DECEMBER 2016

Aerospace TESTING INTERNATIONAL

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As a third E190-E2 joins Embraer's flight test program, we reveal the tricks behind the aircraft's rapid development

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All aboard with the F-35C

Exclusive report on the third and final shipboard developmental test phase for the F-35C Lightning II

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Global briefing

Inside this issue

// Fit for duty

In an increasingly automated world, where the clamor for a new generation of autonomous vehicles on land, sea and air seems to grow louder with every passing hour, perhaps one day soon we will no longer need to consider the 'human in the loop' from a testing perspective, regardless of how unsettling that may seem. However, one could argue that we do not consider it enough right now, often confining our analysis to structural, electronic and digital systems, without a full and detailed understanding built on scientific observation of how the pilot and crew interact with them and the aircraft as a whole.

"I think the pilot-vehicle interface is extremely important in air vehicle design," notes Frank Colucci, who takes us behind the scenes at the US Army Aeromedical Research Laboratory on page 56. "Before USAARL had a research simulator that could measure the vital signs of pilots under stress, researchers and engineers had only qualitative pilot perceptions with which to work. USAARL provides quantitative performance data about the pilot-vehicle interface in realistic conditions. That brings the air vehicle design back to what the pilot sees, hears and feels."

Based at Fort Rucker, Alabama, the USAARL simulator most recently tested how pilots reacted to new display symbology for an integrated cueing environment to counter brownouts and other degraded visual environments. "The same modified training device previously tested aviator cooling solutions for hot cockpits and a bladder relief system for long-endurance flights," writes Colucci. "According to Flight Systems Branch chief and lead research pilot Erick Swanberg, 'That's really what sets it apart – our ability not to use it just as a training device, but also to collect data in real time from the pilots in an environment we can simulate.'"

Meanwhile our cover story (page 16), written by Thomas Newdick, explores the lessons learned by the Patuxent River Integrated Test Force during the third and final shipboard developmental test phase for the F-35C Lightning II aboard USS George Washington, back in August.

No doubt touching down a US$116m missile-laden fighter on a moving platform subject to the whims of wind and wave is enough to set any pilot's pulse racing! Fortunately all went as planned, unlike the Russian pilot who took an early bath in the Med when he failed to land his MiG-29 on the Admiral Kuznetsov aircraft carrier in November. Ouch.

Perhaps this explains the 'softly, softly' approach the US Navy has taken in getting the F-35C into service. "It's in contrast to the US Marines and Air Force, who have somewhat thrown their JSFs into service and then adopted a policy of 'concurrent' development testing," opines Newdick. "Of course, the F-35C is arguably not so urgently required by the navy, but it is well versed in the rigors of deck operations, so is perhaps also more aware of the advantages of taking things slowly."

As we went to press, our man had to this to add: "I just heard from Capt. Richard Brophy, USN, head of carrier strike aircraft and programs, that the operational test phase for the F-35C is planned for spring 2018 on the USS Abraham Lincoln."

So there you are – clearly it pays to make sure both man and machine are fit to fly, however long it takes! As ever, it's been a privilege editing the issue.

***Anthony James**, editor-in-chief*

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COVER IMAGE: An F-35C Lightning II aboard USS George Washington (CVN 73) for DT-III

WORLD *test update*

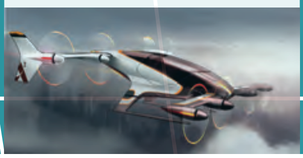
// A3 VAHANA FLIGHT TEST CONTRACT

Vahana, a project from A[3], the Airbus Group advanced projects and partnerships outpost based in Silicon Valley, California, recently awarded a flight test and range services contract to Modern Technology Solutions, Inc (MTSI), and its partner, SOAR Oregon.

A self-piloted flying vehicle platform for individual passenger and cargo transport, Vahana seeks to relieve urban congestion. It features eight rotors on two sets of wings, both of which tilt according to whether the vehicle is flying vertically or horizontally. The contract covers the prototype Alpha Phase, which seeks to identify and resolve major technical and certification risks, culminating in a flight test at the end of 2017.

MTSI will lead the flight test effort, with SOAR providing test range support and other services.

Silicon Valley, California, USA



// GLOBAL 7000 BEGINS FLIGHT TESTING

Bombardier Business Aircraft has completed the successful maiden flight of its first Global 7000 flight test vehicle (FTV1).

The prototype took off from Bombardier's facility in Toronto under the command of Captain Ed Grabman, assisted by his co-pilot Jeff Karnes and flight test engineer Jason Nickel, under clear conditions on the morning of November 4, 2016.

Dedicated to testing basic system functionality and assessing the handling and flying qualities of the aircraft, the flight lasted approximately 2 hours and 27 minutes, during which all flight controls were exercised, and the systems and aircraft performed as expected. The flight crew conducted a gradual climb to 20,000ft (6,096m) and the aircraft reached a planned test speed of 240kts.

This first flight marks the start of a flight test program for the newest member of Bombardier's flagship Global aircraft family, which is scheduled to enter into service in the second half of 2018.

Toronto, Canada

READ MORE IN OUR NEXT ISSUE!

// SLS PROPULSION SYSTEM JOINS MARSHALL STAND

NASA has installed a test version of the interim cryogenic propulsion stage (ICPS) for the Space Launch System (SLS) rocket in a 65ft-tall test stand at its Marshall Space Flight Center in Huntsville, Alabama. The ICPS is a liquid oxygen/liquid hydrogen-based system that will power Orion beyond the moon before it returns to Earth on the first flight of SLS and Orion in late 2018.

The ICPS will be stacked with three other test articles and two simulators that make up the upper portion of the SLS rocket ahead of a rigorous test series in early 2017.

"The installation is another big step in getting ready for the test series, which will ensure the hardware can endure the incredible stresses of launch," said Steve Creech, deputy manager of the spacecraft and payload integration & evolution office at Marshall.

The ICPS joins the core stage simulator and launch vehicle stage adapter, both of which have already been installed at the test stand.

Huntsville, Alabama, USA

SEE PAGE 13 FOR FURTHER SLS TESTS

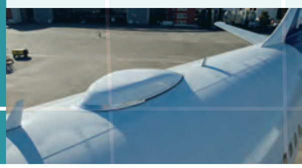
// AIRBUS TESTS HIGH-BANDWIDTH ARCHITECTURE

Airbus is evaluating a new standard high-bandwidth architecture that will provide faster and more wide-reaching connectivity services on board its aircraft. Airbus is using its in-house A330 testbed to flight test the new connectivity platform, which will enable faster internet, mobile telephone services and support applications for passengers and airlines via high-throughput satellites.

If successful, the new solution will allow airline customers to choose from a range of new high-throughput satellite technologies, such as Ka-band and Ku-band, for continuous worldwide connectivity.

"Our initial testing in high-bandwidth connectivity is a new step to improve the passenger and crew experience," explained Bruno Galzin, head of Airbus's connectivity program and upgrade services. "The number of connected commercial aircraft is expected to grow from 5,000 to 16,600 over the 2015-2025 period, accounting for 62% of the global commercial fleet," added Galzin.

Hamburg, Germany



// IRKUT MC-21 REACHES POWER ON STAGE

The first flight-capable prototype of the new Russian narrow-body MC-21-300 program has reached the power-on stage, with electrical system testing undertaken in early November. Frequency response tests are scheduled for December, as well as flight management system and landing gear tests.

The prototype will then be delivered to Irkut's flight testing facility in January or February 2017, where final preflight system tests will be conducted before its first flight, scheduled for late February or early March 2017.

The second test aircraft is currently undergoing a set of tests at the Central Aerohydrodynamic Institute, where it recently completed model flutter tests, and is now conducting airframe fatigue tests.

Irkutsk Aviation Plant is assembling the fuselage of the third flying prototype and expects to complete the assembly before the end of 2016.

Moscow, Russia

// THIRD MRJ PROTOTYPE BEGINS FLIGHT TESTING

A third Mitsubishi MRJ flight test vehicle (FTV-3) made its debut flight on November 22, bringing to four the tally of prototypes now engaged in the certification program for the model. FTV-3 took off from Nagoya Airfield for a two-hour flight test, with six test personnel on board.

The FTV-3 flight occurred just three days after Mitsubishi MRJ FTV-4's arrival at Moses Lake, Washington, where it joined FTV-1 for US-based flight testing. FTV-4 took 18 hours and 43 minutes to fly the 7,600-nautical mile route from Nagoya to Moses Lake, making several planned stops along the way.

Mitsubishi is keen for flight testing to progress as smoothly as possible, in order to restore the confidence of launch customer All Nippon Airways, which had been warned of a "risk of delay" regarding the delivery of its first MRJ regional jet. No change has been made to the delivery schedule at present, however.

Toyoyama, Japan

SEE THE MARCH 2016 ISSUE FOR MORE!

// BOEING SEES STRONG ASIAN/OCEANIC GROWTH

Boeing's Current Market Outlook for the Southeast Asia and Oceania regions, which was presented on November 22, during the Association of Asia Pacific Airlines' 60th annual Assembly of Presidents meeting in Manila, forecasts a demand for 3,860 new aircraft, valued at US$565bn, in Southeast Asia over the next 20 years; and an investment of US$160bn for 1,020 new airplanes is expected in the Oceania region over the same period.

The OEM projects that more than 75% of the aircraft that will be needed in both regions will be single-aisle aircraft, as they continue to see a rise in the number of low-cost carriers, as well as strong annual traffic, with growth rates of 6.4% and 4.7% for Southeast Asia and Oceania, respectively.

Worldwide, Boeing projects a demand for 39,620 new aircraft over the next two decades.

Manila, Philippines

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Scorpion jet completes weapons test

The Scorpion jet successfully completed its first weapons exercise at White Sands Missile Range, while operating from Holloman Air Force Base (HAFB) in New Mexico, this October. The exercise effectively demonstrated the Scorpion's close air support mission capability through the successful deployment and guiding of three widely used munitions.

The design, integration and flight test coordination for all three weapon types were achieved in under three months. Live-fire weapons testing took place from October 10-14 in coordination with the Naval Sea Systems Command (NAVSEA) and the 586th Flight Test Squadron from HAFB. All weapons performed flawlessly, scoring direct hits on all six guided shots. The Scorpion fired Hydra-70 unguided 2.75- inch rockets, BAE Systems' Advanced Precision Kill Weapon System (APKWS) and live-warhead AGM-114F Hellfire missiles. The APKWS and Hellfire weapons were guided to their targets using first a ground-based laser designator system and then an airborne laser integral to the Scorpion's L-3 WESCAM MX-15Di sensor suite.

The Scorpion prototype continues its robust flight test program, while the inaugural flight of the first production conforming Scorpion is expected to take place in Wichita, Kansas, very soon. "Potential customers are excited to see the first production Scorpion jet ,and the company looks forward to having it in the field to demonstrate its highly effective multirole capabilities," said Tom Hammoor, senior vice president of defense at Textron Aviation, which will manufacture the multi-role tactical aircraft.

The company is also moving forward with a limited production run to streamline production processes and provide additional assets for both the flight test program and customer demonstrations. These aircraft are being manufactured in Wichita, Kansas. \\

SEE THE NOV/DEC 2014 ISSUE IN OUR ONLINE ARCHIVE FOR MORE ON SCORPION JET

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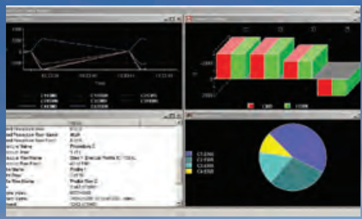
Photo courtesy Airbus Military


Photo courtesy Cessna Aircraft Company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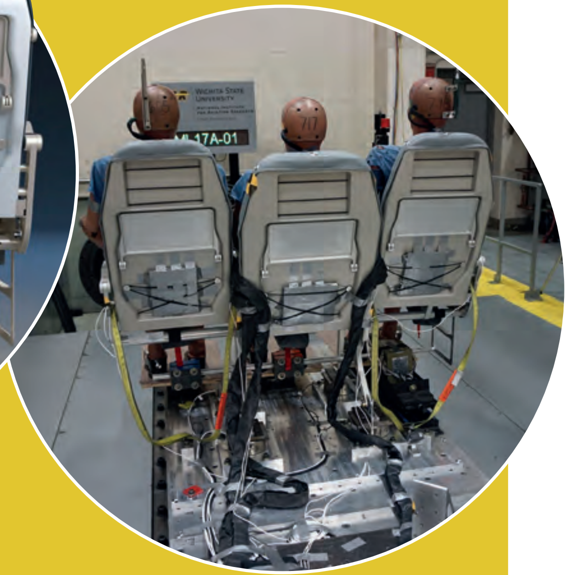

// The Side-Slip Seat has completed FAA dynamic crash testing – first deliveries are expected mid-2017

Side-Slip seat survives crash test

An innovative, new economy cabin seat for the low-cost and short-haul airline market has undergone crash testing at the National Institute for Aviation Research at Wichita State University. Developed by Molon Labe Seating, based in Colorado, the Side-Slip Seat features a unique, staggered design that offers passengers more living space – both in their seats and in the aisle. The Side-Slip Seat allows the normal 20in aisle to open up to a 42in wide aisle on the ground. This permits faster passenger loading/unloading, so aircraft can spend less time on the ground wasting fuel and more time in the air generating revenue.

"This was risk-reduction testing that we conducted on the design," explained Hank Scott, Molon Labe's CEO. "The aim was to complete the main FAA required tests in advance of our TSO testing in January 2017. We did four tests: 16*g* straight, 16*g* with pitch and roll, 16*g* for head path, and 14*g* down. We spent a lot of extra time collating data points before and after the test to mesh it with the digital analysis. We are finding very close correlation, which has helped us with design changes related to mass properties [weight reduction] and durability. We have been concerned about the right mix of weight and durability, so we were pleasantly surprised when the seats still slid after the tests.

"Durability has always been a concern for an airline seat that slides, but after passing the test, to see the seats slide after such a violent test was amazing. Particularly when you consider these tests often permanently deform the seat structure. TSO 127B testing is scheduled for January, and we expect MIDO QC inspections of our facility, shortly after that – on track to our full TSOA issuance in Q1 next year." \\

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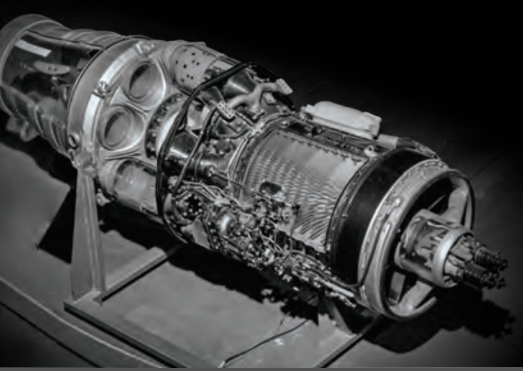


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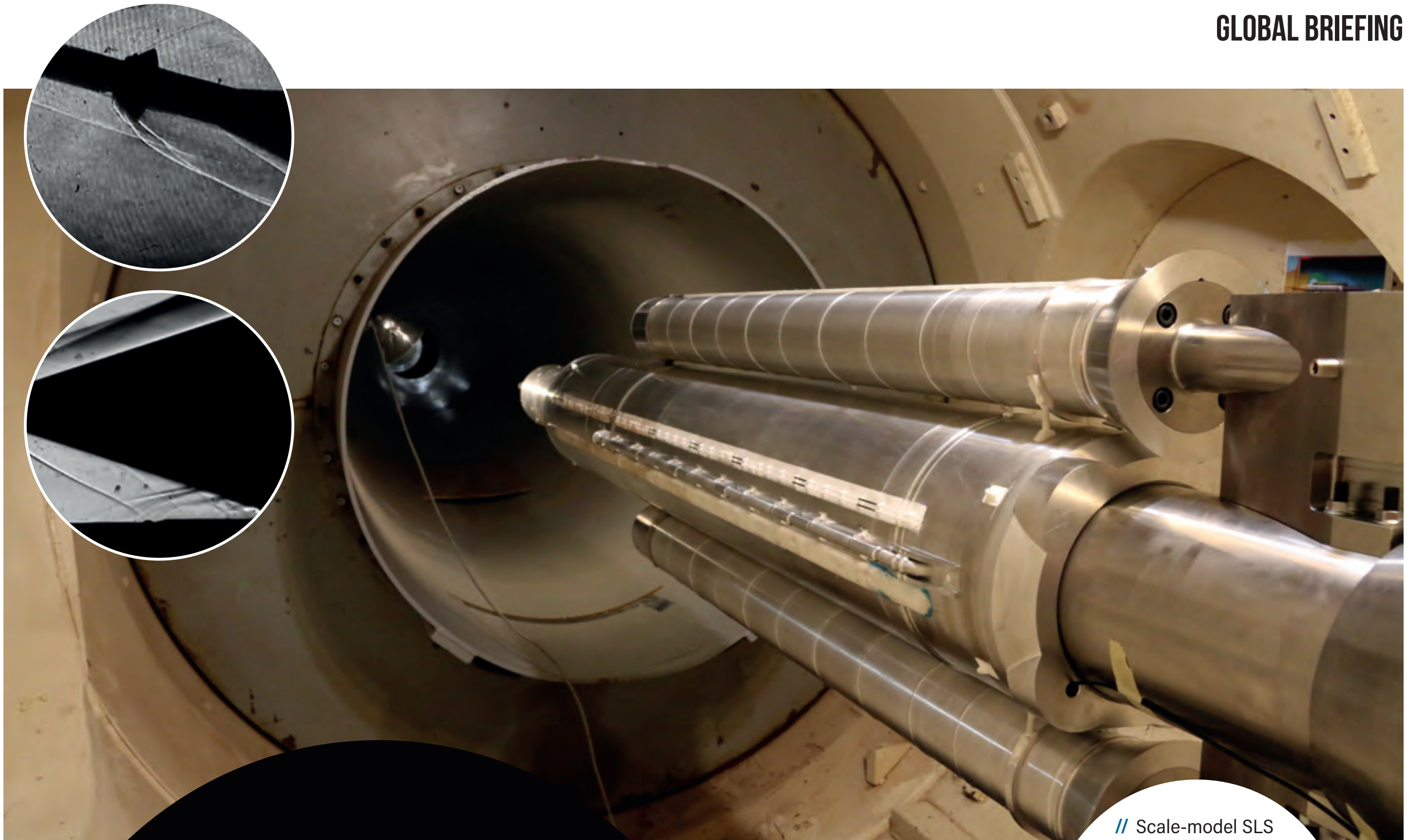

// Scale-model SLS rocket in the shock tunnel and two Schlieren images from the test (inset)

SLS feels the heat at LENS-II wind tunnel

Reaching speeds of more than 17,000mph in just 8.5 minutes, NASA's new Space Launch System (SLS) is set to get a little warm as it blasts its way to Mars. Hence NASA has teamed with CUBRC of Buffalo, New York, to analyze how the SLS will be heated as it ascends into space. A 9.5ft (3% scale) model of the SLS rocket has been designed and built for the first phase of aerodynamic heating tests in CUBRC's Large Energy National Shock Tunnel (LENS-II).

The SLS vehicle will get extremely hot during the second minute of flight, when it will accelerate from Mach 1 to Mach 4.5. The shock tunnel generates airflow at both supersonic and hypersonic flight conditions, matching the temperature, pressure and velocity the rocket will face in flight.

The tests, lasting about 40ms each, reach speeds of Mach 3.5-5. Three measurements are taken. First, pressure and aerodynamic heating are measured at nearly 200 individual sensor locations on the test model. Schlieren imaging is also used during the tests. Finally, temperature-sensitive paint is applied to critical regions of the test model and is imaged during the tests to provide insight into the heating distribution.

"These tests give us a lot of insight into how well our engineering and computer models do at predicting aerodynamic heating on the vehicle," said Chris Morris, aerothermodynamics team lead at NASA's Marshall Space Flight Center. "The data is very important for certifying that the thermal protection system on the rocket will be sufficient to protect the rocket's structure and vital systems inside it." \\

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Environmental testing: hot or cold?

