalls that the certification campaign for the A380, for example, required 20 months, but he notes that the company has demonstrated with the A350 XWB certification that the process can be brought down to 14 months and this result paves the way for future reductions.

This is a challenge, not least because "aircraft are increasingly complex, customer expectations are higher and certification guidelines are stricter," says Alonso. Furthermore, the number of parameters involved in test work has increased by a factor of 50 since 1987: while the A320 test program involved study of 12,000 parameters and saw 8.5 terabytes of data archived, the A350 will examine 670,000 test points and generate 53 terabytes of data. However, through a change of approach and the introduction of a reorganized test campaign, the trend has been reversed in the case of the A350. "We are now back to 14 months between first flight and certification," Alonso explains, "and we are very proud of that. Increased testing upstream is now paying off." ∎

Philippe Pellerin and Etienne Miche De Malleray and engineer Jean-Paul Lambert for first flight of the A320neo

Boeing Northwest Flight Test

Location: Boeing Field, Seattle, Washington, USA

Coordinates
Latitude: 47.537
Longitude: -122.3040
Elevation: 5m

Boeing Everett Factory is the airplane assembly building. Located on the north-east corner of Paine Field, it is the largest building in the world by volume

Historic Boeing Field – or King County International Airport – just south of downtown Seattle, is the hub of global test activities for Boeing Commercial Airplanes. "Seattle is a good, central location," explains Frank Rasor, Northwest regional director of Flight Test Operations for The Boeing Company. "We do a lot of flying in eastern Washington, 10 or 15 minutes east of the mountains in clear airspace, or we go out over the ocean for the same thing."

Specific test requirements nevertheless take Boeing airplanes and testers as far as Bolivia for high-density altitudes, Alaska and Russia for intense winter cold, and Malaysia for heat and humidity.

"Some of the tests we do, we have to find higher than 90°F (32°C) temperatures with more than 90% humidity to see how the airplane responds in those environments," says Rasor. "Even though we base a test program out of Seattle, about 40% of the testing is actually completed elsewhere."

Boeing Northwest Flight Test operates within the larger Boeing Test and Evaluation organization and tests both commercial and military products. In July, Seattle testers concluded work on the stretched 787-9 Dreamliner and are getting ready for the first flight of the US Air Force KC-46 tanker in 2015. The KC-46 test plan calls for four aircraft, and Rasor notes, "We're actually changing the historical model a little bit and doing most of the KC-46 testing right here in Seattle, and doing some specific air refueling work with the tanker at Edwards [Air Force Base, California]."

Seattle development and certification testing is separate from routine production testing at Boeing assembly locations. Rasor says, "We have the flight test organization fundamentally taking and managing airplanes for the duration of a flight test program, and that can be nine months. Production testing is one or two flights at Renton, Everett or Charleston – those are the one or two flights that go along with a new airplane."

TESTERS AND TELEMETRY

Boeing Field opened in 1928, and though eclipsed by Seattle-Tacoma International remains a busy commercial airport. "The earliest testing here goes back to the beginning of The Boeing Company," notes Rasor. "The most significant was probably during the World War II era with the B-17, the B-29 – that's when they were turning out an airplane every couple of days. That's what really built the facility here at Boeing Field."

The Northwest Flight Test organization today occupies a hangar and two buildings that include real-time test monitoring facilities. "We have a telemetry base and telemetry system here in Seattle," says Rasor. "We can operate almost anywhere in the country and relay data back to Seattle." Boeing Field testers, for example, watched flutter tests of a 747-8 operating out of Moses Lake in central Washington state.

In recent years, Seattle testers have flown the 787-8 airliner, 747-8 freighter and P-8 Poseidon maritime patrol aircraft. "We have a large portion of our Boeing Test and Evaluation organization here in the northwest. Roughly 2,500 people support from the end of flight testing back up through wind tunnels, structures, electromagnetic effects, etc."

The Northwest test organization has a specialized but flexible workforce, according to Rasor. "It's primarily engineering. Below that, it kind of breaks out into flight test engineers, structure engineers, electromagnetic engineers, technical support staff and business support staff. There's also a considerable amount of design engineering because of the design of test fixtures and test installations." He adds, "We have been able to become efficient because we are a test organization. A number of people move from program to program. In some of our specialties, they may support one program one day and another on another day."

Northwest Flight Test crews come from several Boeing sources. "Our cadre of test pilots primarily support flight test, but they regularly rotate in through production testing. We also have military-qualified pilots who rotate through flight test from Boeing Defense and Space." Aircraft deploy with purpose-built teams to capture relevant conditions. The Boeing 787-9 test team, for example, waits for forecast winds to give them the take-off/landing test conditions they want to support crosswind testing. The right conditions took them to Lubbock, Texas. "We send a team that goes with the airplane wherever it needs to go," says Rasor. ∎

Testing of the 787-9 stretched Dreamliner was conducted by Boeing Northwest Flight Test

Embraer: São José dos Campos

Location: Campos, São Paulo, Brazil

Coordinates
Latitude: -23.2237
Longitude: -45.901
Elevation: 598m

The Legacy 450 sets off on its first flight at São José dos Campos

Embraer conducts its primary ground and flight test activities at its São José dos Campos headquarters site and a more recent facility at Gavião Peixoto. It also conducts cabin testing for its E-Jets program in a joint facility at the University of São Paulo.

Embraer's principle Brazilian facility, São José dos Campos, sits between the major cities of São Paulo and Rio de Janeiro in the Paraíba Valley. That most famous of Brazilian aviators, Santos-Dumont, identified the region around São José dos Campos as ideal for the establishment of a flying school in 1918, but it was a Brazilian Air Force officer, Montenegro Filho, who drove the establishment of an aerospace educational facility in the city.

As head of the Aeronautics Ministry's materials division, in 1943, Filho began campaigning for what would become the Centro Técnico de Aeronáutica (CTA) and Instituto Tecnológico de Aeronáutica. Academic work at the site began in 1950, with the modern facilities attracting talent from around the world, including Heinrich Focke, formerly of Focke-Wulf.

Aviation manufacturing and test facilities inevitably grew up around the institutes and when thoughts turned toward the production of a rugged turboprop transport in 1965, pressure mounted for the creation of a national aerospace manufacturing base. Empresa Brasileira de Aeronáutica, or Embraer, was created on August 19, 1969. Its first product was the twin-turboprop, developed as the EMB-110 Bandeirante.

Today São José dos Campos remains at Embraer's heart, as a combined design, production and test facility. Alexandre Figueiredo, Embraer's ground and flight test director, notes that the site hosts the headquarters of Embraer SA at its Faria Lima unit, which employs around 10,000 people.

Figueiredo explains: "Company activity began on January 2, 1970 with construction of the administration and operational buildings in an area next to the campus of the former CTA, which is now the Department of Science and Aerospace Technology. The main headquarters building, on Avenue Brigadeiro Faria Lima, is numbered 2170 as an allusion to that historic date.

"Hangars and other buildings were constructed next to the runway where São José dos Campos Airport is now located. Hangar F-20 was among the first built, as accommodation for the former Department of Technology, followed by F-30, housing parallel final assembly lines for the Bandeirante, Xavante and Ipanema."

TESTING DIVIDED

Embraer continues to perform much of its test work at São José dos Campos, but built a new facility at Gavião Peixoto in 2001, moving most of its engineering flight test to the latest establishment. Gavião Peixoto was erected specifically to house Embraer's military business and to support its flight test programs.

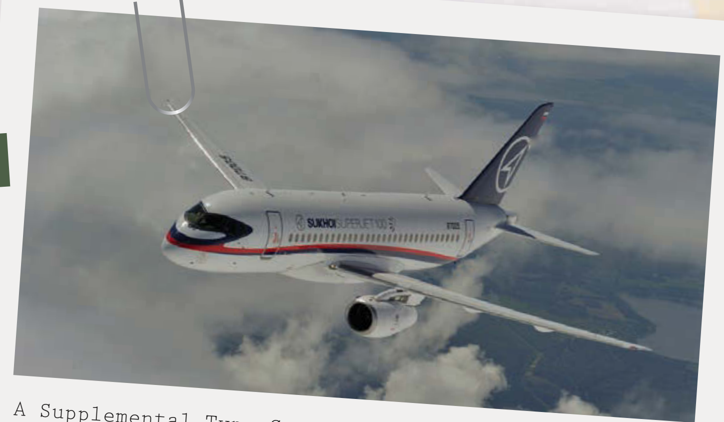
As such, it boasts the largest runway in the southern hemisphere, the 5,000m-long, 95m-wide strip allowing Embraer to perform test work that it previously had to take abroad. Nevertheless a huge amount of test work continues at São José dos Campos, as Figueiredo notes: "Production test flying, ground test procedures and flight preparation are carried out at São José dos Campos, as well as experimental manufacturing and flight data evaluation (for system performance, aircraft handling and equipment malfunction, among others). "Moreover, our Eugênio de Mello unit (near the main facility) houses test rigs and structural test labs, as well as most of the 'iron birds', the simulation and embedded systems used to test aircraft system integration. "Right now Embraer is involved in one of the most active periods of its history, with key programs including the KC-390, Legacy 500 and E-Jets E2 evolution, all of which demand special attention from the test team," Figueiredo explains.

Outside these two primary test stations, Embraer operates a Comfort Engineering Center in cooperation with and located at the University of São Paulo. Aimed primarily at developing cabin systems for regional jets, the facility was established around a 30-seat E-Jet cabin section, fully instrumented and equipped for the application of multiple variables.

Embraer has been able to manipulate characteristics as fundamental as cabin pressurization, examining their effect on passengers and how they interact with other environmental variables. Tests have been undertaken to examine the reactions of individual passengers as their environment changes, while separate work has looked at the effect of the airport experience on passengers before they even enter the cabin.

Figueiredo says that the tests Embraer performs and the technologies it is required to test are constantly evolving: "For instance, although all our new programs use iron-bird platforms, their use and the scope of that use is also increasing. We believe that Embraer's ground and flight test capabilities are now state-of-the-art, but we continue to work hard. Our primary challenge for the future is the coordination and greater integration of all our ground and flight test activities." ∎

In November 2011, Embraer stated it would focus its attention on developing revamped versions of the E-Jet family



A Supplemental Type Certificate has been granted for SSJ100 to perform reduced thrust take-off

Komsomolsk-on-Amur Aircraft Production Association

Location: Khabarovsk Krai, Russia

Coordinates
Latitude: 50.567
Longitude: 137.0
Elevation: 38m

The dissolution of the Soviet Union triggered a deep crisis in Russian commercial aviation. A consolidation program led by Vladimir Putin saw the creation in 2006 of the United Aircraft Corporation, a holding company that contains a number of Russia's big aircraft manufacturers, including Tupolev, Beriev, Yahovlev, Irkut and Sukhoi.

Sukhoi is the most important of these. Not only does it boast an impressive roster of military craft, but under the name Sukhoi Civil Aircraft Company (SCAC) it has created Russia's most noteworthy commercial jet venture to date – the Sukhoi Superjet 100 (SSJ100). Built for short-to-medium routes, the SSJ100 is a 100-seater regional airliner with state-of-the art technologies built into its aerodynamics, engine and aircraft systems.

