MARCH 2016

Aerospace TESTING INTERNATIONAL

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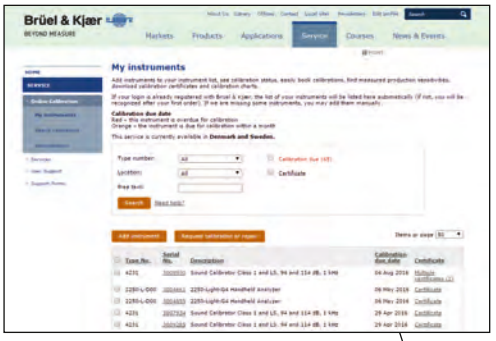

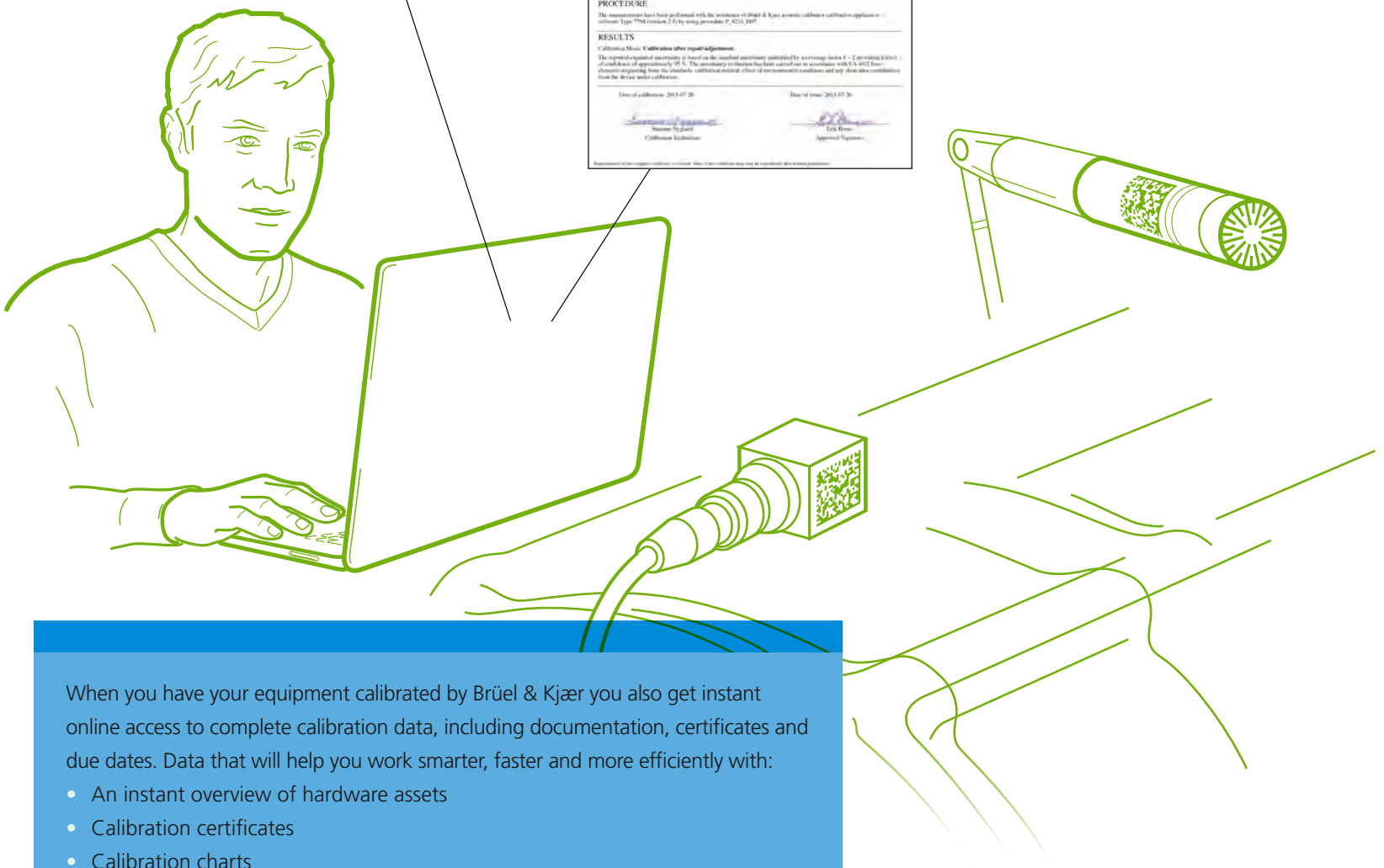

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BEYOND MEASURE

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// Inside edge

A quick glance should be all you need to ascertain that we've undergone quite a redesign here at *Aerospace Testing International*. However, for the RAF's 71 Inspection & Repair Squadron, which provides an inspection and repair capability to support all UK fixed-wing aircraft platforms (both in the UK and on deployed operations), a visual inspection, although highly valuable, often doesn't tell the full story of what's going on beneath the surface.