The world of aerospace testing is no stranger to extreme conditions, but which end of the temperature envelope is the more challenging?

Testing aerospace systems in extremes of cold is without doubt one of the most challenging tasks faced by the engineering community.

As anyone involved in testing will appreciate, trials often consist of long periods of inactivity punctuated by intense, time-critical data-gathering phases. In temperate conditions, the inactive periods provide respite and time for reflection for all parties involved, ensuring that everything is in place for the next test point. In cold conditions, these periods still occur, but in an environment in which inactivity can pose significant risks to the safety of test personnel.

Aerospace systems, by their very nature, generally produce considerable amounts of heat. Therefore, the stress applied to components as a result of changes in temperature is greatly exacerbated when starting from a cold condition. Perishable components such as rubber seals and hoses are particularly susceptible, and their failure modes tend to be both dynamic and safety-critical.

Conversely, the potential exists for systems to quickly drop below acceptable operating limits in the event of delays in testing; this can prolong the exposure of the test team to hazardous situations.

In terms of the potential for harm to test personnel, injuries associated with extremes of cold tend to be more serious in the long term than is the case for testing in the heat. Conditions such as frostbite, the onset of which can be particularly difficult to detect, can result in irreversible, life-changing injuries.

Although appropriate personal protective equipment can provide a degree of mitigation, such items tend to be bulky and restrictive; this has the potential to introduce further hazards such as flying control restriction and delayed emergency egress. The formulation of a test plan that balances these risks will necessarily be complex, and therefore lengthy and expensive.

As if the challenges purely associated with cold conditions weren't sufficiently onerous, such conditions are often also combined with extremes of darkness, snow and ice. By comparison, the sun-baked desert under a clear blue sky seems rather appealing! \\

Garnet Ridgway

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

Sophie Robinson

works at the front line of aerospace testing as a rotary-wing performance and flying qualities engineer for a leading UK-based aircraft test organization. She also holds a PhD in aerospace engineering from the University of Liverpool

Although I can wholeheartedly agree with my colleague on the other half of this page that testing in cold climates is one of the most challenging tasks we face as engineers, I'm not sure that a sun-baked desert does seem any more appealing than testing in the frozen North. If anything, testing in hot climates presents its own unique set of challenges, in much the same way that testing in the cold does – some of which can be even more difficult to deal with.

One of the primary issues surrounding testing in the heat is that aircraft and aircraft systems already generate a lot of heat themselves. Dissipating this into the environment in hot conditions can be a struggle.

This struggle is further amplified in hot conditions. This can result in unanticipated system failures, particularly of electronics, that have to be addressed.

Unpredicted performance losses can also cause problems. Reductions in engine performance or aircraft control authority can often be worse than predicted, resulting in potentially dangerous situations. Similar things can happen when testing novel materials; unexpected failures can be catastrophic.

Actually taking measurements with sensors can also be a problem in the heat – meaning it can be difficult to maintain protection against other external hazards such as fires in hot conditions.

Thermal stress is another factor to consider. It only gets worse with activity in heat; this applies to both the aircraft being tested and the engineers carrying out the tests. Subjecting your engineers to heat can result in dehydration, sunburn and even sunstroke. Although protecting your engineers from this is of the greatest importance, it can be costly in terms of time and money. Writing from a British perspective, we're also not naturally used to dealing with the heat – in a country where we experience rain for 30% of our year, encountering a truly hot day is a rarity – and that can create issues all of its own.

Of course, high temperatures are often accompanied by other environmental factors that have to be considered in testing – like sand. To quote Anakin Skywalker: "I don't like sand. It's coarse and rough and irritating and it gets everywhere." \\


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Back to t

This August, seven F-35Cs could be found arranged on the deck of the USS George Washington, marking the largest carrier contingent of Lightning IIs to operate from a 'big deck' large carrier to date, and signaling the third and final phase of developmental test

the boat

1 // An F-35C Lightning II operated by VFA-101 'Grim Reapers' takes off from USS George Washington

2 // Internal and external ordnance loads have dominated testing at Pax River in recent months, and were a key part of DT-III

Appointed director of Joint Strike Fighter Fleet Integration earlier this year, Rear Admiral Roy 'Trigger' Kelley heads an office with a very clear remit: unifying the US Navy's efforts to bring the Lockheed Martin F-35C Lightning II carrier variant Joint Strike Fighter into the fleet.

"Our goal is initial operational capability (IOC)," says Rear Admiral Kelley. "But in order to reach that we have important dates ahead of us, and milestones to pass. We just have to ensure that everything goes as planned. A good example is the ALIS [Autonomic Logistics Information System], which needs to be integrated in time at air stations and aircraft carriers. Plus, of course, we must have Block 3F software operational. At operational levels, the navy has a lot of work to do."

Critical to reaching this goal was the third and final phase of developmental test (DT-III) that took place this August, on board the aircraft carrier USS George Washington, sailing 100 miles off the Virginia Capes.

In advance of DT-III, Commander Dave Hecht, public affairs officer for commander, Naval Air Force Atlantic, explained what would be involved: "A broad range of elements associated with carrier suitability and integration in the at-sea environment will be tested during DT-III, including day and night carrier qualifications, launch and recovery with external stores, approach handling qualities with symmetric and asymmetric external stores, Delta Flight Path testing, Joint Precision Approach and Landing System testing, crosswind and maximum-weight launches, military-/maximum-power launches, and night operations with the [Generation] III helmet-mounted display."

Before any of these specific tests could happen, however, all pilots involved had to conduct the requisite 'cats' and 'traps'. After all, the carrier qualifications (CQ, or 'carquals') are a fundamental part of getting the F-35C from the developmental test program to the front line.

Previous efforts saw the F-35C conduct DT-I on board USS Nimitz off southern California in November 2014, employing an aircraft assigned to the US Navy's Air Test and Evaluation Squadron 23 (VX-23) 'Salty Dogs', including the aircraft's first carrier landing on

800+

Personnel assigned to the F-35 ITF, including pilots from the US Navy, US Marine Corps, and the Royal Navy and Royal Air Force, as well as 600+ contractors

9

System Development and Demonstration (SDD) F-35s assigned to the ITF: five F-35Bs and four F-35Cs

3

3 // DT-III included evaluation of the Delta Flight Path (DFP) software developed by the US Navy and Lockheed Martin, which provides semi-automatic control inputs in the final seconds before touchdown

November 3, 2014. The major test points included daylight carrier operations, and launch and recovery handling procedures for the flight deck crew.

For DT-II the F-35C embarked on USS Dwight D. Eisenhower in October 2015. Sailing off the Atlantic coast between Florida and Virginia, F-35C test aircraft CF-3 and CF-5 spent nine days on the ship, completing 66 catapults and traps to expand the gross weight and crosswind operating limits established during DT-I. Key test points included catapult launches at maximum gross weight with full internal stores and expanded crosswind limits for launch and recovery.

DT-III saw the US Navy's East Coast test squadron VX-23 continue its work, and added Strike Fighter Squadron 101 (VFA-101) 'Grim Reapers', which is based at Eglin Air Force Base, Florida, and is the first Fleet Replacement Squadron (FRS) to train new pilots on the F-35C. Also involved was the NAS Patuxent River Integrated Test Force (ITF) team.

Captain James D Christie is commanding officer of VFA-101: "Based on our experience, it's our task to write up the syllabus for carquals for pilots that have never landed a tactical jet on a boat."

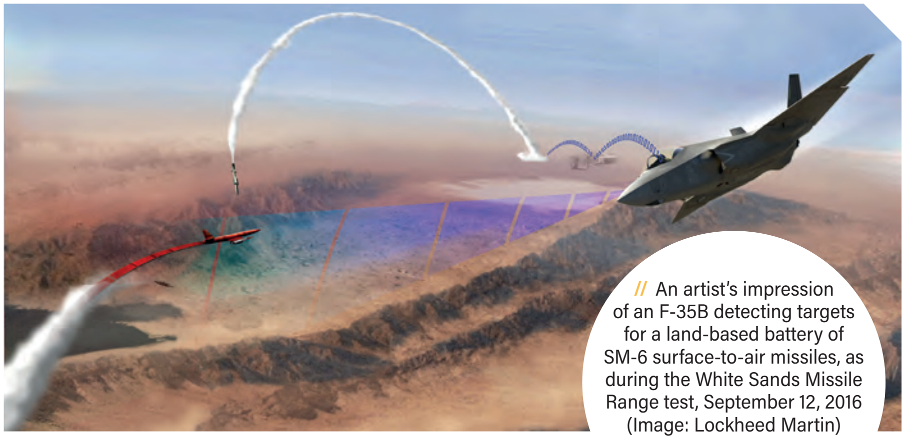
TOUCH AND GO

Before heading out to the carrier, VFA-101 undertook a period of Field Carrier Landing Practices (FCLP) or 'bouncing'. This involves a simulated carrier pattern and touch-and-go landing, at land base, in this instance Naval Air Station Meridian, Mississippi.

During the FCLPs it is the responsibility of the landing signal officers (LSO) to check that everything is

"At operational levels, the navy has a lot of work to do"

F-35B MEETS NIFC-CA



// An artist's impression of an F-35B detecting targets for a land-based battery of SM-6 surface-to-air missiles, as during the White Sands Missile Range test, September 12, 2016 (Image: Lockheed Martin)

The US Marine Corps recently began testing its F-35B short take-off and vertical landing (STOVL) version of the Lightning II as part of the US Navy's new fire-control architecture known as Naval Integrated Fire Control – Counter Air (NIFC-CA). The first live-fire demonstration to test integration of the F-35 with NIFC-CA architecture took place on September 12 at White Sands Missile Range in New Mexico. The test involved an unmodified F-35B detecting an over-the-horizon target for a land-based battery of SM-6 surface-to-air missiles. The aircraft then sent data via its Multifunction Advanced Data Link (MADL) to a ground station connected to USS Desert Ship, a land-based launch facility designed to simulate a ship at sea. Using the latest Aegis Weapon System Baseline 9.C1 and an SM-6, the system successfully detected and engaged the target.

Ultimately, these tests could lead to operational use of F-35s as 'surrogates' for the US Navy's Northrop Grumman E-2D Hawkeye airborne early warning and control (AEW&C) aircraft, providing a useful extension of the detection and engagement range of different munitions. "This test is the start of our exploration into the interoperability of the F-35B with other naval assets," explains Lieutenant Colonel Richard Rusnok, Marine Operational Test and Evaluation Squadron 1 (VMX-1) F-35B detachment officer in charge. "The F-35B will drastically increase the situational awareness and lethality of the naval forces with which it will deploy in the very near future."

NIFC-CA currently combines the E-2D with the Aegis combat radar system found on destroyers and cruisers that carry the SM-6 Standard surface-to-air missile. "The NIFC-CA with E-2Ds [has] the ability to increase the reach of the Strike Group," says Rear Admiral Mike Manazir, deputy chief of naval operations for warfare Systems. "We talk about reach not range of each individual airplane because the reach of the overall network is what's important to us."

being conducted in line with the requirements of operating from a real carrier deck. Should the LSOs discover anything that could be detrimental, the squadron will develop a 'fix' and modify its syllabus accordingly.

To qualify for daytime CQs, each pilot had to complete two touch-and-goes and 10 full-stop 'traps'. This work began soon after the squadron's first four F-35Cs arrived on the carrier on August 14. Of the unit's 15 pilots, 12 deployed to the carrier, where they joined five pilots from VX-23 home-based at Naval Air Station Patuxent River, Maryland, who brought two aircraft with them: the hardworking CF-3 and CF-5. For the first time, pilots from test and operational squadrons conducted CQs alongside each other. Eventually, all the VFA-101 pilots will become instructors, as their unit assumes the role of training squadron for the wider F-35C community.

"I've been working on this for quite some time. It is my job to qualify the pilots and ensure that everything is safe," explains Lieutenant Graham Cleveland, the lead LSO with VFA-101. "It's awesome to see that everybody performs so well."

Pilots performing LSO duties were drawn from both VFA-101 and VX-23, in an extension of the cooperative effort.

"We are on the boat less than 24 hours and almost everybody is qualified without a single 'bolter' [when the tailhook misses all of the arresting wires]," Cleveland continues. "We've not heard any screaming calls from the LSOs and not a single pilot has caught the one-wire, which is less safe than a two- or the preferred three-wire.

"Each pilot had to complete two touch-and-goes and 10 full-stop 'traps'"

4 // VX-23 pilots were able to test the Gen III helmet-mounted display during night launches from the carrier

5 // Compared to DT-I and II, DT-III saw the F-35C operate at heavier weights due to the carriage of external stores – in this case, the 25mm gun pod on the centerline station

We also haven't seen any wave-offs as a result of unsafe approaches."

CORRECTION FACILITY

A veteran of DT-I and II test embarkations, Lieutenant Cleveland's mandate this time around included proving the Delta Flight Path (DFP) system. Developed by the US Navy and Lockheed Martin, the DFP provides the F-35C with partial autonomy during the critical flying phase seconds before touchdown.

Due to DFP, an average pilot will have to make 20 corrections with the throttle, stick and rudder in the last 18 seconds before touchdown in an F-35C. This compares with between 200 and 300 minor corrections without DFP. Ultimately, the aim is to bring the number of corrections down to fewer than 10. "With DFP we have reduced FCLPs to between four and six days," notes Lieutenant Cleveland. "I expect the Navy to reduce day requirements to six traps [for daylight requirements]." Previously, an experienced pilot required between 16 and 18 days of FCLPs.

"The [DFP] control laws allow aircraft to fly a commanded glide slope," says VX-23 test pilot Commander Ted 'Dutch' Dyckman. "Before, you had to manually fly that path through the air. Now, at the push of a button, the airplane will tip over and fly that path. If I have a good approach behind ship, I can push one button. If there are deviations, I can make a correction. Other than that, I may not touch the stick at all during the approach, from the start until touchdown. Coming to the ship is as easy as landing on an airfield now, and that enables us to spend less time training guys to land on the ship."

Once on the boat, the 'Grim Reapers' faced a number of challenges. With the squadron's testing of the aforementioned Gen III helmet incomplete, Christie's aviators could not qualify at night, as originally planned. Once outfitted with the new helmets, VFA-101 will require another period at sea to write the syllabus for night recoveries. "Only a few of us have [Gen III helmets] now but we will all have them by the fall," explained Captain Christie in August. "VX-23 will test [some]

6

6 // An F-35C Lightning II blasts off the deck of USS George Washington while carrying external stores. One key test point examined the logistics of replacing the Pratt & Whitney F135 engine while at sea

software modifications later this month [and] we expect they will be released shortly. We should go back to the ship in spring next year."

Although the lack of Gen III helmets was an undesired aspect of VFA-101's embarkation, the challenge of an engine change at sea was something that was added for the evaluation. "There was nothing wrong with the engine, but we wanted to evaluate how a fleet squadron changes an engine," says Captain Christie. "We remove one engine and put another in, and then we launch it from the ship. It would give us a better understanding of how we have to do that on board. It is not really a test but more an evaluation of how it works."

For the planned engine change, VFA-101 sent a fifth F-35C to the carrier on August 15. Here, the 'Grim Reapers' relied on 70 maintenance personnel, among which were civilians from contractors such as Lockheed Martin and Pratt & Whitney.

AHEAD OF SCHEDULE

According to the F-35 Joint Program Office, DT-III "exceeded expectations". Pilot carrier qualifications for VFA-101 were completed in two days, and the Pax River ITF completed 125 test points and eliminated 101 test point requirements due to "exceptional performance". Indeed, DT-III was concluded on August 25 – one week ahead of schedule.

Following on from DT-II, which included night operations, weapons loading on the aircraft's internal weapons bay and full-power launches, DT-III continued the work on maximum-power launches from all four of the carrier's catapults and established operating parameters with external and asymmetric weapons.

Weapons testing work was underway with VX-23 well in advance of DT-III, as test pilot Commander Tony 'Brick' Wilson explains: "With respect to the C-model we have been doing a lot of [land-based] loads testing with external stores. As far as ship suitability, we are doing a lot of prepping before we embark on the ship for DT-III with arrested landings both here at Pax and at NAS Lakehurst, New Jersey. These tests involve the handling qualities of ship approaches with external stores and clearing all of the external stations for stores."

The work at Lakehurst earlier this year involved a detachment that undertook intensive trials of different external weapons configurations, including GBU-12s and AIM-9Xs on (outer underwing) stations 1 and 11. After a briefing at 07.00, a take-off at 09.30 allowed for a mission lasting around five hours, in the course of which as many as eight to 10 arrestments could be made.

20
F-35Cs assigned to the Fleet Replacement Squadron (FRS), VFA-101 'Grim Reapers' at Eglin Air Force Base, Florida

8,000
Weight (lb) of additional fuel carried in the 'big wing' F-35C compared to the STOVL F-35B

15
Maximum crosswind speed (kts) for F-35C launch as tested during DT-III (maximum crosswind for recovery was 10kts)

While embarked on the carrier, VX-23 completed all of its required DT-III test points during 41 flights logging 39.7 flight hours and featuring 121 catapult launches, 70 touch-and-go landings, one bolter and 121 arrested landings. Among standout test flights were validation of flying capabilities with a full load of inert internal and external stores, including up to four 500 lb GBU-12 laser-guided bombs and two AIM-9X Sidewinder air-to-air missiles on the external hardpoints. Meanwhile, different asymmetric loads were evaluated in handling tests. Maximum-weight launches were tested at minimum power and in a variety of wind and sea conditions.

The testing saw the F-35C carry out its heaviest catapult launch to date, with a 5,000 lb load that included a single 1,000 lb GBU-31 Joint Direct Attack Munition (JDAM), four 500 lb GBU-12 LGBs, two AIM-120 AMRAAM air-to-air missiles and a 25mm gun pod.

No less important were more minor tests, including evaluation of adjustments made to control laws as a result of the previous two developmental test phases.

The ultimate proof of DT-III will be found in the aircraft launch and recovery bulletins (ALB/ARB). These will provide the guidelines within which the F-35C will be operated once in front-line service. Essentially, they provide a manual for launch and recovery parameters in all permitted aircraft weights and configurations.

Although the US Navy has moved more slowly than its US Marine Corps and US Air Force brethren in getting the F-35C to IOC, for Rear Admiral Kelley, the Lightning II will be a vital addition to the future air wing: "Currently, the Carrier Strike Group doesn't have a stealth fighter in the inventory. As commander of a CSG, it is very difficult to get access in heavily defended territories with integrated air defenses. Seventy per cent of the world is covered with water, so typically the first response is from the CSG. Stealth, sensors and the network-centric capabilities of the F-35C allow us access from the first day of a conflict."

Sometime in the second half of 2018, Kelley should get his wish, when the US Navy's VFA-147 'Argonauts' declare IOC for the service's F-35C variant. \\

// PAUL E EDEN

At the d

Embraer has passed through the 25% point in its 2,000-hour E2 trials campaign – its nine-prototype effort should see the next-generation airliner variants enter service in 2018, 2019 and 2020

ouble

1 // Embraer's E190-E2 flight test effort remains on schedule

2 // Embraer rolled out its first next-generation E-Jet, an E190-E2, at its São José dos Campos HQ in February

Responding to airline demands for dramatic improvements in fuel efficiency, reduced emissions and advances in passenger comfort, Bombardier created the clean-sheet C Series, while Embraer turned to its game-changing E-Jet for inspiration. Visitors to July's Farnborough International Airshow were treated to the initial overseas appearance of the E190-E2 first prototype, and could easily have been forgiven for walking away with the impression that little had changed compared with the in-production E190.

In this instance, appearances really are deceptive. Alexandre Figueiredo, Embraer vice president, ground and flight test, reports, "The E-Jets E2 is far from a simple derivative. The driver for our engineering developments since the beginning of the program has been to create the most efficient aircraft family in the segment. To reach that goal, every opportunity to increase efficiency and performance was considered. The family has new engines, new, aerodynamically optimized wings, a new empennage, different landing gear, full fly-by-wire and generally improved systems. From a test campaign standpoint it is a new aircraft."