"The most important thing about the SSJ100 is that it is extremely pilot-friendly," says Sergey Korostiev, chief test pilot at SCAC. "I have flown many aircraft types and I can hardly use the same epithet with another."

The SCAC Flight Test Centre is in Zhukovsky near Moscow. From 2007, SCAC operated four SSJ100 aircraft prototypes for test flights, along with two for static and fatigue trials. The most large-scale flight tests were made to obtain Type Certificates from the Interstate Aviation Committee Aviation Register (IAC AR) and the European Aviation Safety Agency (EASA). In January 2011, the SSJ100 obtained the former and confirmed its compliance with airworthiness regulations, authorizing the commercial operation of the airplane.

CERTIFICATION

"The certification campaign incorporated 200 programs of static, fatigue and flight tests," says Korostiev. "We had ground equipment to perform strain-gauge graduation of sensors to determine the load on aircraft components, frequency response tests of the aircraft itself and 'fly-by-wire autopilot' loops, shimmy tests and tests on water ingestion from runway surface to engines, APU and aircraft components.

"The onboard equipment included an artificial icing imitator to stick to the leading edges of aerodynamic surfaces, smoke generators to produce smoke of target density to test the aircraft fire protection system, equipment for draining tests of fire-hazardous airframe structure chambers, flutter test equipment and everything else you would expect."

The four flying jets accumulated 2,594 flight hours during tests. Throughout its certification period, the aircraft visited over 20 airports across Russia, the former Soviet Union and Europe, proving its airport acceptance at even the most remote destinations. Meanwhile, the ground tests covered the ultimate pressure load of the fuselage, bird strike on the front upper cockpit panel, broken-tire strike on the lower hatch cover of the wing fuel tank and fire-resistance of the composite flap.

Although commercial operation commenced in 2011, the testing continues. In July this year, the AR IAC issued a Supplemental Type Certificate confirming that SSJ100 can operate in CAT IIIa environments, including landing in crosswind conditions. "The SSJ100 is the most important and successful civil aircraft program in Russian history," says Korostiev.

The next stage for Sukhoi is to fulfill its 320 orders for the SJJ100 and begin testing the Sukhoi Superjet 130 NG. The 130 is seen as a link between the SJJ and Irkut's MS-21, which is unlikely to see its maiden flight until 2015. The Sukhoi Superjet 130 NG has been designed to compete with the Airbus A319.

Belgian carrier VLM is to become the first European Union operator

ENTER THE DRAGON

COMAC (Commercial Aircraft Corporation of China) is a state-owned Shanghai-based aerospace manufacturer. It was established in 2008 to reduce the country's reliance on Boeing and Airbus, and to propel China into the world aviation market. Two of its twin-engined regional airliner ARJ21s – comparable in size to the Sukhoi Superjet 100 – finally entered service in May this year. This was after many years of delays, including one of three years before its maiden flight. Following its inaugural flight, wing problems emerged during the static testing, along with issues concerning de-icing and the avionics.

Meanwhile, COMAC's C919, designed to compete with the likes of the Airbus A320neo family, is working toward 2015 for its maiden test flight, having already missed this year's target. Insiders ascribe COMAC's poor scheduling to inexperience.

Bombardier, Mirabel & Wichita BFTC

CSeries test site, Canada

Coordinates
Latitude: 45.663753
Longitude: -74.001964
Elevation: 73m

Bombardier CSeries engineering simulator (ESIM)

CSeries Flight Test Vehicle FTV - interior view

Bombardier tests its aircraft at Mirabel near Montreal, Canada and Wichita, Kansas, with the focus of CSeries work at Mirabel, where the groundbreaking Complete Integrated Aircraft Systems Test Area (CIASTA) rig has been erected. Wichita also has a hand in CSeries testing, but focuses on the company's business jet, CRJ, Q400 and specialized aircraft ranges.

Bombardier bases ground and flight testing of its extensive aircraft product range at two primary test sites. Bombardier Flight Test Centre (BFTC) Mirabel is the center of CSeries test work, while BFTC Wichita is responsible for flight testing all Bombardier business, commercial and specialized aircraft.

Around 1,000 employees work across the two centers, and both facilities report to Marco Biondo, vice president, BFTC, product development engineering, aerospace, based in Montreal. He explains Bombardier's flight test philosophy: "BFTC is integrated in new product development during the design phase to define and optimize the test program, working with the integration team, suppliers and authorities before testing begins."

CSERIES TRIALS

Mirabel is dedicated to CSeries flight testing, with assistance from Wichita, which currently operates a pair of flight test vehicles (FTVs). Biondo notes, "The Kansas site has completed a large number of test programs since the BFTC was established 20 years ago. Regional aircraft programs include the original CRJ200, the CRJ700 and its variants, and the CRJ900 and CRJ1000 programs. The Q400 turboprop was also tested in Wichita.

"Its clean-sheet business jet programs include the Learjet 45, Global Express and Challenger 300. Over the years, many upgrades and variants have also been flight tested, including the Learjet 40, Learjet 70, Learjet 75, Challenger 605, Global 5000 and 6000, Global Express XRS and Challenger 350."

In addition to the CSeries, BFTC Wichita is actively working on the Learjet 85 and Challenger 650, as well as ongoing product improvements across the Bombardier aircraft range. "Also noteworthy," says Biondo, "are preparations for the Global 7000/8000 program."

TECHNICAL FACILITIES

"Wichita's facilities include a main engineering office, store and assembly shops for all the equipment and tools that flight testing activities require, integrated avionics test rigs for most platforms, telemetry rooms and a ground station, a flight test hangar and a special missions design group," says Biondo.

Mirabel offers a number of possibilities not available at Wichita, although inevitably the two have telemetry and ground station facilities and flight test hangars in common. Outside this, Biondo says Mirabel boasts an environmental control system for testing full-size pressurized cabin mock-ups on the ground, the CIASTA rig dedicated to the CSeries, and ESim for ground-based pilot and flight test engineer training.

According to Biondo, CIASTA "is one of the few state-of-the-art complete aircraft systems testing centers in the world." It is a fine example of Bombardier's efforts to evolve new test technologies to match evolving capabilities in airframe, engine and avionics design. "Systems and technology have evolved significantly," he says. "And its not only the aircraft systems, but also our flight test equipment and systems. In simple terms there is so much more that is now digital.

"While most of the means of compliance and test techniques remain the same, the complexity of achieving these and the data involved in demonstrating compliance has measurably increased. The strategy to address these challenges revolves around using more simulation and enhanced test rigs for integration and development to reduce the amount of required flight testing. For example, with the CSeries we invested in new technology that enabled us to validate more parameters and systems on the ground. It's about value-added and more efficient flight testing." ∎

Frame game

High-speed photography remains a vital tool in stores separation testing. Digital cameras are increasingly the norm, and the photography itself is now used in combination with sophisticated computer analysis

BY PAUL E EDEN

Loading an AGM-86B air-cruise launch test missile onto a B-52H Stratofortess on February 26, 2014

For decades, high-speed photography has provided imagery for detailed analysis of stores separation tests. The principle behind the technique is to record multiple frames per second (fps) – as many as one million low-resolution images per second in some scientific and industrial applications – and then play these back at regular video rates of around 25fps, 'stretching' each second of recording over a much longer viewing period to produce slow-motion footage. Photron manufactures a huge range of high-speed digital cameras, and Andrew Bridges, sales and marketing director for Photron USA, says, only half jokingly, "We make high-speed cameras for slow-motion analysis."

He goes on to provide a basic outline of high-speed camera technology, explaining that digital photography has revolutionized the industry. "The heart of any digital high-speed camera is the sensor. They're not of particularly high resolution compared with a typical consumer camera – the high-end for us is 1080 HD – but the majority of our cameras are around one megapixel resolution. Nevertheless, they have as many as 128 channels to stream data off at very high speed."

Data is buffered to an onboard memory, then downloaded post-mission. High-resolution images are generally not required for analysis, and even if they were, at high speeds it would be impossible to buffer to memory fast enough. "It's typically the bottleneck," says Bridges, "although it's not so much of a concern in airborne applications. We have sensors specifically designed and engineered to our requirements at considerable cost, and since we don't serve a mass market, high-speed cameras represent considerable investments. We've migrated from CCD [close-coupled device] sensors to CMOS [complementary metal oxide semiconductor]. CCD suffered 'blooming', or 'tearing', so that if an aircraft turned, and the sun entered the frame, you'd end up with a column of white that would destroy any information in the column where the sun appeared. In CCD, black is created at 0V [zero volts] and white at 5V, and the problem was that electrons could overflow into neighboring pixels, corrupting the whole column. With CMOS, black is 5V and white is 0V, and since voltage can't go below zero, we don't have blooming or tearing problems anymore."

THE TRIALS OF SEPARATION

Airborne separation trials, especially from fast jets, naturally occur in a harsh environment of low temperatures, slipstream and, perhaps, high or negative *g*. Fortunately, digital high-speed cameras are inherently tough, given they have no moving parts. Even high-speed film cameras were capable of performing under harsh conditions of freezing temperatures at altitude or considerable vibration and delivering steady, well-exposed images at up to 1,000fps.

100	The range of the Vympel R-77 air-to-air missile in kilometers
500-1,000	Typical shooting speed used for flare ejection trials (fps)
1,850	Range of air-launched Skybolt ballistic missile in kilometers
86,000	Weight of airborne Minuteman ballistic missile in pounds

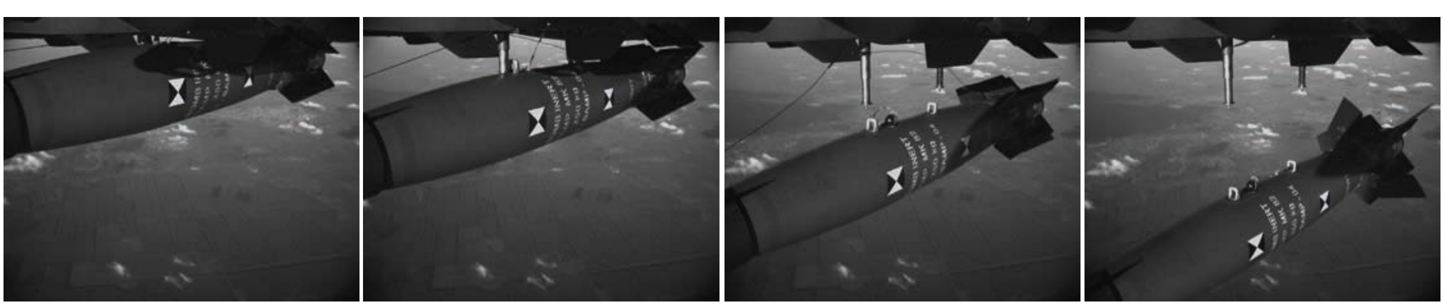
Photron builds ruggedized cameras for particularly harsh environments – "We do high-speed cameras that can withstand 100*g* and we do a lot of work for car crash testing" – while cameras used in airborne work are specially mounted. Converted missile bodies and modified drop tanks or similar pods are frequently used as camera containers in airborne work. Some cameras may also be equipped with a right-angle optic so that the body is arranged in line with the slipstream for minimal drag, or so that they will fit inside a long, narrow pod, while the lens looks out at 90°.

AOS Technologies' high-speed camera range includes units built to military standards. CEO Stephan Trost says that fast jet stores separation testing produces the most severe environment for its cameras. He notes, "These tests are expensive, so the cameras have to be reliable under these harsh conditions because a failure would be costly. The build and engineering is quite different to an industrial camera; the military cameras are built to our highest specification and independently lab-certified to military standards."

Trost says that although modified pods or tanks are often used as camera housings, AOS offers alternatives: "We have containers that can be filled with

LEFT: An AOS S-EM in action, mounted in a pod

BELOW: An AOS high-speed camera captures an aircraft bomb separation frame by frame



nitrogen gas to avoid condensation and they also have window heating – it depends on what the customer wants. Often it comes down to the infrastructure available at the range or test site and what the test requires – it may even need multiple cameras."

Interestingly, separation trials can be about more than weapons, as Trost describes: "Recently, we've done very different types of trial. We've worked with transport aircraft, filming decoy flares ejecting from their launchers. The trial was to ensure that they didn't enter the engine intakes and that they followed the correct trajectories, recording at between 500fps and 1,000fps. We also did some work filming the separation of freight pallets, and we've placed cameras in UCAVs for trials into their flight performance."

> "WITH FILM CAMERAS, YOU HAVE TO GET THE FILM UP TO SPEED AND THEN THERE'S A FINITE AMOUNT OF TIME BEFORE THE FILM RUNS OUT"

DEALING WITH DATA

Image manipulation has become an important facet of high-speed photography, offering choices in mounting configuration, since images can be mirrored or rotated. Less obviously, exposure can also be controlled, as Photron's Bridges explains: "For explosive events or tests involving a missile plume, for example, the lighting changes very dramatically from one frame to the next, and we have the ability to 'clip' the exposure of every pixel. We set a time threshold of 20% in a one millisecond exposure for example, and if the pixel reaches its exposure within that threshold, we reset it and expose it again, so that instead of a bright flame whiting everything out, we capture a little more detail at a pixel-by-pixel level."

Camera activation is typically integrated into the aircraft's systems and linked to the firing or release mechanism as part of the flight test instrumentation. "With film cameras, you have to get the film up to speed and then there's a finite amount of time before the film runs out. It might be possible to stop and start it a few times, but the acceleration and deceleration between events consumes film," explains Bridges. "With digital, we can continuously overwrite the data, so in theory you could put the camera in 'record' mode before you took off and we could grab the few frames required for the event, or partition the memory into as many as 64 blocks, each of 1GB per event."

REAL-TIME TELEMETRY

Discussing the possibilities for real-time telemetry from a high-speed camera, Stephan Trost says, "There's no real-time datalink because it would jam the telemetry systems, but there is the option of a video output, from the same high-speed camera, that provides a live view during recording, via downlink to a ground station. Operators can also choose to see the camera status – is it buffering, how much memory remains, is it live recording? – on a screen on the ground."

Modern high-speed cameras in airborne applications are typically small and light. Many applications, in scientific work for example, require a great deal of connectivity and functionality beyond the basics of the camera and memory, but these are not typical of airborne applications, which tend to require little more than power and a trigger. Such cameras therefore often weigh less than a kilogram, with perhaps a 7.5cm² front cross-section and 10cm depth, depending on record time, resolution and specific test functionality. Three or four cables are all that is required to connect the camera to the wider system. ∎

Paul E Eden is an aviation writer based in the UK

HIGH-SPEED AT BAE SYSTEMS

Chris Ryding, trials photographer at BAE Systems, details how the company uses high-speed photography in its stores separation work: "Typically we record at 200fps or 400fps, playing the footage back at normal video speed to slow the event down by 8 or 16 times, although normally the information is analyzed frame by frame. Most of our stores trajectory work is now done using computer predictions, however, so we don't film as many releases as we used to. Photography has become a tool to confirm these predictions, so we only film a couple of releases at the extremes of the release envelope for any store.

"We use the images to ensure that the store separates cleanly, without damage to the aircraft, and predictably. Other stores can affect the way air flows over and around the test store, and we film to look for adverse interactions. We also look at ejection mechanisms and activation lanyards, making sure they're working correctly, and that electrical connectors release cleanly.

"Our equipment is a combination of high-speed cine, high-speed video and real-time video cameras. Most of them are fitted in dedicated pods, modified from drop tanks for Typhoon and Skyshadow pods for Tornado, although we also fix cameras to the aircraft's skin. The real-time video is transmitted over the telemetry, while high-speed video imagery is stored in non-volatile memory on board the aircraft. On a typical release trial, we mount six to eight cameras onto the trial's aircraft and occasionally we have a camera in a chase aircraft.

"Markings are painted on the store and aircraft for trajectory analysis. We use a computer program called Trackeye for this, using virtual models of the aircraft and store. The software tracks the markings frame-by-frame and provides detailed analysis in 6DOF."

Killer instinct

The US Missile Defense Agency has successfully completed a unique missile strike test designated Flight Test Ground-based Interceptor-06b (FTG-06b)

BY DR CHRIS BROWN

On June 22, 2014, a diverse team of military servicemen, engineers and support personnel demonstrated US missile defense capabilities to detect and destroy a complex, exo-atmospheric ballistic missile target, representing a threat to the homeland. The successful test, designated Flight Test Ground-based Interceptor-06b (FTG-06b), was conducted by the US Missile Defense Agency (MDA) and combined personnel from the US Air Force 30th Space Wing, the Joint Functional Component Command for Integrated Missile Defense, US Northern Command, and the US Navy, to operate the Ground-based Midcourse Defense (GMD) missile defense system and an array of sensors. The test marked a milestone in GMD development and demonstrated the USA's ability to defend the homeland against ballistic missiles in long courses of flight.

GMD, as part of the nation's integrated Ballistic Missile Defense System (BMDS), protects the USA from long-range ballistic missile attack. The system uses hit-to-kill doctrine, which means that it intercepts and destroys missiles using only direct impact and kinetic energy, similar to shooting a bullet with another bullet. This requires great precision, because both the target missile and interceptor travel at thousands of miles per hour. Therefore, missile defense requires a wide array of sensors to act as an integrated system to detect and track targets. After detecting a target, sensors continue to track it and cue other sensors to look toward the target. These sensors provide multiple streams of information to the weapon system, allowing for high-fidelity tracking and inflight corrections to the interceptor trajectory.

TARGET LAUNCH

The FTG-06b test began with the launch of a launch vehicle (LV)-2 intermediate-range ballistic missile (IRBM) target from the US Army's Reagan Test Site on Kwajalein Atoll. An IRBM has a range of 3,000km to 5,500km, meaning it is a potential threat to the US homeland. The MDA Targets and Countermeasures division provides target missiles for flight tests that mimic the appearance and flight characteristics of real-world adversary weapons, helping to provide an operationally realistic test scenario.

The LV-2 target missile's two-stage booster carried a threat-representative payload on a northeasterly trajectory from Kwajalein Atoll across the Pacific Ocean to the north of Hawaii. Satellite-based sensors provided the first indication of the target launch to US sea- and ground-based radars, which acquired the target.

The US Navy Arleigh Burke-class destroyer USS Hopper (DDG 70) acted as a forward-based sensor for this test, exercising its long-range surveillance and track mission. USS Hopper, an Aegis BMD-equipped destroyer, detected the target shortly after launch from the Reagan Test Site, using its powerful onboard AN/SPY-1 radar system, cued by satellite data. The AN/SPY-1 is a multifunctional, phased-array S-band radar that performs threat surveillance, threat tracking, target characterization and fire control. The ship tracked the target for several minutes, providing target track data to the GMD fire control (GFC) system. GFC used the track data to calculate the path of the target missile and develop a firing solution for the ground-based interceptor (GBI) located at Vandenberg Air Force Base, California, USA.

RIGHT: The Missile Defense Agency successfully conducted a flight test of a three-stage Ground-Based Interceptor from the FTG-06b test in 2014

LEFT: **Notional graphic depiction of the FTG-06b scenario**

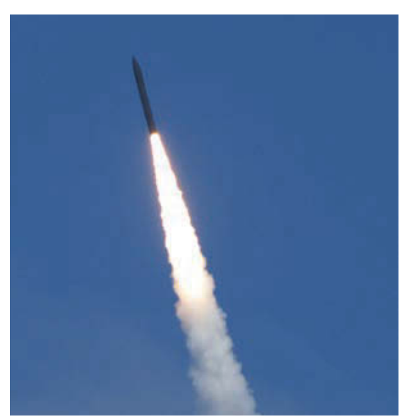
About six minutes after the LV-2 target launched from Kwajalein, an operational crew of US Army soldiers from the 100th Missile Defense Brigade, located at Schriever Air Force Base, Colorado, USA, remotely launched the GBI from Vandenberg Air Force Base. A three-stage booster rocket system propelled the interceptor's capability enhancement II (CE-II) exo-atmospheric kill vehicle (EKV) into the target missile's projected trajectory in space, according to the GFC firing solution. The 100th Brigade and GFC at Schriever Air Force Base are part of the overall GMD ground support system, which consists of redundant fire control nodes, interceptor launch facilities and the GMD communications network.

The AN/SPY-1 radar also passed data to GFC using the Command, Control, Battle Management and Communications (C2BMC) system. C2BMC is the integrating element of the BMDS. It allows different sensors and interceptors to transfer, share and use data. C2BMC binds the BMDS together – it creates a cohesive, layered missile defense system. C2BMC also provides command and control capability to defense leadership, allowing them to dynamically manage the BMDS to meet mission objectives. C2BMC is a key part of every BMDS flight test.

While the target and interceptor were in flight, the sea-based x-band radar (SBX), located in the Pacific Ocean, was cued with track data from the AN/SPY-1 radar via C2BMC. SBX is an advanced X-band radar mounted on a semi-submersible platform, based on oil-drilling platforms, which is larger than a football field and rises nearly 300ft out of the ocean. SBX acquired and tracked the target, and provided a powerful discrimination capability to update target track data. SBX provided detailed information to GFC, which sent inflight updates to the interceptor based on this data, which in turn made inflight corrections to intercept the target.

After receiving updated target track information and separating from the final GBI booster stage, the EKV used its onboard optical sensors to detect and track the target warhead. The EKV made final flight corrections and directly intercepted the threat warhead, using only the force of kinetic energy to destroy it. The intercept took place north of the Hawaiian Islands and at an altitude well outside Earth's atmosphere.