E190-E2 aircraft 20.001 completed the new model's maiden flight on May 23, 2016. The culmination of many thousands of hours of ground testing, modeling and simulation, it was entirely successful and might be considered more validation exercise than flight test.

Figueiredo explains that the aircraft's configuration owes much to the wind tunnel: "Wind tunnel testing was Embraer's primary source of aerodynamic data, helping us understand and optimize aircraft configuration. The E2 aerodynamic database, for example, derives its information from high-end wind tunnel testing with several scale models, each dedicated to understanding a specific phase of flight.

4
Number of E190-E2 prototypes

20,000
Hours of E2 testing completed before first flight

"Besides typical high-speed cruise configuration testing [in the transonic regime] and low-speed characteristics [the subsonic regime], the E2 was also wind tunnel tested for ground effect [in take-off and landing configurations], loads and aero-elasticity, airframe noise and flight in icing conditions."

Simulation is being used extensively in the development program and was relevant from the beginning. "In the initial and joint definition phases, modeling and simulation using the concepts and tools embodied in Embraer's own Virtual Airplane system were heavily used. As development advanced, enhanced modeling and simulation tools were employed, and we began incorporating hardware-in-the-loop systems, including our Mid-EDS and E-SIM engineering development simulators."

Later in the process, an Iron Bird and several rigs came into play, gradually introducing configurations similar to those on the aircraft and eventually featuring fully representative systems. The latter have become integral to the development and certification process. Embraer credits much of its E2 first flight success to this complex validation and verification process which, it

2

3 // Embraer E190-E2 being put through its paces in the static test rig

3

E2 EXAMINED

Embraer recently revealed that by September 30, total orders for its original E170, E175, E190 and E195 series had reached 1,474 with 1,267 delivered. The aircraft remains popular in service, but for it to remain competitive against the re-engined Boeing 737-7 and Airbus A319neo, and especially Bombardier's CSeries, Embraer needed to revisit the winning E-Jet formula.

It claims that the E190-E2's high-aspect ratio wings, complete with swept tips, plus other aerodynamic improvements, combine with its Pratt & Whitney PW1900G geared-turbofan powerplant to enable a double-digit improvement in fuel consumption over the existing aircraft. It also notes that the E2's fourth-generation full fly-by-wire digital closed-loop control system improves fuel efficiency and flying qualities.

Of the three models in the E2 series, the E190-E2 and E195-E2 feature the same revised wing/engine combination; although the E175-E2 configuration is similar, it is optimized for the smaller aircraft. In all cases, the engine pylon offers improved aerodynamics compared with the General Electric CF34 mounting on the original E-Jets.

The E175-E2 is designed for a single-class load of 88 passengers, with a typical 80-seat multi-class layout. The E190-E2 accommodates around 106, or 97 passengers in a mixed-class configuration; the E195-E2 has space for 132 single-class seats or a typical 120 where more than one class is offered.

Embraer aims to bring the E190-E2 to market early in 2018, with the E195-E2 following in 2019 and the E175-E2 the following year. By September 30, 2016, it had taken 82, 90 and 100 firm orders, respectively, for the variants, with 100, 95 and 80 options.

says, validated system integration security; the manufacturer had completed over 20,000 hours of E2 testing before May 23.

Little on that first flight was likely to surprise the flight crew either, since they were involved in the development process early on and had 'flown' the E190-E2's maiden hop many times on the Iron Bird; flight operation was therefore entirely normal and safety scenarios well rehearsed. According to Figueiredo at Embraer, "The involvement of flight crew in the development process, using engineering simulators and rigs, enabled a deep knowledge of aircraft characteristics before first flight. The process enhanced the confidence of our engineers and crew and was largely responsible for such a successful first flight, during which many flight envelope limits were reached."

SUPPLIER TRIALS

With so much of the aircraft new, Embraer has employed a mix of its own system testing with supplier trials. "Avionics system development, including interface systems, began with early integration tests at supplier facilities," says Figueiredo. "After this, we began using System Integration Test Station (SITS) and Avionic Integration Rig (AIR) testbenches at our own and supplier facilities, assessing avionics software and components for system integration, maturity, endurance/robustness, pilot-in-the-loop and requirements validation," he continues.

"The same process was applied to the flight controls, hydraulics, landing gear, electrical system, environmental control, engine control, APU, anti-icing system and fuel system, always beginning at the suppliers' facilities and continuing at Embraer and supplier sites.

"Thanks to this continuous integration testing process, on the E190-E2 first flight all aircraft systems worked as expected, including the flaps, landing gear and FBW, which operated in normal mode. This enabled us to expand the aircraft envelope to maximum altitude and operational speeds."

"All aircraft systems worked as expected"

4 // Inside the first flight test vehicle, with water tanks and equipment racks packed into the cabin

5 // The first flight test aircraft – Embraer plans to carry out a 2,000-flight-hour test schedule

Even with the flight test program at an advanced stage, ground testing plays an important supporting role in integrated product development. It makes an essential contribution to the assessment and certification through system failure propagation trials and structural testing. The latter addresses ultimate loads and fatigue issues, ground vibration work for flutter test clearance and other factors.

EARLY MATURITY

There could have been no greater demonstration of the E2's systems maturity than the transatlantic Farnborough trip, which came just 45 days after first flight. Flown at less than optimum altitude given the phase of flight test, the aircraft nonetheless performed more efficiently than Embraer's extensive modeling had suggested.

Invited guests aboard the aircraft explored a cabin packed with equipment racks, operator stations and, most obviously, ballast tanks. Very far from the E2's operational configuration, 20.001's interior is furnished for three flight test engineers, and the aircraft features extensive embedded instrumentation for data acquisition. The primary operator station provides an overview of all test parameters and control over the aircraft's cameras and flight test systems, including ballast and telemetry. Engineers at the other stations are able to follow the data being collected, but unable to interact with the test systems.

The entire aircraft is instrumented, with in excess of 10,000 sensors and around 30 cameras. Combined with the data generated by the aircraft's digital buses, this equipment array generates around 100,000 parameters used in the aircraft development and certification process.

Yet most of the cabin is given over to the large ballast tanks. The system enables engineers to change the aircraft's center of gravity in flight by pumping water between tanks, or dumping it overboard.

The cockpit is equipped with cameras and equipment that record the aircraft's flight deck display screens. The test pilots have access to a summary of primary flight test data, similar to that displayed on the cabin workstations, through an in-cockpit tablet.

Flight test crews typically comprise two pilots and an engineer, but the engineer cadre is increased for more complex trials. The aircraft accommodates a maximum of two pilots and four flight test engineers.

Although the prototypes are extensively instrumented, Embraer is also using chase aircraft and high-speed photography during the E2 flight test campaign. Chase aircraft are especially useful during the initial phases, cross-checking air data readings (before the prototype's system has been fully calibrated), and for the more prosaic task of enabling visual checks for issues with

10,000
Sensors fitted to the E190-E2 first prototype

100,000
Test parameters recorded by E190-E2 first prototype test instrumentation

"Data may also be telemetered in real time"

prototype integrity – open doors, loose panels, fluid leaks, smoke and so on.

Although the company has a veteran Hawker Hunter on its chase aircraft fleet, it is particularly proud of its E2 chase aircraft, says Figueiredo: "We employ two state-of-the-art machines from our business jet family, a Phenom 300 light jet and a Legacy 500 fly-by-wire aircraft."

FLIGHT TEST ANATOMY

Embraer aims to complete one flight test of approximately two hours' duration every day. It targets 50 to 60 hours per month, per aircraft, as it works toward the 2,000 hours required to complete the test campaign.

Preflight planning begins a week before the test flight, with the crew and engineers defining the work and completing their risk assessment. Two days prior, the test card is generated, containing all the information related to the planned trial. The crew and engineers meet again for a one-hour preflight briefing on the day of the test and again for a 60-minute debrief afterward.

During the flight, the engineers at the cabin workstations analyze aircraft data points for validation. If a data point is not validated, procedures might be repeated during the flight to achieve a valid result. Data may also be telemetered in real time to ground stations, but the flight test parameters are always downloaded for analysis after landing. The flight test report is released some days after the trial.

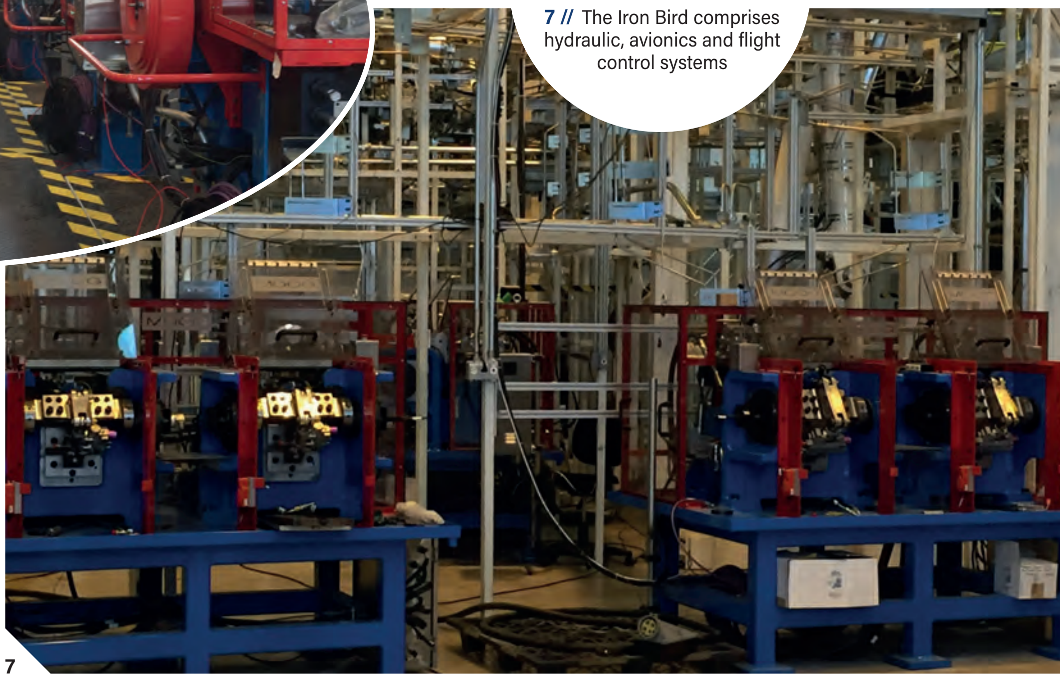
By August, three E190-E2 prototypes were flying and had accumulated 240 hours between them. Trials are primarily out of Embraer's Gavião Peixoto flight test center in Brazil, but adverse weather work will require deployments abroad. Early in 2017, for example, the third prototype will fly maturity and adverse weather trials, including cold weather operations, in the USA.

The full flight test campaign requires four E190-E2 prototypes, two for the longer E195-E2 and three more prototypes for the smaller E175-E2. First flight of the final E190-E2 prototype is imminent. Of the E190-E2s, 20.001's primary tasking involves system, loads, aero elasticity, external noise and crosswind testing; 20.002 is also flying system tests, and is engaging in performance flights; 20.003 is taking responsibility for flying qualities trials, including icing evaluations; 20.004 will have representative cabin furnishings, required for cabin evacuation, comfort and internal noise assessment.

By early October, the E2 campaign had performed envelope expansion, ground loads calibration and in-flight thrust determination (IFTD) trials. Ongoing work included stall, climb performance and brake system evaluation. Embraer was also working to freeze the E190-E2's aerodynamic configuration and control laws, an important milestone for the flight test campaign. "The E-Jets E2 program is on schedule and on target. The first aircraft to come to market will be the E190-E2, in the first semester of 2018," concludes Figueiredo. \\

6

6 // Embraer has completed over 20,000 hours of tests in ground-based rigs, including an Iron Bird simulator of the flight control system



7

7 // The Iron Bird comprises hydraulic, avionics and flight control systems

X-way visi

Will NASA's X-57 electric research airplane go down in history as the aircraft that helped define a new, greener, cleaner, electric age of aviation?

NASA proclaimed the birth of a new era of aviation earlier this year when it announced it was to begin testing a distributed electric propulsion technology on the experimental aircraft designated X-57.

Speaking to *Aerospace Testing International* in October, Sean Clarke, NASA's principle investigator on the X-57, said he views the project as the first step in a program that seeks to demonstrate many new opportunities for aircraft design: opportunities that would allow the industry not only to drastically reduce fuel consumption, engine emissions and noise, but also make aviation more accessible to the public.

The X-57 is nicknamed the 'Maxwell' after the 19th century Scottish physicist James Clerk Maxwell in recognition of his work on electromagnetism. The demonstrator will be created by modifying a Tecnam P2006T twin-engine, light aircraft; the conventional wing and two piston engines will be replaced by a long, skinny wing embedded with 14 electric motors all turning propellers. There will be 12 motors on the leading edge for take-off and landing, and one larger motor on each wing tip for use while at cruise altitude.

Clarke hopes the aircraft will highlight what he describes as some of the "radical" improvements to aerodynamic efficiency that electric propulsion makes possible.

"We are designing this aircraft to take advantage of installing the propulsion system in locations on the vehicle that were not practical with turbine and piston engines," he says. "Electric motors are lighter and are very efficient across a wide range of power levels, and they will continue to become more and more reliable as the technology matures further."

The Maxwell is part of NASA's New Aviation Horizons initiative, which will include the development of as many as five larger transport-scale X-planes, all intended to introduce advanced technologies into the market.

NASA expects the X-57 itself will prove that by distributing the electric power across a number of motors, carefully integrated with the wing, it is possible

on

1 // The Hybrid-Electric Integrated Systems Testbed's (HEIST) modified wing sits atop a big rig at NASA's Armstrong Flight Research Center *(Photo: NASA/Tom Tschida)*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2 // HEIST performs a full power ground test at 224kW of Leading-Edge Asynchronous Propeller Technology to test lift at low speeds *(Photo: NASA Photos/Tom Tschida)*

to achieve a fivefold reduction in the energy required by an airplane of its size to cruise at 175mph. Researchers believe this could translate into a 40% reduction in overall operating costs for small aircraft. Typically, to get the best fuel efficiency, an airplane has to fly slower than it is able. Electric propulsion essentially eliminates the penalty for cruising at higher speeds.

In addition, the X-57 will be powered by batteries, eliminating carbon emissions in flight.

There have been many attempts at electrically powered airplanes in recent decades, including manned and unmanned aircraft. The drone industry has taken advantage of improvements in battery technology and energy density; progress has also been made in the development of solar-powered and fuel cell powered aircraft such as the Helios Prototype and the Solar Impulse 2, which completed the first around-the-world flight earlier this year.

However, Clarke says advances in electric motors and the ability to integrate airframe and propulsion design are now at a stage where it is possible to build a demonstrator with a view to commercialization. “We have been studying the potential of tightly coupled propulsion airframe integration (PAI) for many years, and are excited by the state of the art of electric motors and the PAI design tools that are finally letting us build a demonstrator with these key technologies.”

MULTIPLE RESEARCH

The X-57 Maxwell belongs to the SCEPTOR project (Scalable Convergent Electric Propulsion Technology and Operations Research), which is a collaboration across several NASA centers, and is one of several projects seeking to advance electric propulsion technologies.

Another is the Hybrid Electric Integrated Systems Testbed (HEIST) at Armstrong Flight Research Center. HEIST will allow researchers to study the interaction between multiple energy sources, such as batteries, turbines and fuel cells; it will also aim to develop novel control laws that will take advantage of the unique capability of these distributed electric propulsion systems to reduce the reliance of drag-based control surfaces such as ailerons and rudders.

There is also the NASA Electric Aircraft Testbed (NEAT) at the Glenn Research Center, which is working on advanced electric propulsion component and powertrain models. Clarke said the aim was to optimize the next generation of electric propulsion components such as motors, generators and power inverters.

Meanwhile, the development of the X-57 is split into several configuration stages referred to as modifications. Mod 1 included testing of an unmodified Tecnam P2006T aircraft to collect stock handling and performance data. In Mod 2, the team will flight test an electrified version of the P2006T with batteries instead of fuel tanks, and high-performance electric motors instead of engines.

“This will allow us to evaluate the operational and safety capability of the electric powertrain in a flight environment,” explains Clarke. In Mod 3, the team will replace the standard wing with one designed “for optimized propulsion airframe integration”.

Clarke says, “This means the electric motors will be located at the wingtips so that they reduce the vortex energy for lower drag, and the wing will have a higher aspect ratio for optimized cruise performance. This will result in compromised low-speed stall characteristics in this phase, though.”

In Mod 4, which is not yet approved, Clarke says they hope to demonstrate how leading-edge propellers driven by distributed electric motors across the

5
Total X-plane demonstrators due in NASA’S New Aviation Horizons program

14
Electric motors that will be installed on the X-57

40%
Projected reduction in overall operating costs for light aircraft using X-57 technologies

wing would recover the low-speed stall capability enabling operation throughout the original P2006T envelope.

"We completed the Mod 1 flight tests in 2015, and plan to conduct Mod 2, 3, and, if approved, 4 flight tests in 2018, 2019 and 2020 respectively."

COUPLED CONUNDRUM

The X-57 design incorporates a "highly coupled" motor, propeller and wing interaction, which presents both a challenge and an opportunity, says Clarke.

"Our redesigned wing relies on the propeller locations to achieve the targeted performance, but also presents structural integration challenges when incorporating so many distributed masses. It's also a very small volume as a result of the higher aspect ratio, so we are challenged to incorporate our experimental power distribution system alongside our command databus, our research instrumentation system, and our mechanical flight control system."

The opportunity, says Clarke, is to mature the relevant technologies to a level at which the aerospace industry can then adopt the design techniques. "We plan to demonstrate a five-times improvement in efficiency at high-speed cruise flight, which is a huge leap forward in aircraft performance that should scale to even larger vehicles."

The approach to the first flight tests will be taken in steady, incremental steps. Clarke says the new electrical components, such as the motor testing, will mirror many of the conventional engine development stages.

"We are completing ground testing on our high-precision motor test stand (Airvolt) in order to evaluate the motor design, reliability and operation in a similar test program to a new engine checkout. We will conduct increasingly integrated subsystem and system tests leading up to a Combined Systems Test, taxi tests, and eventually flight."

"We plan to demonstrate a five-times improvement in efficiency at high-speed cruise flight"

The build-up to the final Mod 4 configuration is designed to carefully introduce new technologies in the safest configuration possible.

"In Mod 2, we will demonstrate airworthiness of our experimental electric powertrain all the way from the batteries to the motors and all the power components in-between," he says. "This will be done in a controlled vehicle configuration such that a failure anywhere in the system will be easily handled by our test pilot. When we graduate this power system design to Mod 3, we will have a more challenging failure mode that we will be prepared for: the loss of propulsion at one wingtip. We will mitigate this by limiting motor power at the wingtips during take-off and landing, and using the long main runway available to us at Edwards Air Force Base – 12,000ft paved with an additional 5,000ft of groomed surface on the dry lakebed. This will ensure that the pilot always has sufficient control authority by getting airflow over the rudder and ailerons with a minimum of power.

"Once we are airborne, we will methodically expand the flight envelope to reach the high-speed cruise design point and demonstrate the drastically reduced energy required by our demonstrator as

80MPH
Speed at which the wing assembly was tested while truck-mounted

2018
Year for first flight tests for the X-57

3

3 // Artistic rendering of the X-57, which will use 14 electric motors to turn propellers integrated into a uniquely designed wing

compared with the original Mod 1 configuration."

The team also conducted ground-based tests of a full-scale wing with distributed electric propulsion, similar to the design used on the X-57. As part of the Leading Edge Asynchronous Propeller Technology (LEAPTech) project, the test fixture was mounted on a truck and driven at different speeds and angles.

"We completed a series of tests at up to 80mph and various wing elevation angles, power settings on the motors (up to 300 horsepower total), and flap configurations," says Clarke. In addition, the team also used several CFD models of the aircraft to quickly optimize the integration of the propulsion systems and the airframe.