30	There are currently 30 Aegis BMD combatants (5 cruisers and 25 destroyers) in the US Navy – 16 are assigned to the Pacific Fleet and 14 to the Atlantic Fleet
65	This test (FTG-06b) was the 65th successful BMDS hit-to-kill intercept of a target out of 81 attempts since 2001
210	Russia's R-36M2 Voyevoda ICBM (known to NATO as the SS-18 'Satan') weighs 210 tons and carries 10 nuclear warheads, each with an explosive yield of 700 kilotons
880	North Korea is believed to be pursuing a submarine-launched ballistic missile program, which could deliver a 2,600 lb warhead more than 880 miles



LEFT: **A long-range ground-based interceptor launched from Vandenberg Air Force Base intercepted an intermediate-range ballistic missile target launched from the US Army's Reagan Test Site on Kwajalein Atoll**

ABOVE: **Personnel at the Missile Defense Integration and Operation Center on Schriever Air Force Base in Colorado Springs work at the test control facility during Flight Test Ground-Based Interceptor-06b**

> **"FTG-06B PLAYED A KEY ROLE IN ACCOMPLISHING THE MDA MISSION, WHICH IS TO DEVELOP, TEST AND FIELD AN INTEGRATED, LAYERED BMDS TO DEFEND THE USA"**

Debris from the target and interceptor safely burned up on re-entry.

TEST RESULTS

Preliminary post-test analysis showed that all FTG-06b BMDS components worked as intended, including initial launch indication, radar acquisition and discrimination, GBI launch and successful intercept of the target.

From target launch to intercept, satellites, ground- and sea-based radars, and the GMD weapon system acted as integrated components of the US Ballistic Missile Defense System (BMDS). They detected, tracked and destroyed a complex target resembling those that adversaries could potentially launch against the USA.

FTG-06b played a key role in accomplishing the MDA mission, which is to develop, test and field an integrated, layered BMDS to defend the USA, its deployed forces, allies and friends, against all ranges of enemy ballistic missiles in all phases of flight, by demonstrating the credibility of the portion of the system tasked with homeland defense.

This test was a milestone for the GMD program, marking the first intercept using the new capability enhancement II (CE-II) version of the EKV. As nations acquire and develop new missile-related technologies, missile threats from potential adversaries become increasingly complex. FTG-06b successfully demonstrated GMD and its CE-II EKV's ability to defend against evolving missile technologies.

MDA's test program provides critical data to demonstrate the operational effectiveness, suitability and survivability of the BMDS. Flight testing contributes to US nuclear non-proliferation goals by sending a very credible message to the international community about the nation's ability to defeat ballistic missiles in flight. This reduces the value of nuclear and non-nuclear ballistic missiles to potential adversaries.

Individual flight tests also provide data to anchor modeling and simulation. They demonstrate aspects of performance that MDA cannot currently model digitally. The wide array of sensors and assets, including space-, air-, sea- and land-based sensors gather data used to further bolster BMDS modeling and simulation. The models and simulations allow for cost-effective development of current and future capabilities.

This test was the 65th successful BMDS hit-to-kill intercept of a target out of 81 attempts since 2001. The GMD system has had four successful intercepts since 2006 using the operationally configured EKV. The operational GBIs are deployed at Fort Greeley, Alaska; and at Vandenberg Air Force Base. As MDA adds more interceptors to the operational fleet and enhances capabilities with the new generation of kill vehicles, the GMD system will continue to provide a credible deterrent and an important part of US defense. ▮

Dr Chris Brown is a trainer for mission execution teams with the Missile Defense Agency based in the USA

SMART INTERFACE

Integrated concepts for avionics test equipment are enabling the development of scalable and more portable solutions

The need to minimize investment in avionics test equipment has driven the development of interface products with a common functional core and software-compatible programming interface across differing platforms and form factors for more than a decade. From the software point of view, more integrated applications have appeared in subsequent years to support the test and integration of mixed (hybrid) avionics databus and network systems.

Today, preferences for the implementation of test systems vary widely with respect to the platform and form factors. Such an approach for modules with common functionality is still valid and beneficial for test system developers and for test equipment users, which ultimately select the 'best fit' solution for the application in hand. The capabilities on the application software side need to offer a wide set of functional features, plus customization to tailor the software to the specific application and user's needs. This is the foundation building block in the conceptual baseline for any integrated test system and systems solution.

However, more recently, demand has arisen for smarter, more portable and scalable systems. New form factors such as USB are increasingly popular, in addition to the well-established PCI-X/PCIe, cPCI, PXI, VME and PMC platforms. In fact, USB-based interfaces have taken a large share of applications that were previously implemented using PCMCIA/PC cards. With the decreasing support of these standards by PC vendors (due to obsolescence), USB has gained a further share of the market for portable applications.

Another aspect to be considered when using USB-based solutions for the implementation of test equipment is the separation of the interface hardware from the control platform. The PC platform technology, advances at such a pace that a PC platform may be out of date within two to three years. This obsolescence occurs even more rapidly with new and upcoming tablets (highly portable devices), which are integrated with even more new technology and features.

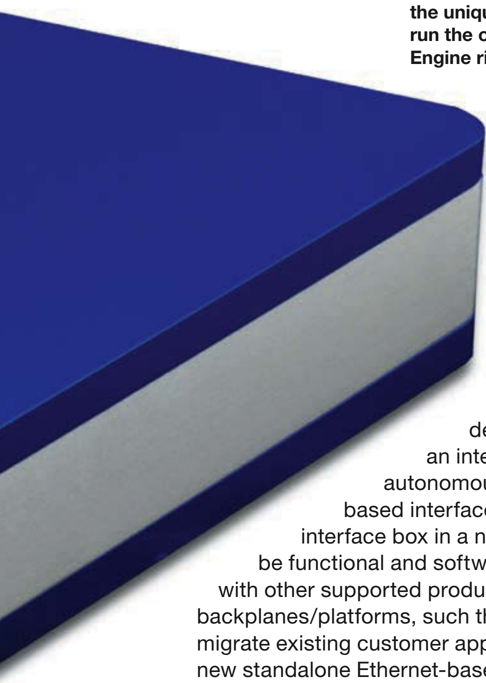
Despite the advantages of USB (and improvements with the 3.0 standard), the ability to draw only limited power over USB means that scalable solutions requiring more than one interface will need additional hubs and cabling. The maximum distance between the interface and control station, as well as I/O latencies, also becomes an issue.

It should be noted that typical test equipment and simulation is not necessarily limited to up- or downstreaming of bulk data between the control station and interface. But latencies introduced by USB may become an issue for event-driven operations.

WIRELESS ETHERNET

An upcoming alternative to support the separation between interface and controller is based on one of the most established communications standards over the past three decades: Ethernet. Almost every computing device today offers an Ethernet interface. Furthermore, the use of wireless Ethernet for application software offers further options for the implementation of test equipment and system solutions. The adoption of Ethernet as a new kind of 'backplane' for avionics databus interface hardware can keep pace with development and offers a wide range of applications.

FIGURE 1: ANET docking station (tower variant)



LEFT: The ANET 429-x embedded Linux operating system gives the unique capability to run the optional PBA.pro Engine right in the box

The first design goal for an integrated and autonomous Ethernet-based interface (standalone interface box in a network) must be functional and software compatibility with other supported products and backplanes/platforms, such that it is easy to migrate existing customer applications to the new standalone Ethernet-based products.

These applications can be based on an application programming interface (API) or on a software application framework (supporting scripts, user-defined graphical user interface, projects, and so on).

Ethernet-based interfaces provide additional functionalities beyond operating simply as 'another' type of interface hardware, such as offering fully autonomous operation with built-in scalability and flexibility. This gives rise to an open design with a common software platform, as opposed to a closed system design with limited configuration capability. This now becomes the baseline and building block of an 'integrated and smart' test system solution.

A good example of an open interface is the ANET family of Ethernet interfaces from AIM. These host an embedded Linux operating system, executed on a system-on-chip processor (SOC) and interfaced to the avionics databus interface core logic, common to other interface types and by definition functionally compatible. One task of the SOC is to offer a web-based configuration interface. For basic compatibility with existing software applications, the common API implements the fully transparent use of the Ethernet-based interface with minimal changes to existing code for establishing the Ethernet connection.

Added value comes with additional auxiliary interfaces of the interface box inherent within the Linux-based SOC. A general-purpose USB 2.0 port connects general-purpose USB devices for handling serial-to-USB, mass data storage and wireless Ethernet, all supported by default by the Linux operating system.

Conversion from a wired Ethernet to a wireless Ethernet avionics databus interface is fairly straightforward. Using a wi-fi-capable Windows or Linux controller plus the AIM application software framework, PBA.pro, a wireless and portable control station can be implemented (Figure 2). Support of de-facto standard encryption (for example, WPA2) and operating modes (ad-hoc, managed) are useful to meet policies for the use of wireless devices.

Fully autonomous operation is supported by an onboard Python interpreter for the execution of Python scripts utilizing the onboard API, identical to the common API, or by the optional software development kit for writing dedicated C/C++ applications (again, based on the common API), for execution on board the SOC processor, for example, for a customized avionics databus to the Ethernet gateway.

Another option is integration of the core engine of PBA.pro on the interface, which can be controlled from any TCP/IP-capable client, thereby completing the tool set for smart test equipment solutions.

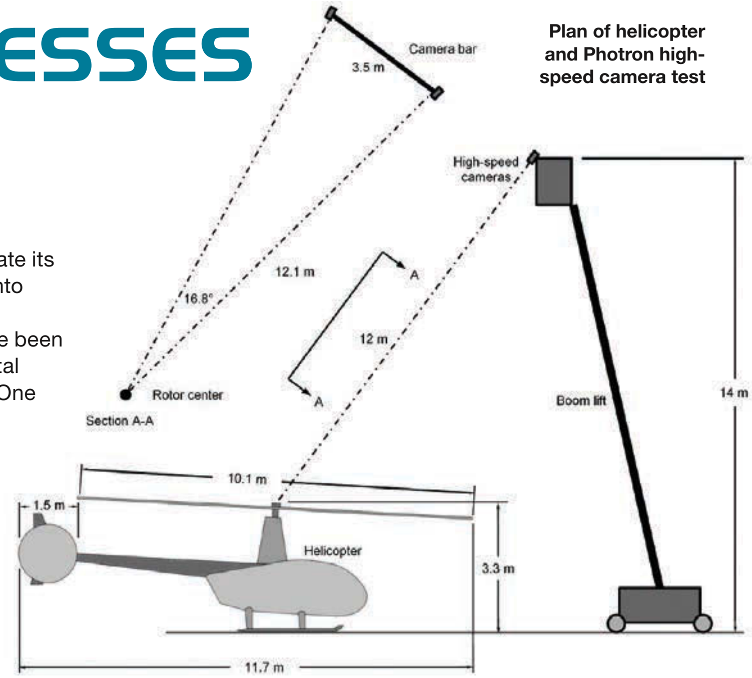
The real potential for smart and integrated concepts of test systems is derived from all these interface features designed within the new ANET family of Ethernet-based avionics databus interfaces working seamlessly with the PBA.pro application software platform.

Another new dimension for designers of test systems is the recently introduced docking station concept for Ethernet-based interfaces. This incorporates the common infrastructure for the Ethernet-based interfaces, including the power supply, a network switch and optional wi-fi router, so that multiple ANET units can be combined in a single chassis with just a single mains and network connection (Figure 1). ∎

FIGURE 2: ANET 429-x wi-fi operation

HIGH-SPEED PROCESSES

New high-speed camera models provide important data for the aerospace testing industry



Plan of helicopter and Photron high-speed camera test

Aerospace testing covers a wide range of applications, from dynamic testing of landing gear tires and suspension components, to fuel-injection spray patterns and combustion studies as well as wind tunnel analysis of flow, aerodynamics and turbulence. Other applications include material testing to measure surface displacement and stress, crack propagation on components and windshields, and ordnance testing for weapons release.

High-speed cameras have long been used as valuable test instruments, dating back to early 16mm film cameras, and more recently new solid-state models have been introduced that make it even easier for engineers and researchers to see and understand the results they need. These high-speed systems can record fast-moving processes at speeds up to two million frames per second (fps), capturing the most minute movements and the briefest of phenomena. Test engineers can then play the images back in slow motion and high definition, to review the results. Images can be studied on the spot, archived for later review, or analyzed in the finest detail before being approved or sent on to other departments and divisions for feedback and response.

One such camera, manufactured by Photron, is the Fastcam SA-Z high-performance camera, which features ultra-high speeds and outstanding light sensitivity, delivering high-quality images. The Fastcam SA-Z employs a square image format, ideal for applications requiring viewing through a round or square port, such as combustion studies or applications where a camera may need to be mounted to provide a non-typical view without sacrificing resolution in one axis. The SA-Z also has the ability to rotate its orientation when fitting into unconventional sites.

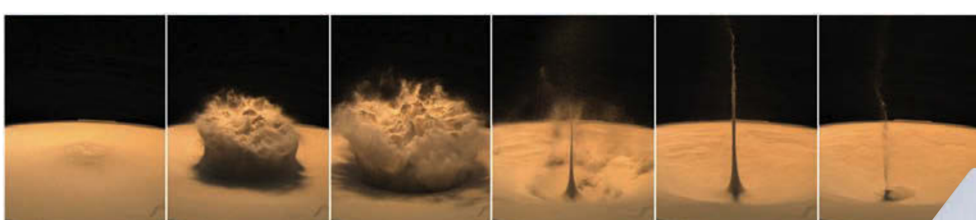
Photron cameras have been successfully used in digital image correlation (DIC). One example is where a random pattern is sprayed/applied to the solid surface to be analyzed as in non-contact testing of helicopter rotor dynamics. This type of testing avoids difficulties with cables and wiring and offers the ability to collect dynamic measurements in three dimensions. This application employs two cameras raised up above the helicopter blades and records the motion of the rotor when the helicopter is both on the ground and hovering. Researchers are able to see rotor dynamics and reveal full-field strain measurements and see both flexing and twisting deflection shapes.

Another area of testing is jet engine certification/blade-off testing, where a fan blade is explosively released from a running engine or component rig test. One primary measurement is the reaction of the lightweight containment ring. As the blade tumbles, strain propagation is measured and the dynamic response of the engine mount can be measured as well as the fan spool-down. Other fan blade tests by high-speed cameras are impact testing, using ice or ballistic gelatin for the impact. Testers can look at of both the blades and the engine.

Photron cameras are also being used to study the relationship between gas and granular motion, as when a craft lands on the surface of a planet. As seen by the high-speed camera, when a large, heavy object is dropped into a sandy material, a crater is produced and sand jets emerge.

Experiments recorded with the high-speed camera are ongoing to determine if these sand jets form because of the collapse of the sand's surface or due to air effects. Studies at the Institute of Physics in Puebla, Mexico, are investigating crater formation by gas explosions and the mechanism for cavity collapse, using Photron high-speed cameras.

To conclude, Photron high-speed cameras are a valuable tool to aerospace researchers and engineers for a wide range of applications covering a variety of tests that help improve safety while simultaneously helping to increase performance, efficiency and reliability. ∎



Crater formation made by pressurized cavity collapse. Photos: F Pacheco-Vázquez and F E Loranca-Ramos

Photron Fastcam SA-Z high-speed camera

WITH OR WITHOUT A PILOT

The Korea Aerospace Research Institute is developing an optionally piloted vehicle and testing its flight control system by running simulated flights in the laboratory with a test bench based on a dSPACE hardware-in-the-loop simulator

The advantage of using optionally piloted vehicles (OPVs) is that they can manage without a human crew on easy-to-navigate missions that do not require any on-the-spot decisions to be made by a pilot. Tedious, long observation missions are typical examples. Obviously, without a pilot on board, an OPV needs particularly mature (multi-redundant) flight control systems in order to fly autonomously and safely. The Korea Aerospace Research Institute (KARI) is developing algorithms for such flight control systems.

REALISTIC FLIGHT SIMULATION

The flight control systems are being developed with the aid of test bench tests (i.e. virtual flights in the laboratory). Suitable MATLAB/Simulink models have to be developed for this. To reduce the differences between virtual and real flight, the flight dynamics model was validated with flight test data. To aid pilot training, taking off, landing and taxiing on the airfield were also simulated. The virtual flights also have to cover different weather conditions (such as squalls). Using the validated flight dynamics model, all the automatic flight control laws were validated and tuned during the hardware-in-the-loop (HIL) phase. As a result, no tuning was necessary during unmanned flight tests. The performance matched that of virtual flight very well.

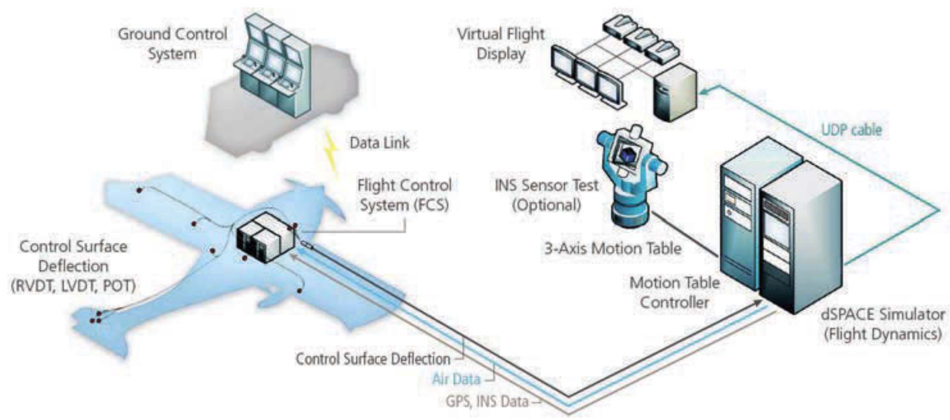
VIRTUAL TEST FLIGHTS IN THE LAB

The system that simulates flights for flight control tests consists of a dSPACE HIL simulator that computes the flight maneuvers and associated sensor values. It calculates the sensor values – the aircraft's position (GPS data), attitude relative to the direction of flight, acceleration, speed, and so on – and sends them to the flight control system via RS232. The flight control system uses this data to adjust the aircraft's control surfaces and guide it along the preplanned route. The positions of the control surfaces are then returned to the simulator to control the aircraft flight motion. All experiments are controlled and monitored from the test and experiment software ControlDesk. ControlDesk supports tasks such as manipulating the experimental conditions (wind, etc) and inserting any desired failures to test how the flight control system reacts – failed sensors or actuators and broken wires are some typical examples.

With this setup, comprehensive and complete tests can be performed without the aircraft having to leave the laboratory. This approach considerably reduces the number of real test flights, while increasing the reliability of the overall system at the same time.

UNMANNED TEST FLIGHTS

The aircraft has already successfully performed its first test flight, which contained all the auto flight modes: stick auto, knob auto, loitering and point navigation. The flight control system automatically computes the resulting pilot stick positions to guide the airplane. As a result of the accurate flight dynamics model and the preflight tests via the HIL system, no tuning interventions were necessary. ∎



ABOVE RIGHT: Schematic of the laboratory setup. A wide range of test scenarios can be performed on it without the airplane having to leave the laboratory

RIGHT: The ground control station transmits commands to the aircraft and displays all the aircraft's instruments. Virtual 3D graphics give a virtual cockpit view, which is useful for monitoring the aircraft's situation in the event the pilot-view camera malfunctions

DATA RECORDER

Unlimited scroll-back during long-term testing with Dewetron's DejaView

For long-term testing, a key issue is the missing or insufficient ability to view data in the past, while still recording. Dewetron recognized this problem and unlike the company's DEWE and DEWE2 series of instruments, which are aimed at R&D applications, the TrendCorder was designed from the ground up for basic data acquisition applications in industry. An all-new user interface and several key breakthroughs in the hardware have made it possible.

When the TrendCorder is turned on, an app loads and shows the incoming data immediately. It does not operate like a typical Windows-based computer. The TrendCorder can be operated 100% by touch, including alphanumeric entry, channel setup, and display configuration. The TrendCorder has four slots for user-exchangeable TRION series plug-in modules. A great selection of modules for virtually every sensor is available for the TrendCorder, from 100kS/sec to 2MS/sec, and with 16bit and 24bit resolution.

This wide variety of sensors leads right into the issue of having the correct physical input available. Dewetron's new TrendCorder offers four slots for TRION series modules. TRION modules are available for almost every sensor and combine the power of simultaneous sampling ADC technology with advanced Dewetron signal conditioning. These modules can be exchanged by the user in moments, at any time. Calibration is stored on the modules and running a self-test after installing a new module ensures proper function.

Each channel has independently selectable ranges. The user can select filtering for each channel at any frequency and with up to eight orders of roll-off. The filters are done in hardware, therefore they impose no load on the computer. You can select any filter on any channel, at any sample rate, even for the high-speed modules, which run at 2MS/sec per channel.

TrendCorder brings the intuitive multi-touch operation of an elegant app on an Apple iPad or smartphone, to the data acquisition world. Recording is started by one single touch. Gestures that you use on your smartphone also work on the TrendCorder and make browsing and zooming data very easy. Besides simplicity, the intuitive 64bit application with multi-touch technology shows its full power when past data needs to be viewed.

DEJAVIEW FEATURE

Even while the TrendCorder is streaming data continuously to disk at high rates, the user can scroll back on the recorder graph to any place in the recording and pinch/zoom on the graph to see any detail, no matter how far back in time it might be – and all without interrupting recording. This DejaView feature is very often needed by test operators conducting long-term testing, which cannot be interrupted. It is often not possible to stop recording just to allow a look back in time at previously recorded data. The TrendCorder's unique data-handling architecture represents a major technical breakthrough in power and performance.