Distributed electronic propulsion will not only help to reduce fuel consumption and emissions, it could also offer some progress on solving the vexed issue of aircraft noise. On take-off and landing, the technology could make it possible to improve performance within the noise limitations of a typical general aviation airfield, although acoustic testing hasn't been scheduled yet.

4 // The Airvolt electric propulsion test stand, ready for research *(Photo: NASA Photo/Lauren Hughes)*

AIRVOLT ELECTRIC MOTOR TEST STAND

Researchers at NASA's Armstrong Flight Research Center in California are using a unique 13.5ft-tall test stand to better understand how electric motor systems work. The Airvolt test stand will help NASA explore whether integrated electric propulsion can be used like traditional aircraft propulsion. If there are distinctions in how the systems work, researchers will have to find methods of managing the differences. For example, research has already highlighted problems with electromagnetic interference (EMI): "EMI issues impacted data collection and real-time displays and gave us false indicators in the control room," reveals Yohan Lin, Airvolt integration lead. "It was caused by the electric propulsion system's noise." The solution was to install a combination of hardware filters on the test instrumentation and use digital filters on the acquired data.

The first Airvolt tests in late 2015 focused on the energy-efficient Pipistrel Electro Taurus electric propulsion system, typically used for motor gliders. The system consists of an EMRAX motor and Pipistrel-designed motor controller, propeller, lithium polymer batteries, and throttle controller. The motor produces 40kW of power; however Airvolt can test systems that use up to 100kW of power. The test stand can also withstand 500 lb of thrust.

Airvolt is now testing a Joby Aviation JM-1 motor. Data collected will include torque and thrust measurements, high-fidelity voltage analysis, power efficiency, and details on how the system behaves. A simulation model will then be developed to study flight controls, power management and transition issues of a distributed electric aircraft. "You want to understand the characteristics of one motor system first so variables can be reduced when trouble-shooting the multimotor configuration," explains Lin. "Overall, we are getting excellent data."

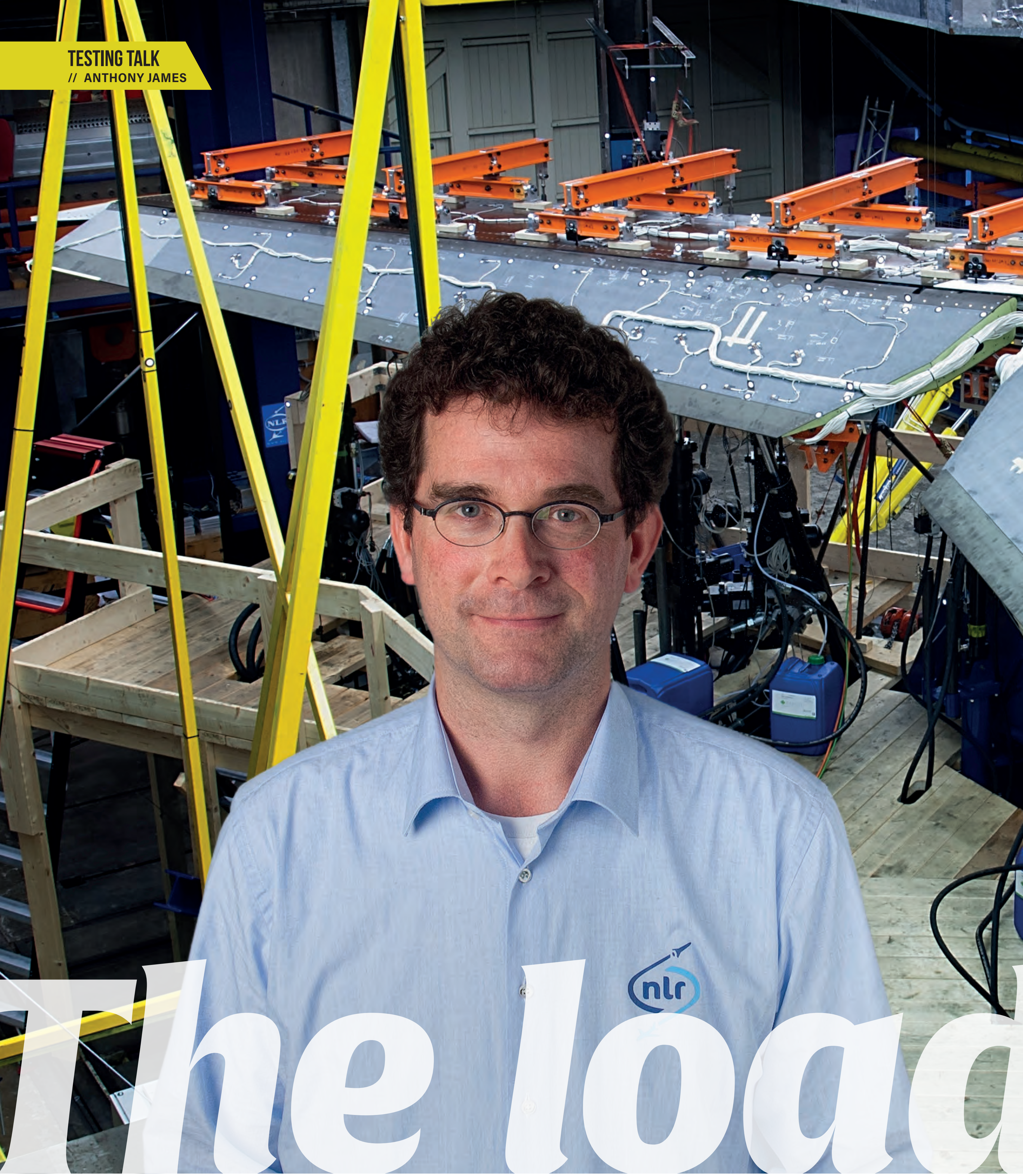
"We haven't committed to acoustic testing with the SCEPTOR project, but we will be evaluating what research opportunities this vehicle could provide, given our unique configuration," says Clarke. "NASA is studying these effects with acoustic models and the X-57 configuration could be an ideal test platform for this."

NEW CHAPTER

NASA believes electric propulsion offers many new opportunities for aircraft design, of which the X-57 Maxwell will highlight just a few. This is the beginning of a new chapter, claims Clarke, which will make this type of aircraft, and aviation in general, more available to the public, particularly with the continued improvement in battery technology.

"Battery technology has been improving at an exponential pace for many years, and if it continues at this rate, all-electric aircraft will have more and more market niches available to them," he says. "Many of the X-57 technologies are equally relevant in a hybrid configuration, which will overcome the reduced energy density of batteries in the near term. These technologies, along with improved autonomy and next-generation air traffic control, are poised to make aviation more accessible to the public than ever before." \\

// ANTHONY JAMES



The load

MEET RENS UBELS, PRINCIPAL PROJECT ENGINEER IN THE STRUCTURES TESTING AND EVALUATION DEPARTMENT AT THE NETHERLANDS AEROSPACE CENTRE

master

1 // Gulfstream G650 horizontal stabilizer in a full-scale test rig at NLR

1

// HOW DID YOUR TEST CAREER START?

After getting my degree in mechanical engineering, I started as an assistant test engineer at the Netherlands Aerospace Centre (NLR), managing R&D coupon test programs on composite materials. As an assistant, my job was to arrange everything needed to execute the test program, including design of test tooling and specimen manufacturing. From an assistant, I became a project engineer responsible for the execution of the test programs, planning and financial issues.

// WHAT WAS YOUR FIRST TESTING JOB?

NLR started full-scale testing with the certification test on the Fokker 100 tailplane in the 1980s. After the bankruptcy of Fokker in 1996, NLR took over the test department of Fokker. With this expansion of test activities, the certification test on the NH90 tail [designed and manufactured by Fokker Aerostructures] and several other certification test programs on smaller full-scale aircraft components, like the Dassault Falcon 7X aileron and rudder, became part of the NLR full-scale test portfolio. After the NH90 full-scale test setup moved from the Fokker site at Schiphol to the NLR site in Flevoland, I became project engineer of this test program in 2008 and was responsible for the restart of the actual testing at the new location. Right now, NLR is executing the full-scale test programs on the Dassault Falcon 5X tailplane and the flap tracks of the Bombardier C Series. Compared with the test on the Fokker 100 tailplane, which took place more than 30 years ago, the main difference is in the increased level of control, data acquisition and network technology. We can now handle and process large amounts of test data, which provides a better insight into the actual status of the test.

// WHAT WAS THE MOST VALUABLE LESSON FROM THOSE EARLY DAYS?

Full-scale testing is teamwork. Open communication with your team members and your customer is very important. Even when nothing is happening, tell your customer that nothing is happening. Getting commitment from your operators and subcontractors is vital to meet your deadlines. Furthermore, be sure that the expectations of your customer are always correct.

// WHAT IS YOUR CURRENT POSITION AND WHAT DOES IT INVOLVE?

As a project engineer I am responsible for the correct execution of test programs. Not only on full-scale test articles, but also on small coupons as tested to generate

> ***"Be sure that the expectations of your customer are always correct"***

material data. These test programs are executed in the framework of commercial projects for aircraft suppliers and national and/or European research programs such as Clean Sky. A project engineer at NLR has multiple projects at a time in order to be fully occupied, and is responsible for technical, planning and financial issues. Besides the executing of projects, a project engineer also has to acquire new projects and customers.

// DESCRIBE A TYPICAL DAY

Running a full-scale test program is a dynamic event. During fatigue testing it can be relatively quiet, especially when no deviations are observed. However, when the limit load and ultimate load test campaigns are on the schedule, things can be really hectic and intense.

A typical day starts with checking the progress of the test campaigns; meetings with the operators to check if there are any anomalies; updating the documentation; and briefings with the customers. And there are always issues that need to be checked and re-arranged, or preparations to be made for the next test phase.

// WHAT ARE YOU WORKING ON RIGHT NOW?

Two large full-scale test programs are currently active: we are testing the flap tracks of the Bombardier C Series – three flap tracks in total; and we are carrying out a

“The existing set of F-16 wings would last until the arrival of the F-35”

full-scale certification test on the tailplane of the Dassault Falcon 5X.

For both these programs, the greatest challenge is to execute a full-scale test program at the lowest possible cost. The major part of the budget is absorbed by the design and manufacturing of the test-rig. Because full-scale test articles are never identical, previous test frames can often not be reused. However, to keep costs down, we have been building test frames with pre-fab modular beams and rods. Bolted on a slotted concrete floor, a stiff and cost-effective test frame can be built. Only the local interface structure with the test article will then be a dedicated design.

We are also very focused on visualizing test data during the execution of the test program. By broadcasting the test data over a secure network, we offer customers the possibility to semi-live-monitor their full-scale test. By using templates, NLR reduces post-processing and reporting efforts for the customer.

// TELL US ABOUT THE NLR'S UNIQUE FACILITIES

Our biggest advantage is that NLR is a one-stop shop. We can take care of every aspect of a structural test program for the customer, from test-rig design, manufacturing, assembly and test execution, to generating test loads, data analysis and assistance with certification regulations.

We are also proven specialists in non-standard testing. For testing at extreme low temperatures or in extreme environments, we design and build test rigs that are able to meet extreme test goals.

For the test campaign on the Bombardier C Series flap tracks, part of the endurance testing was conducted at -55°C. For this purpose, we designed and built a mobile climate chamber based on vaporizing liquid nitrogen. It had to be mobile because it had to be used in three test frames. It was successfully used during 24/7 testing of all three flap tracks.

Furthermore, NLR designed and built a portable impact system for application of impact damages in, for instance, full-scale composite structures. At locations that are normally difficult to reach, impact damages can be applied in a controlled way with this device. Onboard data acquisition measures the applied impact energy. We have already sold a few of these portable impact devices to several aircraft manufacturers all over the world.

2 // Overview of Bombardier C Series flap track test rigs with climate cabinet for testing at -55°C

// WHAT ARE YOU DOING TO SUPPORT THE RNLAF'S F-16s?

Besides the regular load monitoring activities of NLR's Structural Health Monitoring team, we tested a wing set of one of the RNLAF's F-16s in 2014. The main question from the Netherlands Air Force was whether it had to order a new set of wings for its current fleet of F-16s, while awaiting the delivery of its first F-35s [The Dutch Parliament approved an order for eight Lockheed Martin F-35As in March 2015, confirming the aircraft as the official replacement for the F-16 for the Royal Netherlands Air Force]. This potential purchase of new wings for its F-16s would obviously represent a major investment for the air force.

From a wing set with a known history, one wing was dismantled (tear-down inspection) to record the actual status, while the other was subject to an extensive full-scale test. NLR built a test setup with 21 hydraulic actuators loading the wing with a representative load sequence, including loading of fuel tank and armory interfaces.

After testing the wing until the end of its fatigue life and analyzing the test data, it was concluded that the purchase of a new set of F-16 wings was not necessary as the existing set of F-16 wings would last until the arrival of the F-35.

// HOW LONG IS A TYPICAL FULL-SCALE TEST AND WHAT DOES IT INVOLVE?

Assuming that there are no delays, a typical certification full-scale test on, for instance, a tailplane lasts about 18 months, starting with compilation of the test plan. The following activities can be identified for such a test (in chronological order): test rig design; instrumentation of test article parts at the customer's production site; fabrication and installation of the test frame; completion of the instrumentation of the test article; installation in the test rig; shake-down and strain verification testing; fatigue test campaign; static test campaign (limit and ultimate load cases); damage tolerance test campaign (fatigue); and residual strength test.

The test article itself is equipped with hundreds of strain gauges. As well as strains, deflections, applied loads and reaction loads are also measured. At NLR, data is captured 24/7 in a binary file, even when the test is not running. Out of this binary file, data sets are taken for analysis. During a first quick check, the critical sensors are analyzed and the data is checked for minimum/maximum values. By performing regular checks, trends can be observed that might be an indication of damage development. In consultation with the customer, a sub-set of the data is visualized in graphs, which are accessible via a secure website. In this way, the customer can monitor the progress and the test data.

// WHAT IS THE LARGEST RIG YOU HAVE BUILT?

The largest full-scale test rig is the currently installed horizontal stabilizer of the Dassault Falcon 5X. In this setup, stabilizer and elevators are tested together with the elevator under different deployment angles. This full-scale test involved over 1,000 data channels and the most advanced data acquisition setup. However, the test rig with the largest number of actuators [21] and the highest load levels was the full-scale test on the F-16 wing.

But the test program with the most advanced test concept and load control configuration is the Bombardier C Series test campaign. In this setup, the applied air load on the carriage is the result of vector decomposition as a function of the flap angle. Furthermore, hydraulics are combined with electrical actuation. The fatigue program is conducted flight-by-flight, in realistic environmental conditions [dirt, temperature at -55°C].

At the moment, building activities are ongoing for a new increased test site with 880m² of floorspace, of which 600m² is reinforced and slotted. This will provide enough space to test six Dassault Falcon 5X horizontal tailplanes at the same time. The new facility will be fully air-conditioned at 23°C, and will have a total test volume of 9,000m³. The new test site, at the NLR location in Flevoland, will open in the second half of 2017.

// HOW HAS STRUCTURAL TESTING CHANGED?

The evolution of computer technology has made load control, data acquisition and computer network systems incredible powerful. Data from load control and data acquisition systems is now stored in databases 24/7. With scripting software, data can be extracted from these databases, analyzed, presented online in clear overviews, together with the predictions, and broadcast over secured networks, in order to monitor the test from any location. With current optical measurement systems, strains, deflections and positions of large areas [field data] can be collected in one instance to support local readings. Compared with 10 years ago, the potential to monitor tests and extract as much data as possible has increased tremendously.

3 // Dassault Falcon 5X horizontal tail plane with elevators in maximum upward position

// DO YOU TEST TO THE POINT OF FAILURE?

For a national research program we tested a G650 horizontal stabilizer partly made of thermoplastic composite. At the end of the test program, the aim was to test the stabilizer until failure, but the test article was stronger and more flexible than expected. We ran out of stroke on the actuators and were not able to test to rupture, although we reached 240% of limit load.

// HOW HAVE YOU IMPROVED TEST EFFICIENCY?

By visualizing test data during the entire test program and direct comparison with predictions, we can reduce the lead time of a static test campaign. By using the reporting templates of the customers, which are filled with test data by NLR, the reporting effort of the customer is reduced. We receive a lot of positive response from customers about the fact that their test report is more or less ready right after the actual test is finished.

// WILL SIMULATION EVER REPLACE TESTING?

No doubt models and simulation techniques have been improved and will improve further. It's also true that during execution of full-scale test campaigns, we have noticed that the customer's predictions are fairly good. But there are always details in the design that are not covered, or only partly covered, by calculations. In every model, assumptions have to be made for some design parameters. With testing, the models can be tuned and improved. In future, the number of tests, and the scale of them, will reduce, but testing will be needed to ensure a safe flight. \\

// NIGEL PITTAWAY

A new high-speed 3D imaging system originally developed for blast mitigation research during military vehicle testing has huge potential for aerospace applications

Another dime

1 // The High-Speed 3D Imaging System developed by DST Group is ideal for recording time-critical events such as explosions *(Photo: The Australian Department of Defence)*

Australia's Defence Science and Technology Group (DST Group) has developed a three-dimensional, high-speed imaging system that has the potential to be of great benefit to aerospace testing activities.

The concept is being promoted as the Superfast 3D Tracking System but is perhaps better known as the High-Speed 3D Imaging System, which provides next-generation high-speed video in 3D and has applications in aiding the understanding of what occurs inside time-critical events such as an aircraft crash or bomb explosion, or even the launch of a missile or rocket.

The organization says that complex integrated systems that undergo a rapid change behave in ways that are not always predictable, and the ability to measure the trajectory of objects inside the event not only leads to a better understanding of the object or system being tested, but will aid the determination of root cause assessments and, as a result, influence design improvements.

Consisting of a series of commercially available high-speed cameras within a surveyed frame of reference and linked to a data acquisition unit (DAU), the system

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2 // Australia's DST Group is currently using the High-Speed 3D Imaging System for military vehicle testing *(Photo: The Australian Department of Defence)*

provides detail of the movement of objects in three dimensions, which, when used in conjunction with other time-correlated capture systems, provides an enhanced understanding of dynamic events.

According to DST Group, the High-Speed 3D Imaging System is believed to be the only one of its type in the world, and the organization has recently demonstrated its capabilities to overseas testing authorities. Following positive feedback, it is now looking to engage with industry partners to further develop the concept.

AEROSPACE APPLICATIONS

Although the High-Speed 3D Imaging System has initially been developed within DST Group's Land and Maritime Division and is primarily used in blast mitigation activities during military vehicle testing, project manager and scientist Tania Holmes says it has equally valuable use in other time-critical events, such as aerospace testing.

"When you film a time-critical event using only high-speed cameras, you only see the results in two dimensions and you may very well miss some vital information," she says. "There are certainly applications for aerospace if anyone needs this fidelity of detail."

HIGH-SPEED CAMERAS AND EQUIPMENT

The cameras used in the High-Speed 3D Imaging System are commercial-off-the-shelf items. Different units can be used for each individual test, but all are capable of withstanding 100*g*. Examples for internal use include the Photron FASTCAM MH4 high-*g* camera system with up to four miniature heads and the Vision Research Phantom Miro 3 two-megapixel unit. For external use, a Photron FASTCAM SA-5 motional analysis camera is often used. It can record over a million frames per second, although lesser framing rates are used for practical durations of filming and minimum frame sizes.

Two things they all have in common are a global- rather than rolling-type shutter to minimize distortion, and a fast frame rate to capture data in the time-critical space, because the higher the velocity of the object being tracked, the higher the frame rate needs to be. The DST Group's Tania Homes says that, wherever possible, lenses from the same production batch – ideally with consecutive serial numbers – are procured, to ensure that they have similar optical qualities and no major differences in aberrations or manufacturing defects. Lighting also is critical, as it has to work reliably under extreme conditions.

1-2
The number of milliseconds the sound of a balloon bursting lasts

2-20
The number of milliseconds in which vital events occur during an explosion

One recent example of how the system could have proven beneficial to aerospace testing was the helicopter drop test carried out by NASA at its Langley Research Center in Hampton, Virginia, in October 2014.

The tests involved the 30ft (9.14m) drop of a CH-46 Sea Knight helicopter onto a prepared dirt surface, as part of the Transport Rotorcraft Airframe Crash Testbed (TRACT 2) full-scale crash test at Langley's Landing and Impact Research (LANDIR) facility. Inside the helicopter were 13 fully instrumented crash test dummies and two non-instrumented manikins.

"That particular test would have been a perfect application for the High-Speed 3D Imaging System, where, for example, if a bolt or some other projectile was dislodged, you would know exactly where in space it was and you can then calculate its trajectory, velocity and acceleration," explains Holmes.

"Even just being able to see what is happening in 3D versus 2D gives you a better idea of spatial relativity. If you have two crash test dummies seated opposite

3

4

3 // The new imaging system is helping to explore blast mitigation strategies

4 // AGM-154 Joint Stand Off Weapon live firing trials carried out at Woomera, South Australia


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one another and their limbs flail around at the point of impact, you can determine if and where one contacted the other."

Further possibilities include the accurate mapping of blast fragments during explosive tests on aircraft structure, such as those carried out on a retired Boeing 747 airframe at Bruntingthorpe, north of London, in 1997 or, in a limited sense, the effects of various weapons.

"The definition of the size of fragmentation in a warhead detonation and their velocity during the detonation are things we are looking at in our testing now, but the trouble with explosive environments is that things tend to get very bright," continues Holmes.

"We slow our cameras down as much as we are able for that sort of event, but sometimes the scene's dynamic range is too large for the cameras to capture. To be able to see inside that explosion is something we are working on.

"For the other applications we know it works, but we also realize that it needs to be further refined, so if someone in the aerospace testing environment wanted to develop it further, we would be happy to share information and piggy-back off one another."

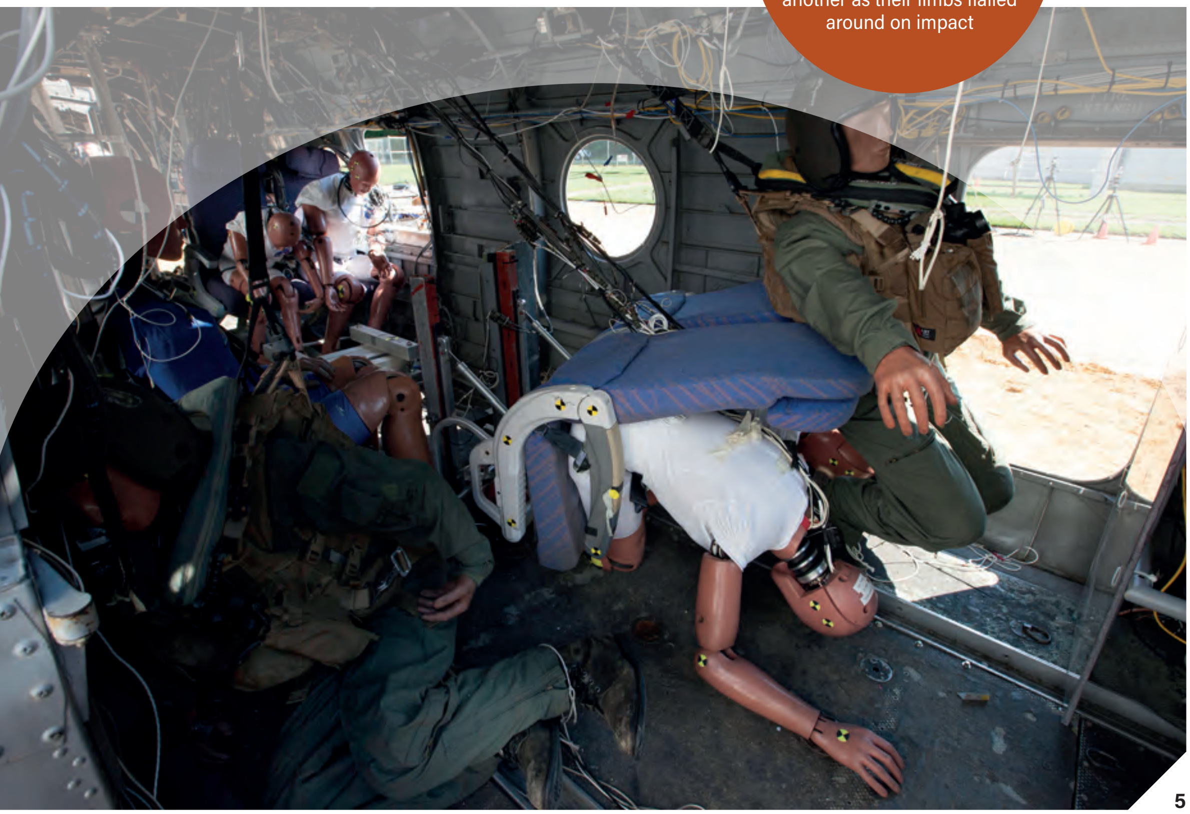
DST GROUP PARTNERSHIPS

The current head of DST Group is the chief defence scientist, Dr Alex Zelinsky, who has overseen a recent strategy to build partnerships with industry and academia.

"We want to share information about our capabilities and some of our projects," he says. "When I talk about partnerships I don't mean a client-provider arrangement. I am talking about a long-term strategic partnership with a co-investment in developing capability – in other words, a genuine partnership."

To this end, he has established an annual Partnerships Week, where DST Group opens its doors to potential partners; this year the event was held at Fishermans Bend in Melbourne, home of the High-Speed 3D Imaging System.

The project is just one of many that DST Group is working on, across the land, sea, air and space domains, but it is one that has definite potential for application in the aerospace testing industry. Zelinsky says that DST Group is happy to discuss licensing and collaboration options, including the potential for transfer of intellectual property, with organizations wishing to explore the viability of the system for specific applications, or to collaborate with his scientists on the technique.



5 // The High-Speed 3D Imaging System would have been beneficial in a recent NASA helicopter drop test to determine whether the occupants contacted one another as their limbs flailed around on impact

5

SYSTEM DESCRIPTION

Because the High-Speed 3D Imaging System uses commercial-off-the-shelf (COTS) hardware and software, it is a concept rather than a product, and users are able to add or change the various components to best suit their individual trials.

The concept has its origins in work undertaken by the Defence Science and Technology Organisation (DSTO, now DST Group) in conjunction with QinetiQ Australia on blast testing of vehicles on behalf of the Australian Army. Historically, blast testing was filmed in 2D, but it was realized that 3D imaging would provide a great deal of additional knowledge of an event. The 3D system was used for the first time in 2011, during blast testing of candidate vehicles for the Australian Army Protected Mobility Vehicle – Light (PMV-L) program.

A 3D frame of reference is established using surveyed points, which are photographed from all directions using a calibrated camera and the data fed into an initial piece of software. The test object is then marked with reference points and these are also entered into the computer, together with the surveyed ground reference points and their distance apart.

"From there the software is able to calibrate that space and it produces the coordinates for all the reference points on the test object," explains Holmes. "Then we go to another piece of software and enter the coordinates, and that's where we bring in our 3D high-speed vision."

High-speed cameras capable of withstanding up to 100 times the force of gravity are mounted in pairs and have their frames locked together to provide what is known as 'synchronized image acquisition', whereby both cameras image one frame at exactly the same time, then advance to the next frame simultaneously.

"A lot can happen in just a few milliseconds, and time hides things. The sound of a balloon bursting, for example, lasts for around 1-2ms and many critical events are unfolding in that time," adds Holmes. "During a land-mine event, for example, whether a person lives, dies or is injured is mostly determined in the first 2-20ms. Using high-speed cameras in a 3D array we have been able to calibrate the space of an area; and moving objects can be tracked and measured in that space. It shows us what happens, when it happens and where it happens."

6 // NASA's Langley Research Center crash tested a CH-46 helicopter in October 2014 as part of the TRACT 2 full-scale crash test to investigate cabin safety

FURTHER DEVELOPMENT

According to DST Group, the advantages of the system are that it allows for 'a greater understanding of dynamic events by providing the detail of movement in three dimensions'. Furthermore, because the equipment and software are all COTS-manufactured items, it is able to collect an expansive data set at a relatively low cost and can provide model validation in multiple planes.

100
The number of *gs* the high-speed cameras are built to withstand

1,000,000+
The number of frames per second that can be recorded by the Photron FASTCAM SA-5 motional analysis camera

At the present time, however, the concept has two separate and time-consuming processes: the first is the setting up of all the equipment, the creation of the surveyed frame of reference and the entering of data; the second is the processing of the images post-event.

"Although the cameras, lights and software systems are all COTS sourced, I think that there may be a better way of doing this, and we are looking to industry and academia to help us with the commercialization side of things," says Holmes. "For example, if someone were to produce one piece of software that could do everything for us, rather than having to go through multiple software steps, it would be a great advantage."

One of DST Group's recent strategies has been to collaborate with industry on the commercialization of technologies it is developing for mutual benefit, and the High-Speed 3D Imaging System is a good candidate, being able to offer an important means of tracking time-critical events at low cost.

"The system is applicable to anything that is time critical, and because most things that cause injury in a land mine event occur in the first 2-20ms, we needed to get inside that timeframe to see what happens," concludes Holmes.

"Although we have developed the High-Speed 3D Imaging System to target our science in the blast mitigation area, if someone in the aerospace testing domain has something that time-critical as well, that is the kind of thing our system will be really good for." \\

7 // Inside an Australian Army vehicle during improvised explosive device testing – the trajectory of items such as fasteners and fittings dislodged during the event can be accurately tracked with the new imaging system

Photron

HIGH-SPEED CAMERAS FOR SLOW MOTION ANALYSIS

Photron provides a wide range of highly light sensitive high-speed cameras for slow motion analysis. Or high-speed motion analyzers include systems ideally suited to particle image velocimetry (PIV) and digital image correlation (DIC), with mega pixel resolution to 21,000 frames per second (fps) and 4M pixels producing HD to 2,000 fps. Photron has a slow-motion camera for every application.

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// FRANK COLUCCI

Cockpit unders

Stress

The US Army Aeromedical Research Laboratory uses a unique flight simulator and instrumented research helicopter to quantify human factors in combat cockpits

1 // The US Army Aeromedical Research Laboratory NUH-60FS simulator collects aviator performance data under realistic cockpit stress

2 // Research 69 is a JUH-60A Black Hawk with a comprehensive avionics suite and onboard recording systems for flight and physiological data

The US Army Aeromedical Research Laboratory (USAARL) at Fort Rucker, Alabama, addresses medical, health and human issues that challenge the safety and performance of army aviators. Within the lab, the Flight Systems Branch operates an NUH-60FS flight simulator and JUH-60A Black Hawk helicopter, both uniquely instrumented to record crew vital signs and performance versus flight stressors.

The high-fidelity Level D simulator with its cockpit Environmental Control System most recently tested display symbology for an integrated cueing environment (ICE) to guide pilots through brownout dust and other degraded visual environments (DVE). The same modified training device previously tested aviator cooling solutions for hot cockpits and a bladder relief system for long-endurance flights. According to Flight Systems Branch chief and lead research pilot Erick Swanberg, "That's really what sets it apart – our ability not to use it just as a training device, but to collect data real-time from the pilots in the environment we can simulate."

The US Army wants to use DVEs to its advantage, and ICE-Visual, -Aural, and -Tactile (ICE-V, -A, and -T) cues are part of the broader DVE Mitigation (DVE-M) science and technology demonstration begun in September at Yuma Proving Ground, Arizona. The test team at Yuma flew an EH-60L Black Hawk from the Army Aviation Development Directorate/Aeroflightdynamics Directorate at Moffett Field, California, to fly more than 150 approaches to full brownout landing or hover, all with the help of ICE-V symbology. Before flight test, the USAARL simulator enabled researchers to try the intuitive cockpit symbology in realistic brownout conditions (inflight visibility restriction due to dust or sand in the air). Ten experimental test pilots each flew multiple sorties in the simulator and completed surveys still being analyzed for the test report. "We came up with a simulator flight profile that showed how the cueing would work in different environments," explained Swanberg.

The NUH-60FS databases can let pilots practice nap-of-the-earth (NOE), low-level, contour, and formation flight, or deck operations on frigates and aircraft carriers. ICE-V testing used a desert database with an

"It gives you a very realistic brownout landing"

3 // Integrated Cueing Environment-Visual (ICE-V) symbology provides 2D data and 3D conformal cues to help pilots in Degraded Visual Environments

3

out-the-window brownout model created by USAARL researchers and contractors with funding by the Army Utility Helicopters program manager in Huntsville and the Aviation and Missile Research, Development and Engineering Center at Redstone Arsenal, Alabama. The brownout model leveraged NASA simulation work done for lunar landings. "It gives you a very realistic brownout landing," says Swanberg. "It just develops like you'd see it in the aircraft. It kind of builds and builds with a more realistic image of the dust."

The DVE-M helicopter will go to Switzerland in 2017 to try Modernized Control Laws (MCLAWS); radar, LADAR (LAser Detection and Ranging) and long-wave infrared sensors; and an introductory cueing suite in snowy whiteout, fog, and other DVE. Small ICE changes identified at Yuma may be shared by the demonstration helicopter and the USAARL simulator. DVE-M program manager and experimental test pilot Major Joe Minor explains, "While possible, it is unlikely that these changes will be implemented in the USAARL simulator prior to Europe. They will, however, be integrated at some point, and the simulator will be utilized for future DVE-M cueing studies."

USAARL reports to the US Army Medical Research and Materiel Command and focuses its specialist divisions on aircrew health and performance, injury and protection, crew survival, and en-route medical care. Doctors, engineers, scientists and psychologists, identify, investigate and solve medical- and health-related problems that compromise aviator safety or the mission. Skilled research pilots determine whether the solutions are safe to flight test. "If a researcher has an aeromedical question like, 'How long can a pilot stay awake in an aircraft', they can come to us and the research pilots and ask 'Is this viable?'" explains Swanberg. "We can go in the simulator and put your theory to the test."

STRESSFUL SIMULATIONS

The Flight Systems Branch manages flight support assets for all USAARL divisions. The NUH-60FS simulator is used to maintain the proficiency of laboratory flight crews, but it is primarily a research tool to study army aviator performance degraded by psychological and/or physiological stressors including heat, dehydration and medications. A study for the US Defense Safety Oversight

3
Elements of DVE Mitigation – modernized control laws; see-through sensors; and an Integrated Cueing Environment with visual, aural and tactile cues

24%
of US Army Class A/B aircraft accidents from 2002 to 2015 had degraded visual environments as a contributing factor (US Army Combat Readiness Center, Aviation Directorate)

44%
of US Army aviation fatalities from 2002 to 2015 had degraded visual environments as a contributing factor

RESEARCH 69

In addition to its unique flight simulator, the USAARL Flight Systems Branch operates the army's only aeromedical research aircraft. Research 69 is a JUH-60A Black Hawk helicopter (serial 88-26069) equipped to collect flight and physiological data. The aircraft has a 3,400hp UH-60L gearbox, 200-gallon Robinson cabin auxiliary fuel tank, external rescue hoist, and medevac litter carousel. Although it retains the analog cockpit instrumentation of a UH-60A, the research platform has a comprehensive avionics suite including color weather radar, Blue Force Tracker, Fiber Optic Gyro attitude and heading referencing system, and VHF, UHF, FM, HF, and SATCOM radios to relay physiological telemetry to the laboratory. An Aircrew Wireless Intercom System provides a medevac construct to assess medical systems. The army helicopter also has a commercial Garmin 530W GPS navigator with moving map and satellite-based Wide Area Augmentation System capability, a Helicopter Terrain Avoidance Warning System, and Traffic Collision Advisory System.

A Sikorsky Aircraft Information System records flight parameters including air and ground speed, altitude, position, distance measuring equipment and instrument landing system indications, speed, and ground tracking. USAARL installs research instrumentation and uses a Dewetron data-recording system and Go-Pro cameras to collect crew information in flight.

USAARL pursues cooperative studies with other US military and government agencies, industry and academia, and the helicopter has been used for a range of investigations. Flight tests supported studies on motion sickness among airborne unmanned air vehicle operators, pilot performance and alertness with stimulants, and the effectiveness of noise-canceling earplugs. Research 69 flew tests of the Tactile Situational Awareness System after simulator studies.

4 // The convertible USAARL simulator has been used to study helmet- and panel-mounted displays, tactile cueing, aviator cooling solutions, and other man-machine technologies

5 // The NUH-60FS simulator can be converted from analog to digital cockpit configuration with a fully functional UH-60M instrument panel façade

"A USAARL research pilot monitors data collection"

Council in 2008 and 2009, for example, used the USAARL simulator and helicopter to measure how psychostimulants impacted the alertness and performance of fatigued aviators. Another effort for the Defense Advanced Research Projects Agency researched effective field-of-view for panel-mounted DVE displays. Laboratory researchers are planning simulator investigations of man-machine issues related to increasing automation in rotary-wing cockpits, including adaptive automation and bio-monitoring.

The USAARL research flight simulator started as a 1985-vintage UH-60A training device with 6DOF motion base. USAARL upgraded the device with eight Dell XIG visual image generators that show day, dusk, night, and night vision goggle views obscured by blowing sand or snow. Visual scenes are created using real-world satellite imagery of Fort Rucker and other locations. An environmental control system (ECS) behind a transparent cockpit bulkhead maintains cockpit temperatures from 60°F to 105°F ±2.0°F and relative humidity from 50% to 90% ±2%. "Because it's a research simulator, we had the ECS added to it, and we've got all the data collection devices as well," says Swanberg. "That makes it really one of a kind."

Heat-stressed pilots in the simulator validated the Army Aviator Microclimate Conditioning System worn under full nuclear-chemical-biological protective gear. They later compared army and navy cooling systems under the same Mission Oriented Protective Posture (MOPP4) ensemble.

USAARL technicians configure the simulator for whatever data the study requires. An Aeromed computer including a Research Data Acquisition System (RDAS) and a biomedical equipment cabinet sits behind the instructor/operator station (IOS). The RDAS samples and stores hundreds of flight parameters at 30fps. The biomedical cabinet meanwhile collects pilot heart and respiratory rate, core temperature, electroencephalogram, galvanic skin response, eye-tracker, and other physiological readings. Infrared lighting and cameras capture visual records of crew coordination. Digitized physiological data is synchronized to flight data parameters, and the simulator provides empirical evidence of workload and situational awareness in realistic flight conditions.

A USAARL research pilot monitors data collection from the IOS behind the simulator cockpit while medical and research technicians observe from an external

"It gives us an opportunity to look at pilots flying glass as well as traditional"

station. Simulator instrumentation is developed and installed by technicians from the Flight Systems Branch and Research Support Division, augmented by teams representing the principal investigator from one of the USAARL science divisions. Researchers can add custom data collection devices via a laptop or networked computer.

DUAL COCKPIT

The simulator mimics the vibration environment of a real Black Hawk and has an enhanced sound system to recreate cockpit noise. Hardware and software upgrades gave the cockpit up-to-date transponder and enhanced GPS navigator functions to expand IFR capability.

In 2014, the research simulator received a removable instrument panel façade to switch the cockpit from analog UH-60A/L to digital UH-60M/V cockpit configuration. The digital 'glass' cockpit with four multifunction displays presents flight and systems symbology, sensor imagery, threat warnings, and digital maps representative of the latest Army Black Hawk. "The only hardware change is the simulator technicians installing the façade over the instrument panel," says Swanberg. "There is another computer that runs the graphics for that, but that's a real easy setup."

The bottom center instrument console remains representative of a UH-60A. "It's a hybrid cockpit," acknowledges Swanberg. However, the split façade can put UH-60A/L electromechanical instruments on one side and UH-60M/V 'glass' displays on the other. "It's a really unique design, and it gives us an opportunity to look at pilots flying glass as well as traditional if we want to study that. As part of the ICE architecture, a Tactile Situational Awareness System (TSAS) uses vibrating 'tactors' in an aviator's waist belt, the shoulder harness, and seat cushion to cue pilots to lateral drift, changing altitude, or a defined flight corridor."