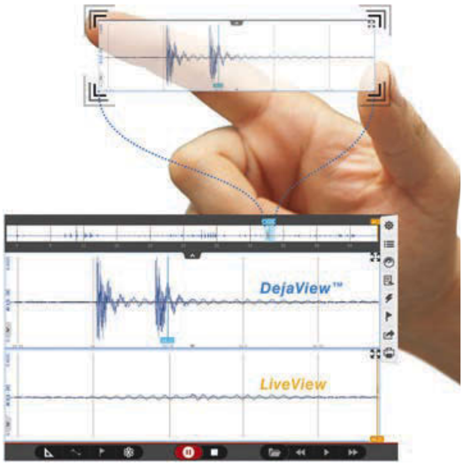
Typical long-term testing applications for such recorders are engine test chambers, burn-in stations, materials production testing, HALT and HASS lifetime testing, bench testing of satellite components, tap testing using high bandwidth accelerometers, and environmental labs. For these tests, besides voltage and current inputs, a wide variety of sensors, including strain gages, accelerometers, force sensors, pressure and load sensors, and thermocouples, are in use.

The bright 15.4in wide aspect multi-touch display is used to control the TrendCorder. Familiar graphical conventions such as pinch and zoom are fully implemented within the operating system, making operation fast and intuitive.

The TrendCorder weighs only 18.7 lb (8.5kg) including the input modules, and has been tested and proven compliant with rigorous shock and vibration standards, EMC, EMI and RFI. Its size is 18.2 x 12.6 x 5.3in (462 x 320 x 135mm). It features an adjustable kickstand that enables users to position the system at a comfortable viewing and operating angle, and then lock it in place.

RIGHT: Multi-touch gestures such as pinch and zoom make the TrendCorder as easy to use as a smartphone

LEFT: As well as the ability to look at old data, live data can also be seen at the same time, either on the same or on a different screen



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MULTIPLE FUNCTIONS

Use of composites in the commercial aerospace industry is increasing. They now make up 50% of Boeing's 787 Dreamliner

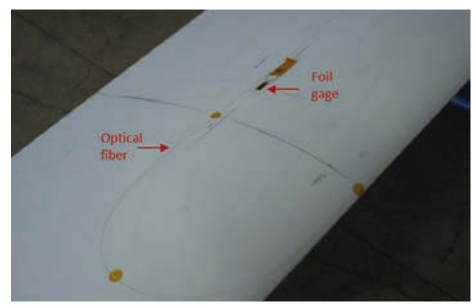
The increased incorporation of composites into manufacturers' built-from-scratch airplanes is attributed to an irresistible slew of benefits: high strength-to-weight ratio; lower pressure tooling; corrosion and fatigue resistance; and the possibility of tailoring the part's shape to your own specifications. Uncertainties remain, however: how does one fully test the performance of a composite part when its composition and structure is so inhomogeneous, and its properties so anisotropic? One way would be to continuously monitor the composite part, in the proverbial 'from cradle to grave' sense.

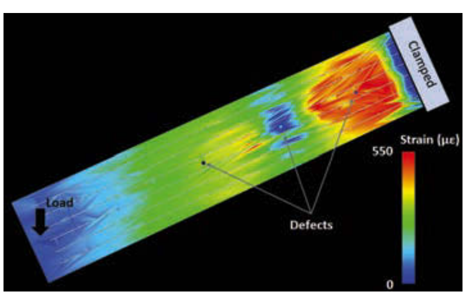
Imagine being able to: monitor the exothermic reaction and temperature uniformity during the curing process; measure the residual strains and non-uniform stress fields that result from the manufacturing process; track the evolution of this strain field with transport and assembly of components into larger parts; carry out active monitoring of the components during service; detect the initiation and growth of cracks within the part; and finally trigger warning signals when the crack has crossed a pre-failure threshold and the component needs to be removed from service. Now imagine being able to do all this with a single type of sensor that is embedded within the composite parts from its inception. This capability would result in improvements that reverberate across multiple aspects, including more efficient manufacturing processes, optimally designed tooling, lighter parts with lower safety factors, and longer service life. The ultimate result would be cost savings on the aircraft manufacturer's part.

This is not as much of a pipe dream as it might initially seem. Fiber-optic sensors could potentially fulfill this role. Fiber sensors are small, light-weight, immune to EMI, radiation-resistant, very strong and extremely fatigue tolerant. With such a low profile (150μm diameter), fiber sensors can easily be embedded into composite parts during the lay-up process, for continuous monitoring during both manufacturing and service. Luna Innovations (Roanoke, Virginia, USA) is applying its technological advantage in the fiber-optic measurement world to distributed strain and temperature-sensing applications. The secret sauce of the Luna system is its interrogators that have been developed to provide very high spatial resolution measurements along a whole fiber sensor, tens of meters in length. This technology enables low-cost, fully distributed sensing capabilities with millimeter spatial resolution and high dynamic range.

Some of the measurement goals as highlighted above have been previously demonstrated in work that Luna carried out with Sandia National Laboratories (Albuquerque, New Mexico) and TPI Composites (Warren, Rhode Island) on a 9m wind blade with carbon-fiber spar caps. Intentional defects were created by casting resin-rich areas prior to lay-up, and fiber sensors were embedded within the blade, as well as bonded on its surface. The blade was then transported from Rhode Island to Boulder, Colorado, where pull, property and fatigue testing were carried out on it. The sensors not only clearly pinpointed the initial locations of the defects, but were also used to monitor developing damage during fatigue loading, and accurately predicted which load location would fail first. Single-point electrical strain gauges placed along the fiber sensor path accurately measured the local strain, but completely failed to detect the presence of the embedded defects.

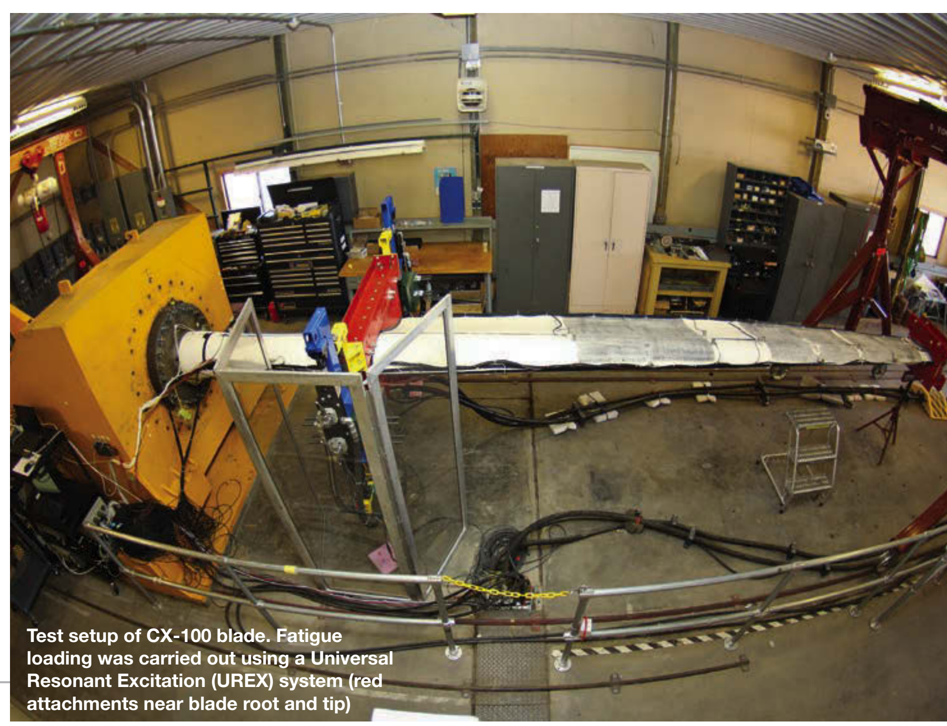
Information obtained from a truly distributed sensing system could provide invaluable insight into the parts and systems integral to the aircraft's performance, from inception through to retirement. ∎





ABOVE RIGHT: A single fiber optic sensor bonded onto the surface of a wind blade produced thousands of measurement points, while a single electrical strain gauge alongside it produced only one

ABOVE: A single fiber sensor embedded within a carbon composite panel in multiple passes resulted in the ability to map the full field strain within the panel. Strain gradients due to intentional defects are clearly visible when the beam is cantilevered



Test setup of CX-100 blade. Fatigue loading was carried out using a Universal Resonant Excitation (UREX) system (red attachments near blade root and tip)

ORGANIZATION-WIDE ACQUISITION

One modular system quickly reconfigures for different tests, covering all vibro-acoustic acquisition from engine testing to noise mapping

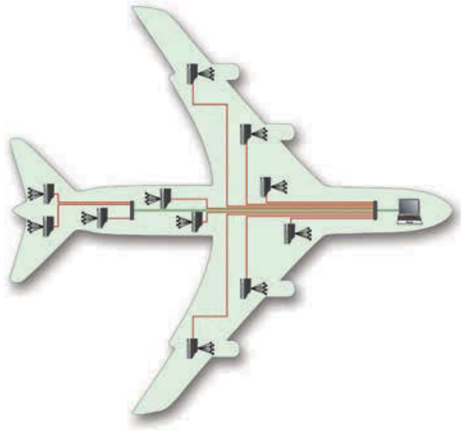
From airframers to engine makers to interior suppliers, vibro-acoustic testing is ubiquitous. Since many types of vibro-acoustic tests are conducted – from ramp noise to structural analysis – data acquisition systems are the backbone of an organization's test capabilities. And given that procurement of such systems requires a major investment in time, research and capital, it makes sense to maximize the potential uses.

The LAN-XI data acquisition hardware from Brüel & Kjær has been capturing acoustic and vibration data for close to a decade. In that time, more than 10,000 modules have been shipped to users, ranging from satellite testers with hundreds of channels, to wind tunnel owners, to engine test facilities, to OEM flyover specialists.

With such diverse uses, there are many demands for these COTS systems, and at some customers' locations, they are divided and reconfigured regularly, according to the needs of the moment. So for large test programs, all the racks of modules can be collected together into highly stable, large systems. But equally, racks of modules or individual modules can be split up and used in different tests by different people in different departments.

With one acquisition platform as an organization's backbone, possible systems can thus be as portable as one module with a laptop, or as large as hundreds of channels in racks. Joining modules and racks of modules is simple, with just a single LAN cable for data transfer and perfect synchronization using the Precision Time Protocol. It can even be wireless, using GPS timing.

Having simple LAN cables for data transfer allows large systems to be positioned near the test object. Being close to the transducers means that the messy and error-prone analog cables that connect the transducers



can be minimized. Equally, modules are distributed around aircraft interiors, engine test stands and flyover arrays. Here, the LAN cables connect all modules to a network switch, and also power them via Power over Ethernet.

The synchronized digital signals can then be further transmitted by fiber-optic cable. What's more, a charge injection calibration feature enables testers to remotely check the complete health of all channels in the distributed network by pressing a single keyboard key.

With many different uses, a wide dynamic range is necessary – 160dB in this case. This is achieved by dual analog-to-digital convertors that seamlessly switch over when one is close to overloading. In practice this means the hardware can measure a wide range, from the lowest levels to the loudest noises, without having to change settings to avoid over- or under-loads – eliminating the setup time needed for input ranging.