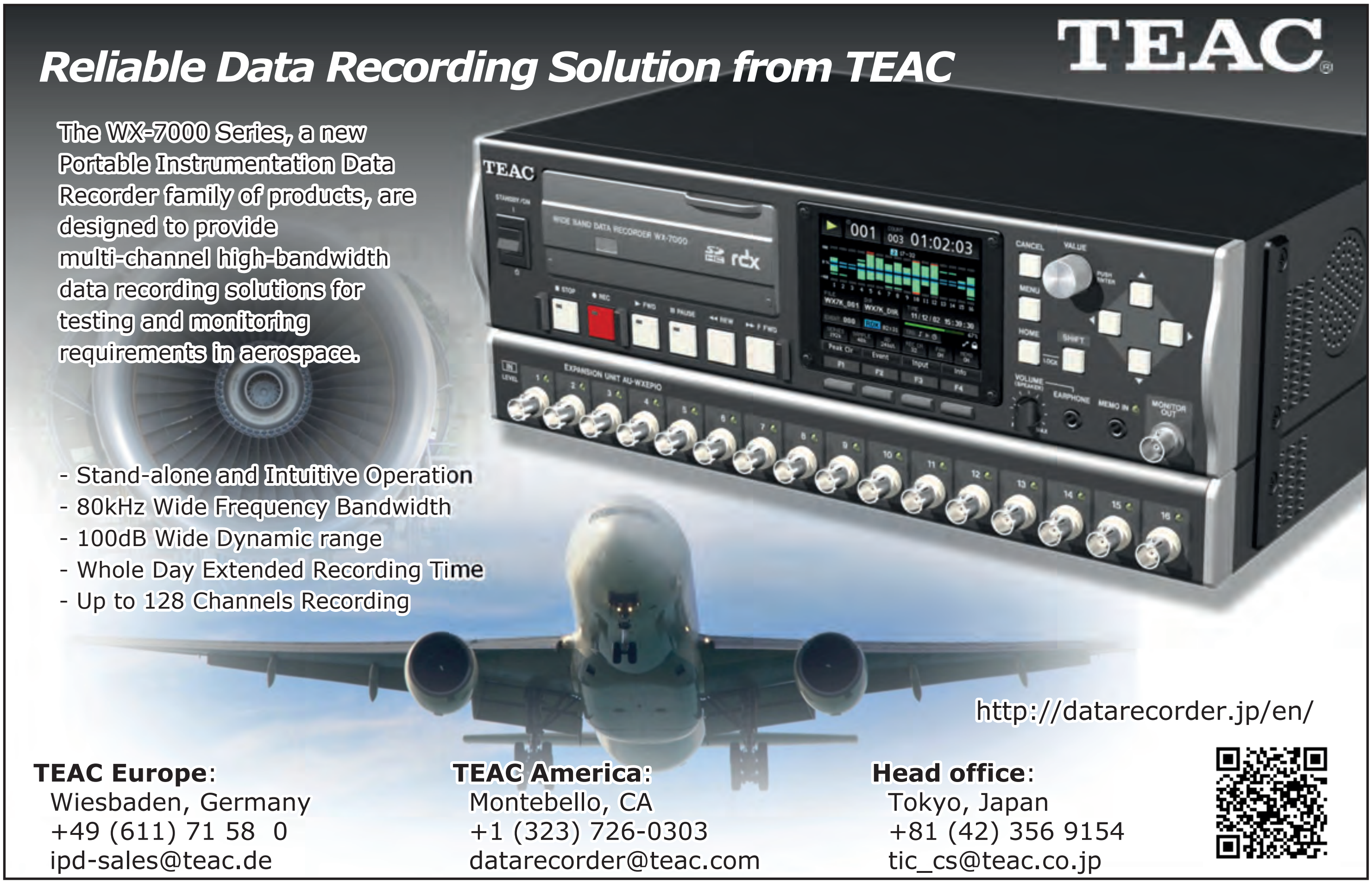
USAARL started cooperative TSAS development in 2009, and the NUH-60FS simulator later gave the commanders of the US Army Safety Center and Army Aviation Center of Excellence chances to try tactile cueing technology for themselves. "It did exactly what it was designed to do and it was well received," concludes Swanberg. TSAS was used in about half of the Yuma DVE-M flying.

Aural cues were also used in about half the Yuma brownout approaches. Military and commercial aircraft routinely use two-dimensional tones, alarms and artificial voices to cue pilots. Three-dimensional audio conveys spatial separation to help pilots distinguish direction of warnings and crew communications. Both 2D and 3D audio are elements of the ICE and will continue to be a subject of research in the DVE-M on the USAARL simulator and the ADD-AFDD EH-60L.

DVE-M ultimately integrates the ICE with see-through sensors and MCLAWS. MCLAWS software now in flight testing will be installed in the USAARL simulator. The Black Hawk research simulator is being used to develop realistic training scenarios to identify and combat spatial disorientation in DVE, and it is receiving a computer upgrade to improve its visual system. \\

6

6 // The US Army Aeromedical Research Laboratory at Fort Rucker, Alabama, has a unique NUH-60FS flight simulator to investigate human factors amid cockpit stress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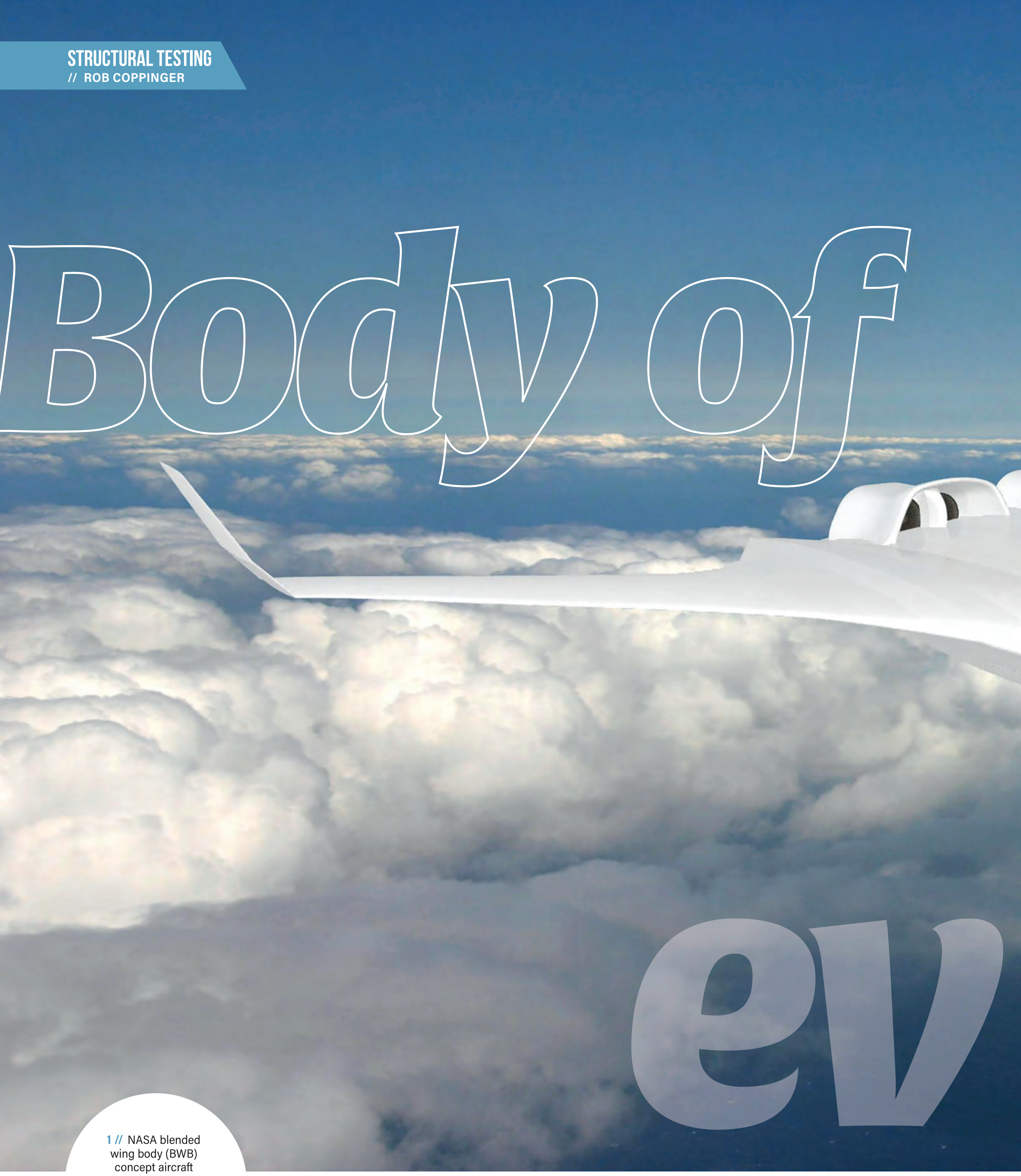

1 // NASA blended wing body (BWB) concept aircraft

A number of new technologies are helping structural testing teams meet the challenges presented by evermore complex blended-wing fuselage designs and CFRP composite materials

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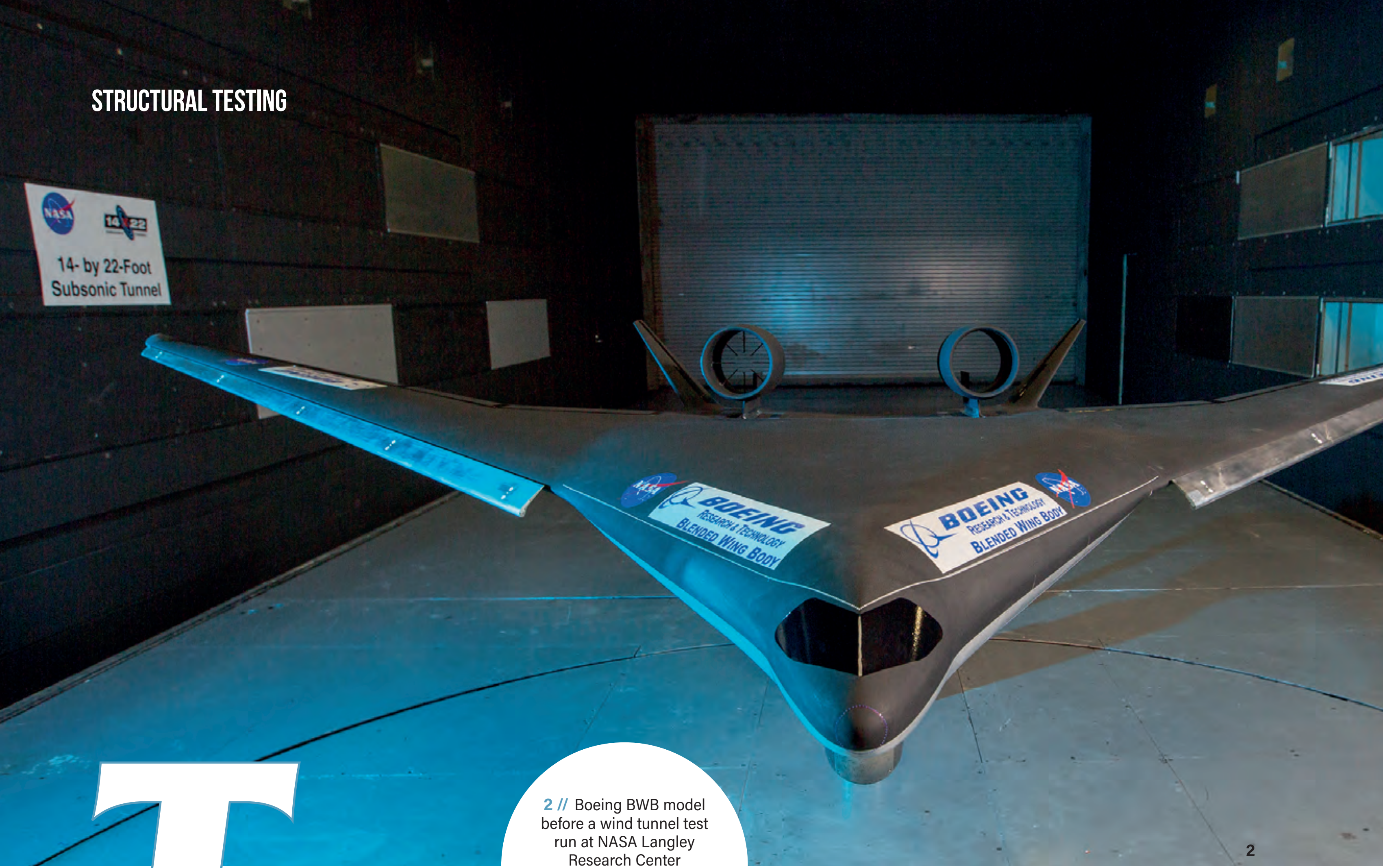


2 // Boeing BWB model before a wind tunnel test run at NASA Langley Research Center

Testing aerospace structures is progressing as aircraft designs become more challenging, with increasingly complicated layers of composite materials combined with more electric systems to operate a wing's control surfaces, such as ailerons. For example, in the USA, at NASA's Langley Research Center, a captive water column ultrasonic probe has been created to overcome the obstacle of having to immerse test articles into a liquid medium – a time-consuming process that requires the part being tested to be removed from the testing rig. In Europe, an x-ray method has been the subject of European Union (EU) research funding and promises three-dimensional images, as well as two-dimensional images, and is considered better than ultrasonics, according to its developers.

Other methods now being used include fiber optics, known generically as a distributed sensor system, and acoustic emission sensors, for listening for the energy released by cracks – micro or larger.

HYBRID WING BODY

Earlier this year, NASA published a report on its testing of an 80% scale model of a fuselage center body for a hybrid wing body (HWB) aircraft. An HWB aircraft is like a flying wing and promises fuel savings of up to 20% over today's airliners, and half the noise.

"I was using a modification of ultrasonic testing, where I used a fixture on the front of my ultrasonic probe that had a column of water captured in it with a rubber membrane, and I had the coupling medium attached to the probe," NASA Langley research scientist Patrick Johnson tells *Aerospace Testing International*, while explaining how a captive water column ultrasonic probe works. To ensure the 'coupling' between the probe and the workpiece, water is sprayed on the piece's surface. "Clearly one problem we have had in the past using that immersion system is taking the part out of the test setup to do an immersion test, and then trying to put it back into the mechanical testing setup."

20
A hybrid wing body aircraft could be up to 20% more fuel efficient than today's airliners

20
X-raying composites could work with structures of up to 20m

2030
Hybrid wing body aircraft are unlikely to be flying operationally until the 2030s

The fuselage center body, also known as a multibay box or MBB, was an 80% scale model of what would be needed for NASA's reference HWB aircraft. This is because the MBB's size is the largest structure that could be fitted to the Langley test rig, known as the Combined Loads Test System (COLTS). The reference HWB aircraft is defined in NASA's Environmentally Responsible Aviation project as similar to a large twin-aisle type aircraft. The project's goals are based on improvements over the performance of the twin-aisle Boeing 777-200 and assumes it is using GE90 engines.

As the MBB is so large and the non-destructive examination (NDE) process being used is manual, Johnston and his colleagues used suction cups to help place the ultrasonic scanning device onto the areas of the MBB that needed to be examined. Up to 18 locations were inspected.

PRSEUS HWB PROJECT

The Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS) structural concept was developed under NASA's Fundamental Aeronautics Program's Subsonic Fixed Wing Project, with the help of Boeing and the USAF's Air Force Research Laboratory. PRSEUS is a structural concept developed by Boeing to address the complex structural design aspects associated with a pressurized hybrid wing body (HWB) aircraft configuration. It is also an integral structural concept for an HWB where skins, frames, stringers and tear straps made of a variable number of layers of dry warp-knit carbon-fiber stacks are stitched together, then resin-infused and cured in an out-of-autoclave process. PRSEUS could reduce weight and cost, and increase the structural efficiency of transport aircraft structures. A key feature of PRSEUS is the damage-arresting nature of the stitches, which enables the use of failsafe design principles. NASA is also studying the blended wing body (BWB) aircraft. The difference between the HWB and BWB is that the hybrid retains a conventional cylindrical pressurized section within its main body, while the blended structure does not. A scale-model HWB aircraft is to be flown by Lockheed Martin this year. The BWB configuration offers more internal volume, higher aerodynamic efficiency and reduced noise, according to NASA.

3

3 // Boeing engineer Stephen Provost checks out a BWB model before a wind tunnel test run at NASA Langley Research Center

The structure successfully tested at Langley directly addressed the biggest structural challenge for an HWB vehicle, which is the fuselage center body. This 'blended' structure takes fuselage and wing bending loads in combination with cabin pressure, all in a non-round, non-constant section geometry that must meet transport aircraft damage tolerance requirements. The HWB structure demonstrated at Langley included the largest and most complex integrated composite panels ever built, according to Boeing.

"Boeing's vision for a hybrid wing aircraft is entirely CFRP [carbon-fiber-reinforced polymer] composite that incorporates the significant advancements made under NASA's Environmentally Responsible Aviation program," explains Boeing's blended wing body (BWB) test director, John Bonet. "Specifically, the use of a damage-arresting, stitched, unitized structure for the wing box and fuselage center body. But, note that aircraft that contain CFRP composite, the Boeing 787, for example, still contain metallic structures such as titanium fittings, aluminum wing ribs, etc. Composites throughout is the objective, but metals will always have a role." The stitched, unitized structure he refers to is the Pultruded Rod Stitched Efficient Unitized Structure or PRSEUS (see *PRSEUS HWB project*, above).

"For sandwich structures, we had good effects"

Bonet also explains that for the COLTS ground testing, fiber optics were used to gather continuous strain data along highly loaded panel edges: "The fiber-optic system performed well, supplying valuable panel response data during testing."

PHASE CONTRAST X-RAY IMAGING

In Europe, the research is not as focused on a particular aircraft concept, but the technology can still be applied to the materials and structures that would be used. "Take aluminum and composite hybrid materials – we can look at these," explains Dr Vincent Revol, a research and development engineer at Centre Suisse d'Electronique et Microtechnique (CSEM), a research and technology organization and a public-private partnership based in the west of Switzerland, in Neuchâtel.

"Our variety of structures is very high – we had structures that were CFRP and we had different defects we qualified. This technology was better for some materials than traditional techniques. For sandwich structures, we had good effects. Ultrasonic systems are not as well adapted for these structures."

Revol was technical lead for the EU-funded Non-Destructive EValuation, Inspection and Testing of

Primary Aeronautical Composite Structures Using Phase Contrast X-Ray Imaging, or EVITA for short. EVITA was centered at Revol's employer, CSEM. Just as the NASA/Boeing work had begun before 2010, CSEM has been working on the x-ray system since 2006. EVITA started in 2012 and ended in 2015. "The development of the measurement system prototype was done here with the collaboration of the partners in the project," says Revol.

While Revol's work does not include a vision vehicle like NASA's twin-aisle, Boeing 777-beating, hybrid wing body aircraft, European research has recently looked at functional composite hybrid materials. The work, which took place over three years in Italy and Germany, examined layers of a new generation of piezoelectric fibers in a sandwich structure, capable of flexing a portion of the wing so it acts as a control surface.

The EU Future Wings project ran from June 2013 to the end of July this year. The European Commission's (EC) project objectives description did describe a possible future aircraft as a "great body with its end structures that could have the possibility to change their shape. The aerodynamic shape of aircraft lifting surfaces must change during the flight." But there is no reference aircraft as specific as NASA's. The EC description added that, "Self-shaping wings, i.e. wings the surface of which can be elastically deformed through its entire length...

"You can scan more complex geometries easily"

such wing performances could be obtained through the application of composite hybrid materials." The project concluded that the technology exists to create the self-shaping wings using composite hybrid materials.

But, despite x-rays' known abilities to go through almost any material and Revol's x-ray's ability to look at sandwich structures, the process cannot scan through a conventional wing. "On the aircraft wing on the tarmac you have a lot of overlaps between parts and this technique is a transmission technique; we go through all the parts with the source on one side and the detector on the other side. This is not adapted for scanning a full wing – you won't be able to distinguish between the different depths," he explains.

"Our x-ray process's advantage is you can scan more complex geometries easily. Another advantage is that there are some defects that are not detectable with ultrasonics, such as microcracking, which this new technique is able to detect much better with much higher

BWB IN THE TUNNEL

In September, NASA aeronautics engineers began preparing for six weeks of wind tunnel tests at the agency's Langley Research Center of a 6% scale-model of a Boeing blended wing body (BWB) concept. A blended wing body is where the wing and body structures blend, rather than the typical aircraft that has a cylindrical body and the wing is fixed by the wingbox to the cylinder. The BWB does not have a tail either. This same model was put through its paces in the Langley 14 x 22ft tunnel in 2014; and in the 40 x 80ft wind tunnel at NASA's Ames Research Center in California in 2015. This time, lasers will be used to map the airflow over the aircraft model. This laser analysis helps engineers understand the airflow going into the engine inlets, which is one of the challenges with this design, since the engines are on top of the fuselage, toward the rear. Putting them on top of the airplane helps shield people on the ground from the noise. The 14 x 22ft wind tunnel has been upgraded and NASA is also using the model to verify the tunnel's performance as it has been tested there before.

4 // NASA Langley Research Center staff use measurement technology during non-destructive testing of the HWB aircraft multi-bay composite box in the agency's Combined Loads Test System (COLTS) facility

4

5

5 // X-ray interferometer, from CSEM's non-destructive EValuation, Inspection and Testing of Primary Aeronautical Composite Structures Using Phase Contrast X-Ray Imaging (EVITA) project

sensitivity," continues Revol. The x-ray process could also replace the acoustic emission sensor process.

While Johnston's captive water column probe solves the problem of moving test articles from the testing rig to the ultrasonic medium tank and back again, Revol's x-ray method can be scaled up from its current 1m² capability. Langley also has a square meter capability for its x-ray work. Revol sees no reason "to limit [the x-ray process] up to a certain size". He explains, "The parts can be really long, in another direction limited to 3-5m for larger structures. You need to develop a new approach for 20m long in both directions."

The next steps for Revol's team is to improve the sensitivity of the process and also in future to get 3D images with a dual x-ray imaging technique. He adds that there is strong industrial interest in bringing the x-ray technology out of the laboratory and into the factory, whether that is for an OEM or maintenance repair organization. With a 1m² capability, component parts are the only aviation structure the x-ray system is going to analyze soon. "We are thinking about production and quality control of components, and only maintenance for overhaul to disassemble parts and check them," notes Revol.

From three-dimensional imaging of sandwich wing structures, to *in situ* testing of large structures in test rigs, a number of exciting, new non-destructive evaluation technologies are going to be in place for the very different airliners of tomorrow. Europe's Airbus has no timeline for an HWB or BWB airliner and neither does Boeing, but Lockheed has proposed a hybrid wing body for a future USAF refueling tanker or cargo transport. "We don't anticipate further testing until NASA's X-plane program moves from the planning to the execution phase," says Boeing's Bonet. In April, NASA announced its plans for its X-plane program and its focus is quiet supersonic flight. A supersonic aircraft is going to be dart shaped, rather than a flying wing. However, Revol and Johnston have plenty of time to perfect their structure inspecting processes. \\

AIR-COOLED SHAKER

A new vibration test system has been designed to offer unparalleled reliability with minimum service requirements, maximizing shaker uptime and reducing running costs

Testing and developing anything new in this era is a complex process: there are laws, standards and regulations with which to comply; there are new materials, potential environments and vibration test systems (available in a variety of sizes and capabilities) to consider; and the different combinations of these factors spawn a multitude of possible test scenarios. It is the ability to accommodate those factors and incorporate them with market trends and needs that is required to create a successful vibration test system.

Looking at the test market, Brüel & Kjær saw that there was a significant gap in the force ratings offered between high-end air-cooled and low-end water-cooled shakers. So to test at force ratings within that gap, users have had to purchase expensive (both in terms of initial investment and ongoing running costs) water-cooled shaker systems. This added expense has often led to projects being delayed, shelved or downgraded, restricting the possible test scenarios.

Additional market feedback indicated that shaker performance is of the utmost importance. A common complaint is poor overturning moment restraint, which relates to the shaker's ability to handle unbalanced and irregular payloads. Suppliers tend not to address this aspect, which often leads to inadequate and unreliable specifications. In addition, the ability to quickly and safely vary the field power has been shown to offer a more balanced performance profile.

Based on the observed gap and market trends and needs, Brüel & Kjær's research and development team, situated in Royston, UK, focused on and succeeded in developing a new shaker capable of achieving the highest force of any air-cooled shaker on the market. The core strategy was to incorporate existing and proven technology (hydrostatic bearings from the vibration industry and inductive sensors from the automotive industry) in a modern and robust system. This led the way to unlocking unparalleled reliability with a minimum of service requirements, maximizing shaker uptime and keeping the ongoing and running costs low.

1 // The LDS V8900 offers increased reliability in payload testing

Minimizing running costs was a key building block in the development of the LDS V8900 shaker as it plays a critical role in keeping the total cost of ownership low. The expense of long-term ownership of high-performance shaker systems can cause problems in what is an ever-evolving industry, so making sure the capital expenditure economics are attractive is key. By creating an air-cooled high-force capacity shaker that overlapped with some of the water-cooled shakers, and taking advantage of the inherent benefits of air-cooling, higher degrees of testing could be achieved at a fraction of the existing initial and ongoing costs.

Brüel & Kjær's LDS V8900 is not only a new class of high-force, air-cooled shaker that addresses the market's need; it also represents a customer-focused solution that is built on a brand-new technology platform that puts the operator at the heart of a system with intelligent service monitoring, ease of operation and simple firmware and hardware upgrades. This shaker has been designed from the ground up to deliver cost-effective performance without compromise – high force, high overturning moment restraint, high frequency and long displacement. \\

AIRFRAME STRUCTURE ANALYSIS CHALLENGES

Standardization of the aerostructure sizing process can be accomplished more easily and collaboratively with Siemens PLM Software

// Siemens PLM software streamlines the global simulation process

Most aircraft companies are facing fundamental challenges in engineering departments. This is most strongly felt in the structures areas due to increased complexity in products and ever-increasing demands for safety and certification. The main challenges in airframe structure analysis are automation, standardization, traceability and deployment.

The global simulation process implies many engineering teams working closely together from CAD definition to CAE model and stress analyses. Automation of the process is key to speed up and improve efficiency of design-simulation iterations.

Also, aerostructure sizing leading to certification means computing millions of structure analyses. Oversight processes may face a lack of experience and inconsistencies in the stress analysis process, so automation and standardization of the processes are key challenges for airframe structure analysis. There is a constant struggle to keep the visibility and traceability of specific data, models and processes/methods to use them from concept to end product.

A global organization may share models with suppliers which implies real challenges in security of data and knowledge, and the organization of work.

Implementing a global aerostructure simulation process

Siemens PLM software offers complete aerostructure simulation allowing traceability of data and results while maintaining consistent global process control.

Simcenter is a comprehensive portfolio of simulation (plus advanced methods) and data management tools, that streamlines the process from the CAD geometry definitions to a CAE environment. Besides a detailed finite element models approach, end-users can size their aerostructure components using analytical methods thanks to LMS Samtech Caesam, an aerostructure stress analysis tool. Stress reports can be generated with safety margins results.

Data management, models, simulation results and tools are managed in Teamcenter for Simulation.

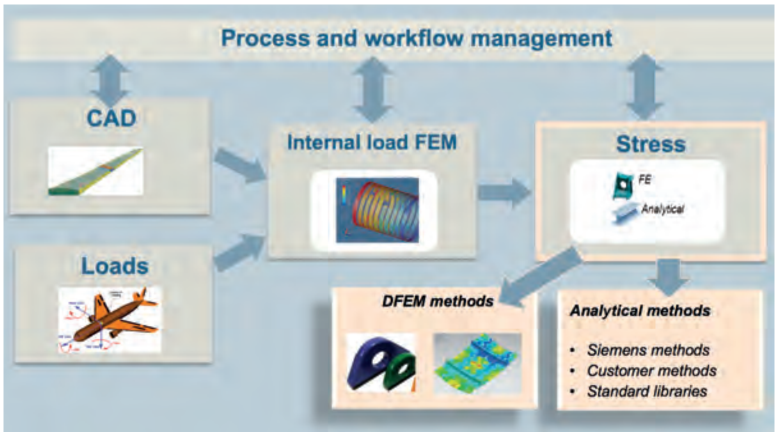
LMS Caesam speeds up certification

To speed up the certification process, LMS Caesam provides end users with software that streamlines the structural analysis process, from the finite element internal loads up to safety margins computation on aerostructure components and stress report generation, giving a time-cost benefit over the full design cycle.

LMS Caesam provides a standard library of engineering methods and out-of-the-box capabilities for pre and post processing. It handles loads management, reporting and comparison, keeps an archive of analyses results, scripting and batch computations, and can connect to Teamcenter and provides end users with a standard aerostructure simulation process that ensures consistency in the airplane program structural analysis.

LMS Caesam secures and capitalizes the experts' knowledge in unique stress analysis applications, providing users with harmonized access to standard and customer methods and maintains automation and traceability of certification data up to the generation of the stress report. Therefore, engineers can concentrate on more advanced engineering aspects.

Applications based on LMS Caesam can be deployed across the globe so that airplane OEMs can outsource and create competition within the supply chain by providing a unique environment to engineers with appropriate methods and tools. \\

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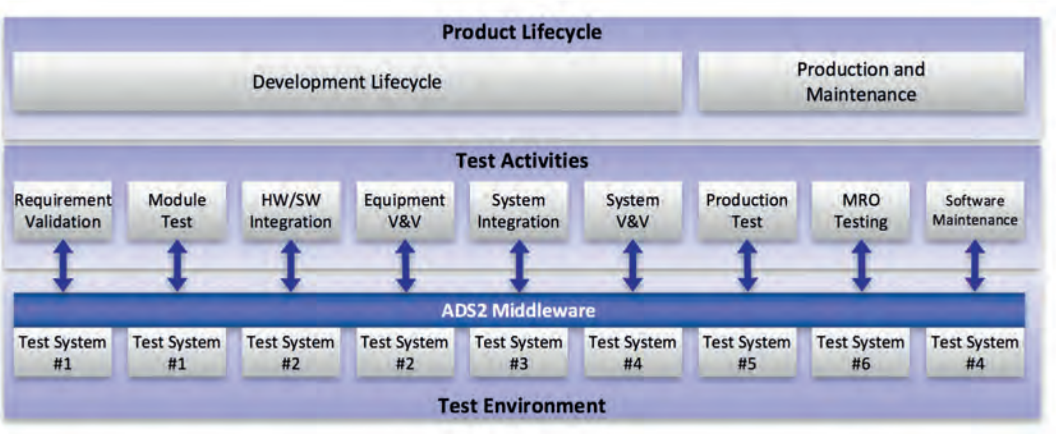
Future test platforms will be based on smart and modular middleware to fulfill customer needs over the entire product lifetime



// The ADS2 test system software is middleware supporting various test systems for the lifetime of the product

Testing has always been one of the most important activities in the aircraft product lifecycle, ensuring safe operation and quality of service. During the development lifecycle, testing includes activities pertaining to integration, validation and verification.

The higher the complexity of aircraft systems, the more effort has to be spent on testing and the higher the demands on the test systems.

Today's test systems are required to support short cycle times down to a few 100 microseconds for hardware/software integration or functional equipment validation and verification of modern airborne controllers. On the other hand, test systems with the capability to run test sessions with more than a million process variables are needed for aircraft system integration.

Therefore, the aircraft or system manufacturer has to procure test systems for the specific test purposes, often from various suppliers and with different operating philosophies. This results in increased need for staff training or extra work caused by incompatibility, e.g. duplicated creation of test cases for different test system software.

These conflicting demands on the test system software are further aggravated by the continuous expansion of testing caused by model-based systems engineering or virtual testing with a large number of different kinds of simulations and hardware emulations in virtual machines.

Aircraft or system manufacturers have a chance to mitigate these problems by using portable, modular, configurable middleware for their test systems that supports hardware abstraction, test automation and documentation of model, software, equipment and system tests with continuous traceability from the requirements to the test results.

TechSAT decided to provide a new version of the ADS2 test system software that is rigorously implemented as middleware and tailored to operate the various test systems over the entire product lifetime.

The modular structure of the ADS2 middleware with easy portability to new test systems supports typical applications, such as hardware-in-the-loop (HIL), model-in-the-loop (MIL), software-in-the-loop (SIL) and processor-in-the-loop (PIL) tests during the development phase. Also supported are test systems for later production and maintenance purposes.

The open ADS2 data and control interface is based on process variables and allows customer-specific extension or use of test systems without recompilation of the test system software or test session. These open runtime data interfaces – as well as the file-based configuration and data exchange mechanisms with a flexible and extendable format – allow broad tool support with deep process integration.

A major feature for fast and agile support of engineering activities is the flexible mapping and relocation of test session components and I/O to computing resources during runtime -for test session optimization.

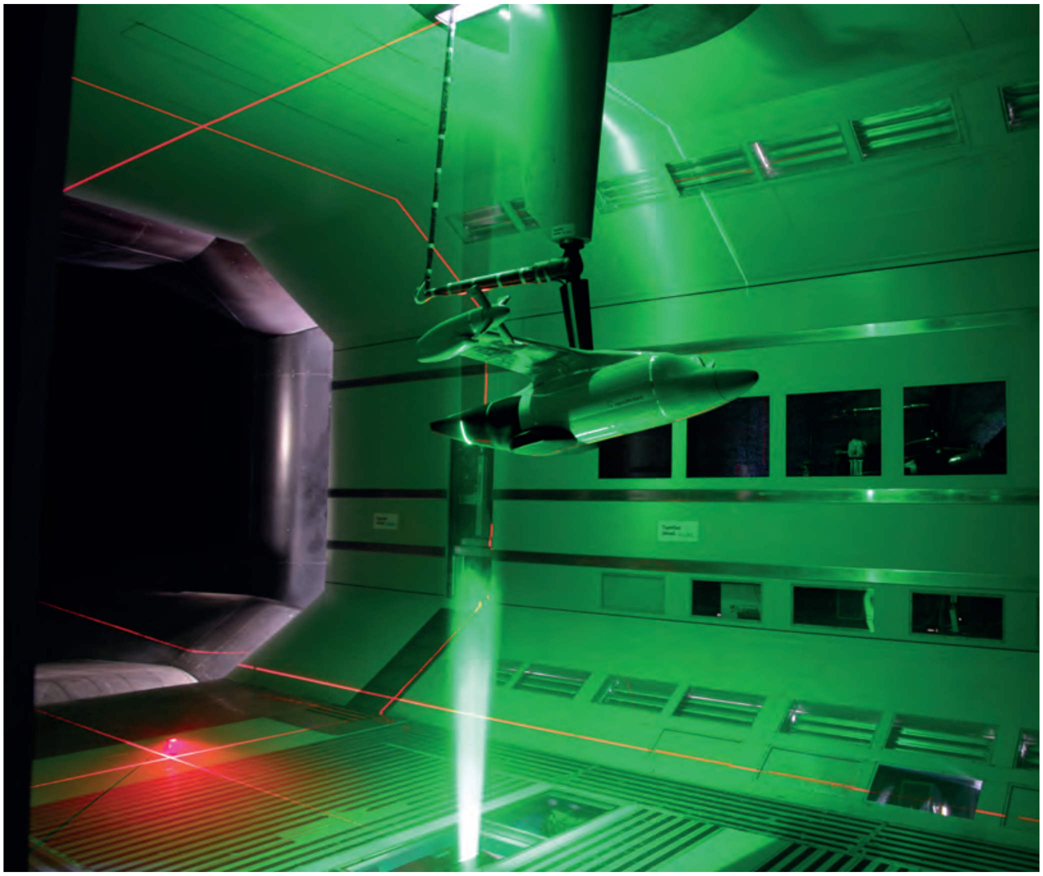
With the new driver development kit (DDK) of the upcoming ADS2 release, TechSAT is opening its middleware for customer-specific or third-party hardware integration by the user. Therefore, development and integration of drivers and simulations are eased by an ADS2 feature to terminate, restart and debug components during runtime.

The ADS2 middleware is continuously being extended to allow for integration of test systems from different vendors and to support future standards like virtual hybrid testing next generation (VHTNG). Health monitoring and inventory management are features to support maintenance and test system availability. A future extension, depending on customer needs, may be the graphical analysis of session traffic on and between computing resources for optimization of test or virtualization environments with numerous simulations.

With the merger of TechSAT and Nexeya, the best technology of both worlds – with well-proven and much-valued test capabilities and services – will be combined on a common technology platform that will be available to all TechSAT customers. \\

FUSELAGE DRAG REDUCTION

A European research project at the RUAG Aviation Large Wind Tunnel has been exploring solutions for reducing drag on tilt-rotor aircraft



// Aerodynamic testing using a wind tunnel tiltrotor model

In 2013, RUAG Aviation and its consortium partners, the University of Padua and the Italian technology company Hit09, were awarded the tender for an EU research project to assess the effects of fuselage drag reduction on a tilt-rotor aircraft. Tilt-rotor aircraft combine the flight characteristics of fixed-wing aircraft and helicopters. The project, titled DREAm-TILT, validated drag computations produced by Hit09 and the University of Padua with experiments conducted on a physical model of a tilt-rotor aircraft. These were carried out at the RUAG Aviation Large Wind Tunnel Emmen (LWTE) facility in Emmen, Switzerland.

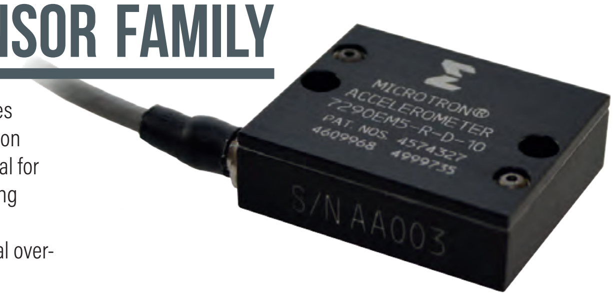
The DREAm-TILT research project was part of the ongoing European Union Clean Skies program, an ambitious research and development initiative aimed at reducing the impact of commercial aviation through improved efficiency and noise reduction. Italian helicopter OEM AgustaWestland (now renamed Leonardo) took on the role of Project Coordinator for the DREAm-TILT research, and maintained an overview of the project.

RUAG Aviation was given responsibility for conducting the experiments, as well as for supporting the evaluation of the experimental data. The consortium's primary focus throughout the project was drag reduction, with team members using numerical flow computations and wind-tunnel experiments to identify measures that would reduce fuselage drag. The RUAG Aviation LWTE is one of the largest sub-sonic, wind tunnel testing facilities in Europe, with a closed-loop circuit and a test section measuring 7 x 5m. The size of the facility, as well as the accuracy of the measurement technology available there, made it well suited to the experimental aspects of the project. An in-house-manufactured RUAG six-component block-type balance was used as the main internal balance. Due to careful preparation, the predicted accuracy of the measurement setup could be easily achieved. The use of a new thermal-imaging camera, which could detect temperatures to an accuracy of tenths of a degree, allowed it to identify the tiniest variation in the surface temperature of the model. These temperature differences indicate the regions of laminar and turbulent flow on the model.

The target vehicle for the experiments was a 1:8 scale tilt-rotor model. Upon completion of all the experiments, RUAG Aviation met its two project partners to compare the experimental and numerical results as part of a blind test. Experimental and computational data agreed quite well and confirmed the previously predicted drag reduction hypothesis and showed that the overall project goal could be met. In a supplementary test right after the DREAm-TILT project, the flow field of the wind tunnel model rear ramp had been subjected to further investigation by particle image velocimetry (PIV).