Different tests require different frequency ranges, so LAN-XI has a range of modules. To name a few, standard modules offer all-round performance and favor more channels; bridge modules address bridge sensors such as strain gauges; high speed modules are optimized for 200kHz; and generator modules have output signals as well, for tasks such as sound mapping. But they are all versatile, so not only can individual systems be specified to meet precise test needs, but the same platform can also be expanded and extended as necessary by subsequent purchases or repurposing of modules.

Across an organization, data acquisition systems are used for increasingly diverse types of input signals, such as auxiliary inputs and differential charge accelerometers, so the modularity addresses this.

A range of interchangeable front connector panels is available, so users can simply unscrew the green panel that holds all the existing input connectors on each module and replace it with an alternative – chosen from over 40 types such as BNC, LEMO, Sub-D and TNC. A special front panel even allows a 132-channel microphone array to be connected in a few seconds.

These front panels contain all the necessary signal conditioning, so users can directly connect anything from charge accelerometers to strain gauges, with whatever connectors they or their transducers prefer. This removes the expense and complications associated with external signal conditioning – such as additional calibration – and enables organizations with large stocks of charge transducers to continue to use them.

Above all, the modular nature of the system means that organizations have a single system, meaning less training and variability, and more options for future test requirements. And with one supplier organization-wide for support, spares, training and new developments, an efficient partnership can bloom. ▮

RIGHT: Systems from two-channel, briefcase-size modules up to racks of hundreds can be quickly configured, or split as required

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DYNAMIC ENVIRONMENTAL SPACE TESTING

The latest technological developments in the international space testing community

Vibration testing is a big milestone for any space program. And no wonder – space is one of the harshest environments in engineering. It doesn't matter if you are launching a state-of-the-art, 8 metric ton communication satellite, the Rosetta spacecraft, or a 1.33kg CubeSat, these orbiting wonders of technology must be thoroughly tested prior to lift-off.

So how does one do this? Basically, following a strict vibration testing process, scientists rule out the impact that noise and vibration effects during launch would have on the overall satellite structure and other expensive equipment and payloads. Nobody wants to see a failed or aborted mission. Comprehensive testing is the best-possible insurance policy. So, one can easily see why the space community places great value on the vibration testing process.

While technology and research move forward, global space programs and commercial endeavors are constantly under the knife to reduce development time and cost. This is influencing testing technology considerably. Will hot topics like multi-input excitation, Direct Field Acoustic eXposure (DFAX) and non-linear dynamics be the new standard in environmental vibration testing? Or will improved virtual testing reduce testing time cycles and cost, while increasing test confidence and safety?

To start a conversation around these topics, Siemens PLM Software gathered a group of world experts from both the academic and industrial space communities in Braunschweig, Germany, earlier this year.

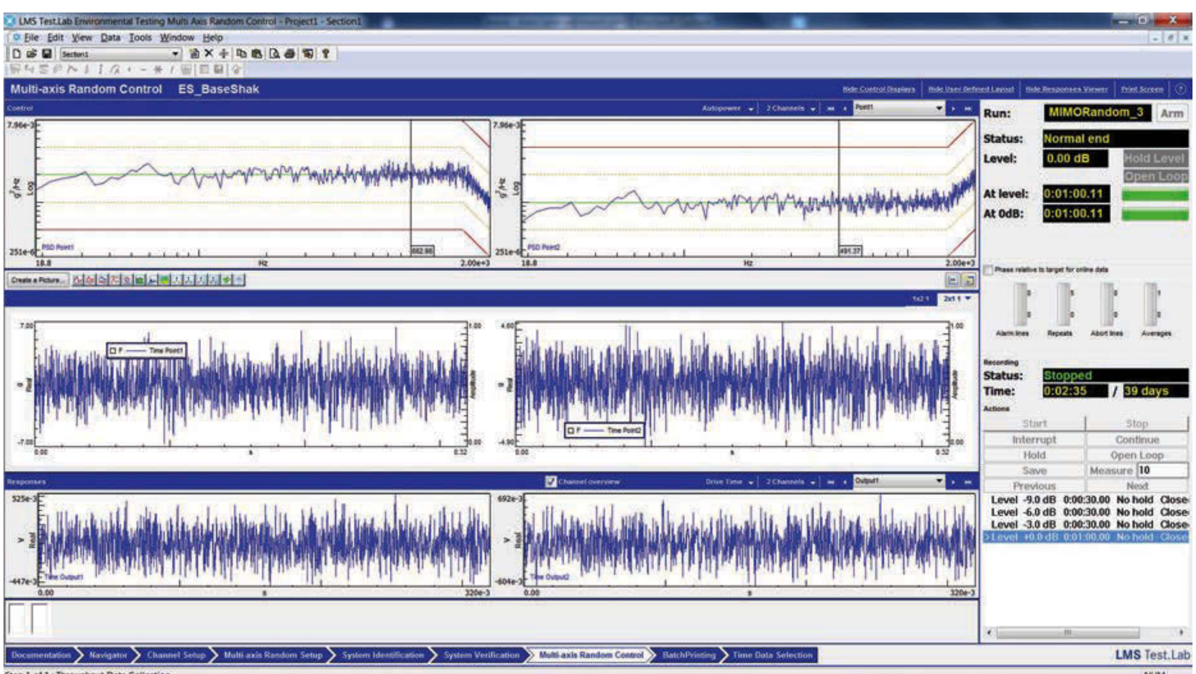
Dubbed as the first user group meeting for experts in space testing, the event included technical presentations from Thales Alenia Space, a satellite OEM; IABG, a major European analysis and testing organization; SABCA, a tier-one supplier to the space industry; and Japan Aerospace Exploration Agency (JAXA), Japan's national aerospace agency.

The audience included experts and academics from various companies, universities and institutions. The discussion concluded with a roundtable led by Rafael Bureo Dacal, head of the structures section at the European Space Agency. From this information and open exchange of views, four key topics emerged: non-linearity; micro-vibrations; DFAX; and multi-input, multi-output vibration testing.

Alex Carrella, product manager of dynamic environmental testing at Siemens, is excited to share the expertise and know-how gathered by Siemens working with world-leading industries in all engineering fields. For example, non-linear testing is used to characterize anti-vibration mounts in the helicopter or automotive industries; and MIMO testing is a reality in the defense sector, where very long structures cannot be excited with only one shaker.

At the same time, hardware is evolving to provide new solutions for space labs. Miniature shakers, like LMS Qsources hardware, can be mounted locally and excite the structure with just a few newtons, an ideal solution for micro-vibration testing. There is also a new dedicated LMS SCADAS data acquisition card that uses voltage or charge input, as well as providing an analog copy of the signal for back-up purposes.

Siemens is also involved in some groundbreaking research projects, including the EU-funded acoustic research on DFAX and the ADvanced Vibration ENvironmental Testing (ADVENT) research program, which will address MIMO, acoustic testing and other such topics. ▮



LMS Test Lab MIMO Random Control is used in several labs to increase vibration test efficiency

AUTOMATING SQUIB TESTING

Missile squib testing has always been a dangerous and time-consuming practice. Now one company says time constraints will come down, and safety will increase

With recent advances in testing automation, it should come as no surprise that automated missile squib testing has finally become a reality in both production and depot maintenance environments. However, with safety being the main concern, no one has been in a hurry to automate a process that could potentially cause an inadvertent rocket firing, which could result in a catastrophe.

So for decades, the process of testing squib circuits on missiles remained a manual and time-intensive task. The testing technicians would work from schematics to connect to each circuit path. "Testing a whole missile would take three people two days to complete," says Rich Welter, an electrical engineer at Raytheon. "One person would connect the leads, a second would record the readings, and a quality assurance person would oversee the process."

Testing a complex squib with multiple resistance, diode and broken wire checks was tedious and prone to human errors. Automating the process would save time and money, but more importantly would also reduce the risk of human error. For these multiple reasons, squib testing was a prime target for automation as long as the safety concerns could be properly addressed.

Space Electronics, a company that has been in the igniter circuit testing business since the early 1980s, has entered the market. For many years, the company sold single-channel portable testers used on shipboard by the US Navy. Their design advanced the safety aspect by creating a test circuit where all of the critical elements are redundant and failsafe. Even if every active test circuit component were to fail simultaneously, the output current would never exceed 5% of a level required to detonate the test article. In addition to their single-channel testers, Space Electronics designed and built several custom testers for various ordnance projects over the years.

Building on dual expertise in automation and igniter circuit testers, Space Electronics designed the SQB product line of squib testers, which were capable of automatic testing of more than 500 circuits with one tester. This new line combines proven safety features, such as the failsafe and current-limited test connection, with new patented inventions, such as fiber-optic connection to a controlling PC with software and a failsafe front-end switching matrix, among others.

Space Electronics' new programmable and multichannel testers are gradually finding their way into the production line as well as the depot. What was once a multi-day and multi-person operation, is now reduced to one test operator and a fraction of the time previously required. In some cases, a total missile system test can be completed in a few minutes.

Depending on the application, testing can be implemented using a number of different methods. A semi-automated method consists of a single-channel squib tester controlled by automation software. In this case, the software instructs a test operator to connect leads to the proper test points. It then acquires data for that channel and prompts the operator to move on to the next channel. This process can be run by a single person.

This semi-automated process lends itself to two different tests. It can first be used for testing many single-channel units, yielding immediate pass/fail results. The same tester can also be used on a complex test article with multiple squib circuits. An engineer pre-defines a test sequence and programs the measurement type, range and pass/fail limits for each channel. The operator is prompted through the sequence to connect the leads and acquire the readings. The results are analyzed immediately. The tester may also be configured to prompt the operator to re-measure any failed circuits.

In the case of a fully automated test, a multichannel squib tester is connected to the test article via an adapting harness. A remotely located computer with automation software then takes control, automatically changing circuit paths, test ranges and test functions through a predefined list of tests.

Whether used in a semi-automated or fully automated mode, all test data is compared to pass/fail limits and logged in a database. Results can be either exported in an electronic format, or printed. Statistical analysis of sets of test articles can be performed.

With its new SQB line of testers configured for maximum throughput and reliability, Space Electronics has safely brought about automation in missile squib testing. ▮

The model 101-SQB-RAK is a single-channel automated squib tester developed for Raytheon and used on the SM3 and ESSM missile programs

Two automated squib testers: a 16-channel version (left) and a 2-channel version (right)

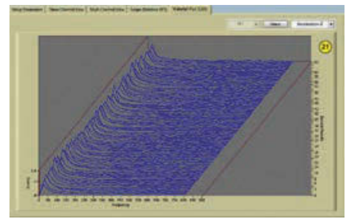
PORTABLE DATA ACQUISITION SYSTEM

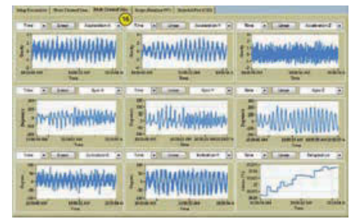
Dytran Instruments has introduced the next-generation VibraScout, a digital 6DOF sensor, combining a triaxial MEMS accelerometer, a triaxial gyroscope and an onboard temperature sensor with a microcontroller to create a smart sensor. The VibraScout 6D is a USB-powered, plug-and-play, cost-effective and portable data-acquisition system where users can quickly and easily measure X, Y, X acceleration, roll, pitch, yaw and temperature using a laptop or tablet.

The Dytran model 5346A is a unique and innovative solution for fast, portable and cost-effective vibration surveys and data acquisition in a myriad of automotive applications, including ride quality, component testing, impact testing and end-of-line testing. The system stores acceleration, gyro and temperature information, and the built-in firmware handles USB communication and provides a number of unique features, including: storage of device serial number; and storage of accelerometer, gyro and temperature calibration data.

The accelerometer contains a variable capacitance (VC) MEMS chip with USB interface. The sensor is hermetically sealed in a titanium housing weighing 13g, allowing it to be used in harsh environments, from test tracks to field monitoring. The frequency range of the VibraScout 6D accelerometer is 0Hz (DC) to 1,100Hz; and the gyroscope is 0Hz to 250Hz. Units can withstand 10,000*g* shock.

The VibraScout 6D vibration measurement system includes: model 7546A (available in ranges of 14g or 200g) USB triaxial DC response accelerometer; model 6330A 15ft, 4-pin to USB cable assembly; VibraScout 6D data-acquisition software; and VibraScout Windows-compatible post-processor software on CD (no license required).





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ACTUATOR TEST SYSTEM FOR LINEAR ACTUATORS

Within the MRO and OEM community, the reduction of turnaround times has been a crucial focus in recent years and it will continue to be extremely important in the coming years as well. One way of economizing is saving time and costs through the reduction of setup times, user friendliness and intuitive handling, since OEMs and MROs cannot afford to reduce the quality of their products and services.

Test-Fuchs, a global expert in innovative test solutions, has again delivered innovation with the launch of a new test stand for electrically driven linear actuators. This test stand will be used within the production, commissioning and testing of actuators for different aircraft programs.

This new testing solution focuses on the precision of the test; the requirements of modern production; and especially on usability and quick handling. Its customers' requirement for extremely high precision in measurement is always Test-Fuchs' main focus, but this test solution ensures that the units under test are tested with the very latest technologies.

On this versatile test system, the linear actuators are loaded on two independent hydraulic cylinders with different load capacities to cover the wide range of different test parameters in the very small required tolerances. The test system has a very ergonomic and compact design; it is basically made up of a test stand with integrated test cells and a mobile user unit.

The basic frame of the test system has doors and covers that guarantee perfect access to all the necessary parts. Mounting and dismounting of the units, and even regular maintenance and calibration operations, can be carried out easily through these doors and covers, saving time during procedures.

Another big issue in every industrial plant is the safety of its personnel, and Test-Fuchs is always eager to come up with new ways of improving safety. In this test system, the actuators are mounted and tested in a special test cell.

The user has full visual control over what is going on at any time and the protective covers cannot be unlocked or even removed accidentally during the test phase. The user-friendly software enables completely automatic test cycles or step-by-step tests, emitting a test report automatically at the end of the test cycle. The user administration and the calibration software are integrated into the TFSW2000 test bench software.

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ANET AVIONICS DATABUS

The PBA.pro Engine option for the AIM Ethernet-based ANET avionics databus interface family (MIL-STD-1553, ARINC429, STANAG3910/EFEX) brings the AIM PBA.pro bus analyzer application software functionality right into the interface level.

The ANET-embedded LINUX operating system runs the PBA.pro application without a graphical user interface, such that PBA.pro projects, simulation setups, databases for payload decoding and scripts can be executed right on board the ANET interface. Control of the PBA.pro Engine is achieved over an Ethernet TCP/IP connection and clients wishing to use the PBA.pro Engine do not require any native driver software. The major benefit is that the ANET with the PBA.pro Engine can be used from any client operating system.

An embedded web server and configuration application enables the setup and control of the PBA.pro Engine inside the ANET via a web browser. PBA.pro elements to be executed via the PBA.pro Engine can be developed offline from the ANET by any standard PBA.pro license or PBA.pro 'No Target' licenses.

In addition, the PBA.pro Engine control over Ethernet represents a high-level application interface for the ANET, which again can be used by any Ethernet- and TCP/IP-capable client. This offers a unique and efficient way to combine the AIM hardware and software capabilities.

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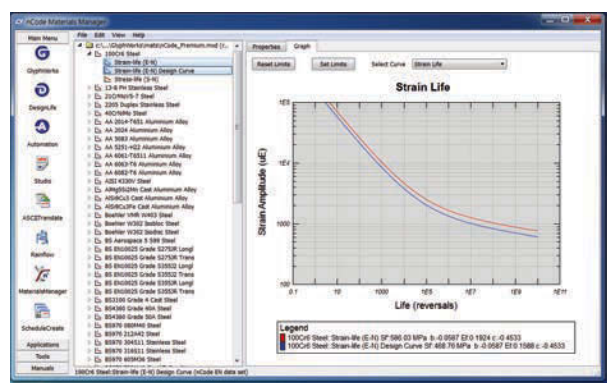
PREMIUM MATERIALS DATABASE



HBM-nCode has recently added 15 new materials into its Premium Materials Database, providing engineers with reliable, high-quality fatigue parameters, helping to eliminate the need for costly material tests. This set of new material data includes fatigue parameters for aluminum alloys typically used in the aerospace industry, such as AA 2124-T851, AA 7050-T7451, and AA 7050-T7651.

The Premium Materials Database consists of 87 materials derived from tests performed in the ISO 9001-certified advanced materials characterization and test (AMCT) facility operated by HBM-nCode. The AMCT facility uses tried, tested and assured processes to gather data on individually tested fatigue curves under this strict certification.

To help select required materials, the database identifies materials according to international standards (ISO, DIN, WNR, UNS, etc) wherever possible. Statistical estimates of scatter are also provided to enable reliability and certainty of survival percentages to be assessed.

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Fighter-powered car

A major milestone in the build of the 1,000mph Bloodhound supersonic car has been reached with the fitting of the Eurofighter engine

BY CHRISTOPHER HOUNSFIELD

In October 2014, the Bloodhound supersonic car (SSC) build team achieved a significant milestone in the construction of the world's most powerful car when they fitted its turbofan EJ200 jet engine for the first time.

Normally found powering a Eurofighter Typhoon, the EJ200 jet engine weighs 1 metric ton (1,000kg) and produces 20,000 lb (90kN) or 9 metric tons of thrust. The engine is largely based on the Rolls-Royce XG-40 technology demonstrator, designed in the 1980s.

A team of five technicians spent eight hours making sure the jet engine is a perfect fit with the upper and lower chassis and the carbon composite air intake, validating 30 years of design.

In the jet fighter, the EJ200 is designed to be hung from a single mounting point (trunion), so Bloodhound replicates this. The upper chassis is made of strong but light aluminum, to which titanium stringers and titanium skin will be fixed using glue and 1,400 aircraft spec rivets. The lower chassis below the jet is made of aluminum and steel and houses the Nammo hybrid rocket. The two powerplants together produce 135,000 thrust horsepower – or the equivalent of 180 F1 cars.

The design has evolved using a series of concepts that have been validated by modeling, or using the designer's experience in consultation with his peers and specialists from outside the team who have the relevant expertise.

ENGINE INSTALLATION

The build team trial-fitted the upper chassis ribs over the jet engine to check the fit and clearance for the numerous fuel, electrical and hydraulic systems before the upper chassis was assembled, bonded and riveted. The upper chassis ribs are covered in plastic wrap to keep contaminants off the bonding surfaces.

Chief engineer Mark Chapman says, "This is a fantastic moment in the project; it's great to see the jet engine fitted, it validates the many years of hard work by our team of motorsport and aerospace engineers."

The workshop has been a hive of activity as the 3,000+ individual components are delivered from manufacturers all over the world and assembled in the Bloodhound Technical Centre in Bristol, UK.

The car is a hybrid of fighter aircraft, car design and latest technology. Chris Fairhead, Bloodhound's delivery director, details the aerospace element: "We used computational fluid dynamics for the shape, and carbon fiber for the main structure housing the driver and the HTP [high test peroxide] tank. The titanium sheet is glued and riveted to 'formers' for both upper chassis (housing gas turbine and rocket) and the fin."

In simple terms, the Bloodhound jet- and rocket-powered car comprises a carbon-fiber monocoque front section joined to a steel, aluminum and titanium rear chassis. Some 70% of the components have either been completed or are with manufacturers – the final 30% will be ordered by the end of 2014.

TESTING TIMES

Fairhead explains the problems the build team have had to face during the early test phase: "Defining the airflow over the car at supersonic speed, and interpreting the influence of the shockwave on the static pressure balance has proved very difficult, leading to many interpolations of the shape of the car. Testing in 2015 will confirm that the actual loads on the car are similar to those that we have calculated and so will enable us to increase speeds in increments to a first test year maximum of 800mph.

"The EJ200 engine has completed a flight test program in the aircraft. The intake on the car has been evaluated for its airflow characteristics by both Bloodhound and Rolls-Royce specialists," he adds.

When asked a question about wind tunnel testing, Fairhead says briefly, "No wind tunnel facility has a moving floor capable of running at 1,000mph. During the design of the earlier Thrust SSC model, a validation test for the accuracy of the software used a rocket test at Pendine Sands in South Wales."

The project is now on course for the finished car to roll out for low-speed testing (up to 200mph) at Aerohub at the UK's Newquay Cornwall Airport in summer 2015. Bloodhound will then fly to South Africa for the land speed record campaign that autumn at Hakskeen Pan, chosen in part for its altitude: "The car will be traveling faster than an aircraft. Hakskeen Pan is at 3,000ft, so effectively it is at flight altitude," says Fairhead.

Bloodhound SSC may be the most powerful land vehicle in the world, with 47,000 lb of thrust, but going fast is not its primarily role. Rather, it is designed to inspire a generation by showcasing science and engineering in the most exciting and accessible way possible, explains the team. With aerospace being such an important aspect of the UK economy, and future skills a key concern, government and the UK's high-value manufacturing sector endorse Bloodhound's mission. ∎


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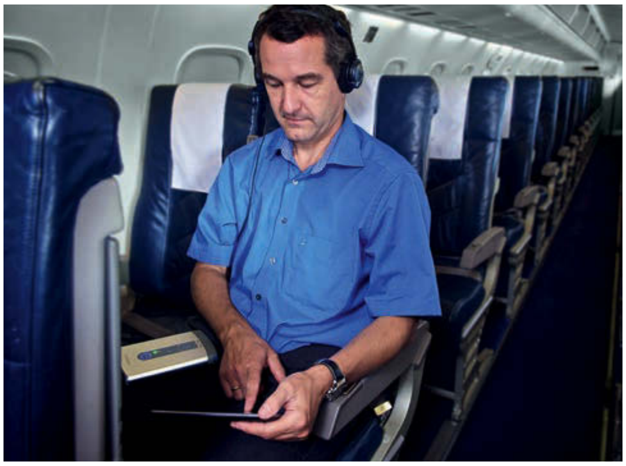

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