The company believes that participation in such research is important. It is an opportunity to test the viability of future technologies and to refine them; it is also a chance to foster stronger relationships and collaborate with OEM partners and potential customers. The DREAm-TILT project is likely to leave a lasting legacy, as a reference for future wind tunnel developments in the helicopter sector: "We learned a great deal from this project," says Daniel Steiling, aerodynamics engineer at RUAG Aviation. "Once the project was completed, we were pleased to be able to present the findings to our partners at international conferences." \\

RELIABLE SENSOR FAMILY



The Endevco 7290EM5 series features ranges from 2*g* to 100*g* with precision digital temperature compensation ideal for low-frequency aircraft testing, including watertight performance for outdoor installations. Gas damping and internal over-range stops allow this transducer to withstand high *g* shock and acceleration loads. Sensors feature +0.2% full-scale output (FSO) typical non-linearity and hysteresis for most ranges.

The Endevco family includes piezoelectric, piezoresistive, Isotron and variable-capacitance accelerometers, piezoresistive pressure transducers, microphones, electronic instruments and calibration systems. All are designed to ensure critical accuracy and reliability in aerospace, automotive, defense, industrial, medical, power generation, R&D, space, and test and measurement applications. \\

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MEGGITT SENSING SYSTEMS

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WHAT'S THE PROTOCOL?

The new ANET-MxAy Mixed Protocol ANET has a maximum of two dual redundant MIL-STD-1553 streams and up to 12 ARINC429 channels. The MIL-STD-1553 section offers concurrent bus controller, multiple RT simulator (31) with a mailbox and chronological monitor functions. All the ARINC429 channels are fully software programmable for Tx/Rx mode as well as low- (12.5kBit/s) and high-speed (100kBit/s) operation.

Standard ANET features like IRIG-B I/O, discrete I/O, trigger I/O and a general-purpose USB2.0 port for hosting USB devices are available for the mixed-protocol ANET with the Ethernet interface supporting 10/100/1000 Ethernet links. An onboard buffered real-time clock (RTC) is also available by default.

The ANET-MxAy is offered with the standard AIM ANET housing as well as a rugged housing variant.

The API interface is compatible with the API of the individual MIL-STD-1553 and ARINC429 ANET interfaces for a very efficient migration path for the customer's application software. Powerful ANET features such as the onboard Python scripting, customer-written C applications and the optional PBA.pro Engine (for execution in the box) are also available via the embedded Linux-based application support processor.

The PBA.pro test and analysis software for Windows and Linux supports the mixed-protocol ANET using the standard resource components for MIL-STD-1553 and ARINC429, as well as the AIM ARINC615-3 data loader extensions PBA.pro-ARINC429-LDR. The AIM EasyLoad-429 standalone data loader application also supports the mixed-protocol ANET for 615-3 data loading via ARINC429. \\

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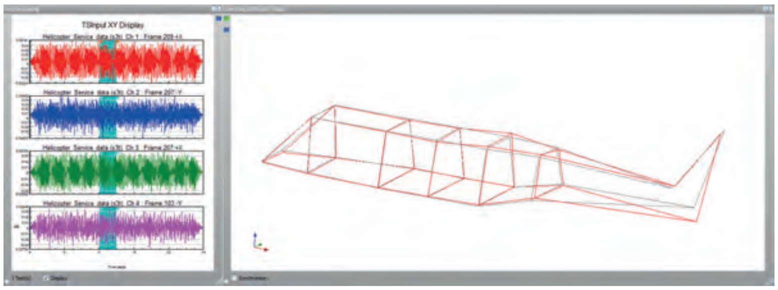
IMPROVED VIBRATION FATIGUE



Aerospace engineers are challenged with maintaining the reliability, safety and robust operation of aircraft and equipment. These engineering challenges are broad in scope, ranging from managing vibration to predicting and extending product life to quickly validating new designs through analytical means such as finite element analysis (FEA) based simulation. HBM Prenscia offers a way to improve the accuracy of these FEA-based fatigue life predictions through the introduction of experimental modal analysis in nCode VibeSys. The addition of modal analysis helps engineers solve noise and vibration problems by answering important questions early on in the development process.

Within nCode VibeSys, users can quickly obtain the natural frequencies, damping ratios and mode shapes of a structure from experimental test. It is also possible to compare the mode shapes obtained experimentally with modal results from FEA with VibeSys's new ODS glyph to investigate modal assurance. \\

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INTERMITTENT FAULT DETECTION SOLVED

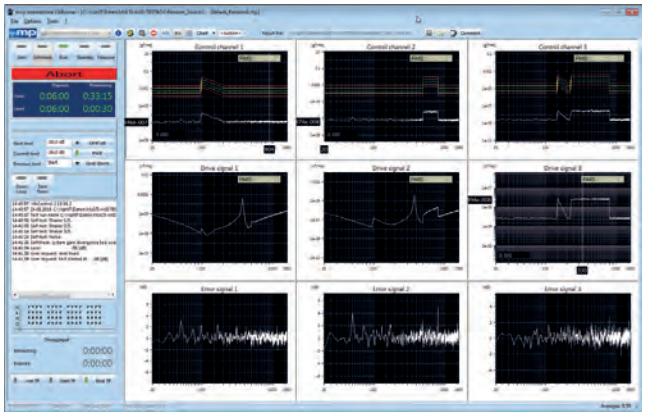
Electrical intermittent faults plague aerospace systems and until now, no test solution could detect them. When traditional testing systems fail to identify the faults, suspect units are returned to service only to fail again. Intermittent faults occur randomly in time and place but unfortunately, rarely during testing.

The DIT-MCO Voyager's test method is a unique design to detect and isolate intermittent circuits to less than 50 nanoseconds on every test point. A low-level DC stimulus is injected into each test point while simultaneously and continuously monitoring all test points for changes. No scanning or sampling is used as these techniques cannot detect a random fault.

Extensive failure analysis of avionics and other aging electronics reveal that nearly all intermittent failures are caused by interconnections, not the electrical components, for instance the connectors, crimps, splices, circuit boards, solder joints or backplanes. The Voyager's development specifically targeted detection of these faults and the results have proved successful.

Intermittent fault detection with the DIT-MCO Voyager results in a higher MTBF and lower costs by finding faults that otherwise go undetected. The savings in time and materials can be substantial when implemented as part of a regular maintenance protocol. \\

MULTI-AXIS VIBRATION TESTING



To reproduce the true environment more closely than with classical single-axis, single-shaker excitation, m+p VibControl provides coupled and uncoupled multi-axis vibration testing (MIMO) in a closed control loop. Components and sub-assemblies are tested on specially designed shaker tables with motion in several degrees of freedom. For seismic qualification the test specimen is fixed to a multi-axis earthquake shake table. Large structures such as aircraft and rockets are excited on multiple shakers, each directly attached to a load input point. This simulates the real-world vibration environment in a precise and realistic way.

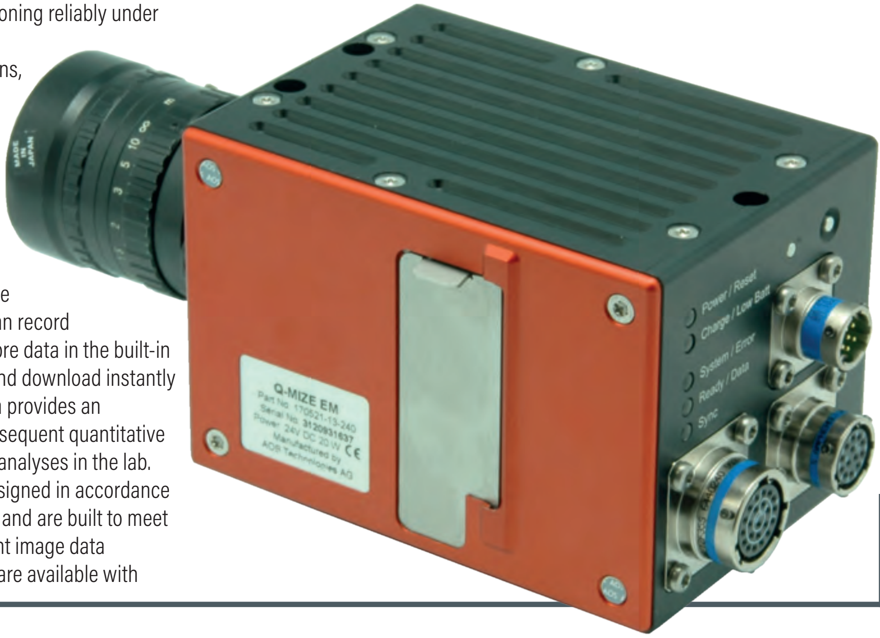
The m+p PCU4 phase and amplitude control unit ensures that up to four shakers are reliably synchronized and coupled to act as one system. It processes sine, random and shock data in a frequency range from 5Hz to about 3kHz (typically 5-500Hz for hydraulic shakers or 20-2,000Hz for electrodynamic ones). Low- and high-frequency phases as well as magnitude and gain are accurately controlled. This specialist phase and amplitude control unit is used for optimization of the effective shaker force in the special application case where shakers are rigidly coupled via a head expander or slip table. \\

HIGH-SPEED CAMERAS FOR AIRCRAFT APPLICATIONS

High-speed cameras from AOS have a reputation for functioning reliably under even the most extreme environmental conditions, for example during real-world military tests. Such specifications make these cameras the ideal choice for mounting in or attaching to aircraft. The high-speed cameras can record multiple sequences, store data in the built-in non-volatile memory, and download instantly to flash cards. This data provides an important basis for subsequent quantitative and qualitative motion analyses in the lab.

AOS cameras are designed in accordance with MIL 810 standards and are built to meet the challenges of inflight image data recording. All cameras are available with various types of MIL-specified connectors for ease of integration into existing aircraft wiring. The cameras comply with GigE Vision standards and can record in standard speed ranges and in high-speed camera mode.

If the application requires it, AOS can provide a special enclosure for the camera, specific software functions, and even extension of functionality vital to the test setup. Finally, AOS can support these solutions during the full life of the camera. For very high flow-rate nozzles, x-rays are used instead of laser sheets so that obscuration problems are avoided. \\

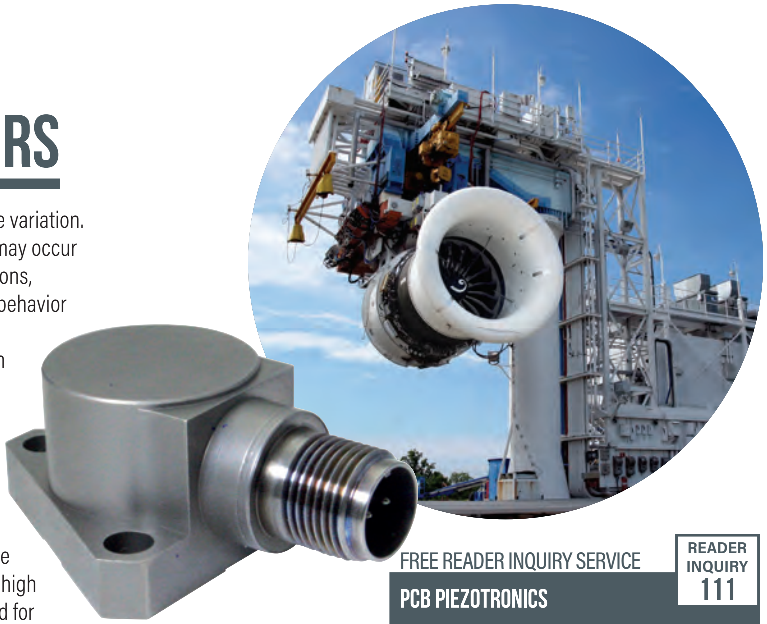


DIFFERENTIAL ACCELEROMETERS

Vibration testing of aircraft gas turbine engines, industrial turbines, rocket propulsion systems and exhaust systems requires accelerometers that are designed to withstand very high-temperature environments. PCB's new charge mode accelerometers with UHT-12 sensing element – Series 357A100 – are manufactured from tough, low mass materials such as titanium and Inconel, are hermetically sealed and have no moving parts. These sensors are ideal for gas turbine engine research and monitoring of turbomachinery.

UHT-12 is a new crystal designed for more accurate, lower-noise measurements during large temperature variations. This technology reduces the effects of temperature variation. The pyroelectricity phenomenon may occur during large temperature fluctuations, generating spikes and disrupting behavior of the accelerometer and the test results. Accelerometers made with UHT-12 technology have improved data quality.

Additional advantages include the absence of pyroelectric noise spikes up to 900°F (482°C), more consistent sensitivity over a wide temperature range and no oxygen depletion at high temperatures, eliminating the need for housing vents or windows. \\



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PCB PIEZOTRONICS

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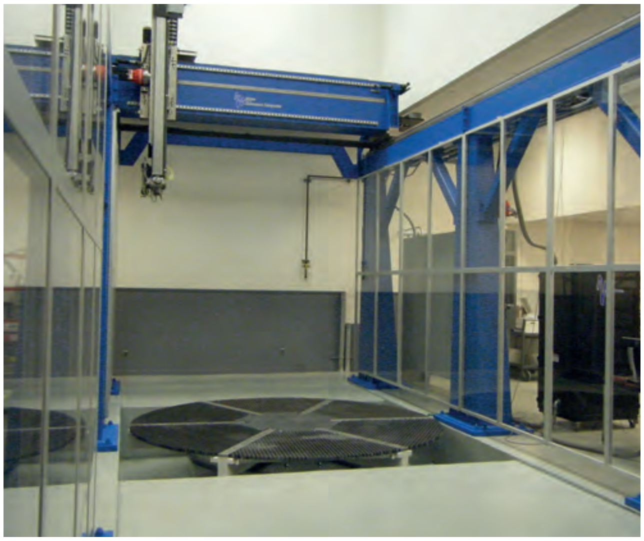
ULTRASONIC TESTING OF COMPLEX CONTOURS

Matec's latest patent-pending ultrasonic testing technology includes complex contour following, high-speed data collection and a feature-packed analysis package designed according to OEM specifications.

The complex contour technology enables much higher scan speeds while maintaining extremely high accuracy. The motion control has, within a single coordinate system, up to 32 axes – some virtual – for inverse kinematics and superimposed moves during complex geometry-following. The technology features dynamic look-ahead/look-back, enabling acceleration and move control anticipation to be buffered ahead of time, resulting in analysis of trajectories in advance and smooth and fast contouring moves. This eliminates the periodic delays and pauses that are typical with other machines.



High-speed data collection coupled with high-speed scanning enables full wave form capture in a multichannel environment, resulting in high-resolution scans. The user-friendly analysis package includes time developed algorithms together with user-specified features, making indication identification easier and more accurate, resulting in high OEM confidence.

The combined technologies are a package that provides improved production rates, reduced time and labor, and high confidence in results. All this adds up to a streamlined process providing huge cost benefits. \\

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Index to advertisers

1

Return to Edwards AFB

Created during the Cold War, the 'master design' for modern jet aircraft has returned to Edwards Air Force Base, scene of its flight testing, to become an important museum display

Museums preserve many interesting aircraft from the past, but seldom have they had the lasting impact on aircraft design that the Boeing B-47 bomber has. The first of two flight test aircraft built at Boeing's Seattle plant, the first XB-47 (46-065, 'X' for experimental), was rolled out on September 12, 1947. Such is its legacy that every large jet aircraft built today is a descendant.

After World War II, the many advances in jet engines and aerodynamics gave designers lots of choices. For example, swept-back wings, developed in Germany before the war, were a way to reduce high-speed drag. Early jet engines had poor thrust at low speeds, so XB-47 prototypes had fittings on their fuselages for 18 solid-fuel rocket-assisted take-off units (nine per side), each providing an additional 1,000 lbf (4.4kN) of thrust.

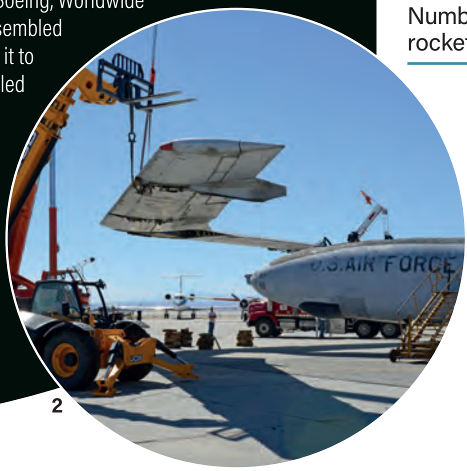
The B-47 was the USA's first swept-wing, multi-engine bomber and it set the design parameters for fast jet travel. The second test aircraft, XB-47A (46-066), took its first flight on July 21, 1948. At the height of the Cold War, the US Air Force needed a fast bomber, and by September 3, 1948, it had already placed its first order for 10 B-47As – by 1951 they were operating with the US Strategic Air Command. More than 2,000 B-47s with various changes were built – all at Boeing's Wichita, Kansas plant.

The location for flight testing the new aircraft was Edwards Air Force Base, which hosted both prototypes and the famous test pilots who flew them, among them Chuck Yeager. The aircraft's form was extremely smooth, leading to some issues in landing. Yeager commented that it was hard to set the bomber down for touchdown as it kept drifting.

There were other issues. At the upper end of the flight envelope, flying at its ceiling of 33,100ft where it achieved the best fuel economy, the aircraft was discovered to have just 5kts difference between its maximum Mach and stall speeds.

The B-47 was the backbone of Strategic Air Command by 1959, after which the B-52 began to assume nuclear alert duties. The last B-47Es were retired in 1969.

After 60 years on static display at Chanute Air Force Base, Illinois, the Air Force Flight Test Museum at Edwards acquired the historic test bomber in September 2016. Thanks to a grant from Boeing, Worldwide Aircraft Recovery disassembled the aircraft, transported it to Edwards, and reassembled it. The XB-47 will be displayed at the privately funded and independently operated Air Force Flight Test Museum. \\



2

JULY 21, 1948
XB-47A first flight

XB-47
Model number

116FT
Span

107FT 1IN
Length

230,000 LB
Max. take-off weight

607MPH
Top speed

557MPH
Cruising speed

4,647 MILES
Ferry range

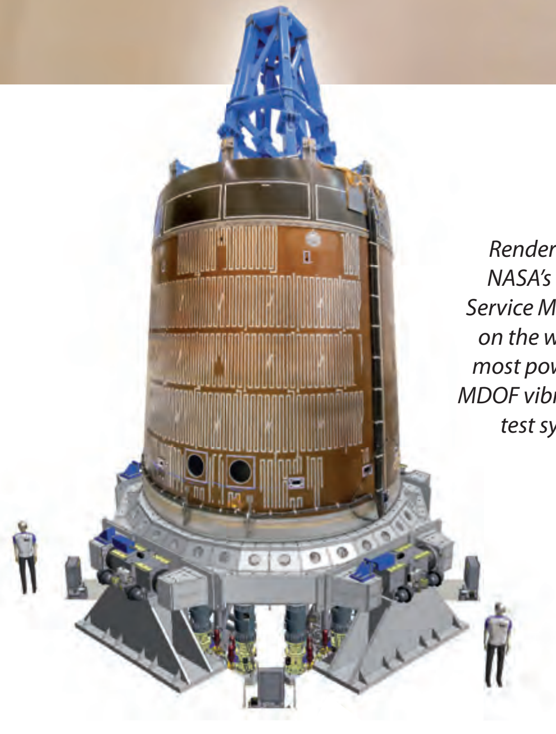
33,100FT
Ceiling

7,200 LBF
Thrust of each of the six GE J47 engines

18
Number of 1,000 lbf JATO rockets for take-off

1 // The XB-47 test aircraft during its flight testing days

2 // Reassembly of the XB-47's wings



Rendering of NASA's Orion Service Module on the world's most powerful MDOF vibration test system.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