Instead, 71 Squadron is able to call on the very latest NDT inspection techniques, to highlight potential problems invisible to the human eye. "We employ six methods, primary among them being penetrant testing and eddy-current testing, then radiographic testing, ultrasonics, magnetic testing and shearography," explains Flt Lt Kevin Scott on page 48, in a special feature that examines the role NDT has to play in keeping aircraft operational.

"NDT is the test that just keeps on giving – I was surprised to find a test process that's factored into aircraft maintenance throughout its flying lifetime," reflects the article's author, Paul Eden, who caught up with the squadron at its RAF Wittering base, from where it provides continuous NDT cover in support of Op HERRICK (Afghanistan), Op KIPION (Middle East) and MPA (Falklands).

"Once an aircraft enters service, its trials program is typically over for all but a few airframes that might continue in support of static or developmental test," continues Eden. "But an oft-overlooked aspect of testing continues throughout an individual airframe's lifetime – with non-destructive testing a constant factor in flying operations."

As Eden discovers, the move from metal to composites is fueling the development of many new methods to support aircraft in the field. "Since NDT procedures are fundamental to aircraft health, new equipment and techniques tend to be developed as new materials evolve," he writes. "The increasingly widespread use of composites is a prime example of how NDT has developed in parallel, since the materials are generally non-conductive and therefore immune to many of the traditional NDT approaches, which were created for metallic structures."

So which methods are showing most promise? Thermography has proved particularly useful in revealing deformation within carbon fiber parts, with problem areas shown as 'white light' when viewed via a display, while shearography also has an important role to play. "Laser shearography and thermography are both developing technologies with the ability to cover large areas reasonably quickly," explains another expert source quoted in the article. "Any areas requiring further attention can be marked 'live' on the scan for subsequent examination with other NDT methods."

Beyond NDT, you'll also find not one but two features on exceptional environmental test sites. Our cover story (page 40) takes a tour of the extraordinary McKinley Climatic Laboratory in Florida, and you can meet the manager of the largest climatic chamber in Europe on page 56. Whoever said we here in the UK are obsessed with the weather? Enjoy the new look and here's hoping you don't find too many errors on closer inspection!

Anthony James, *editor-in-chief*

// Contributors

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Editor of the *Official Royal Air Force Annual Review* magazine and *Salute* historical journal, Paul is a dedicated aerospace writer, editor and blogger.

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A former air-transport editor at *Flight International*, Ian began his freelance writing career in 1993, specializing in non-military aerospace and aviation.

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Average net circulation per issue for the period 1 January 2015 to 31 December 2015 was 9,686

 Aerospace Testing International USPS 020-657 is published quarterly, in March, June, September, and December by UKIP Media & Events Ltd, Abinger House, Church Street, Dorking, Surrey, RH4 1DF, UK; tel: +44 1306 743744; fax: +44 1306 742525; editorial fax: +44 1306 887546. Annual subscription price is £42/US$75. Airfreight and mailing in the USA by agent named Air Business Ltd, c/o Worldnet Shipping USA Inc, 155-11 146th Street, Jamaica, New York 11434. Periodicals postage paid at Jamaica, New York 11431. US Postmaster: send address changes to *Aerospace Testing International* c/o Air Business Ltd, c/o Worldnet Shipping USA Inc, 155-11 146th Street, Jamaica, New York 11434. Subscription records are maintained at UKIP Media & Events Ltd, Abinger House, Church Street, Dorking, Surrey, RH4 1DF, UK. Air Business is acting as our mailing agent.
Printed by William Gibbons & Sons Ltd, 26 Planetary Road, Willenhall, West Midlands, WV13 3XT, UK.

ISSN 1478-2774 (Print); ISSN 2397-6411 (Online)

COVER IMAGE: F-35 undergoing cold trials at the McKinley Climatic Laboratory, Eglin Air Force Base

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WORLD *test update*

// BOEING 737 MAX MAKES FIRST FLIGHT

The Boeing 737 MAX 8 took its first flight on January 29, 2016. The on-time milestone marks the start of a comprehensive flight-test program leading to certification and delivery.

The first 737 MAX aircraft completed a 2 hour 47 minute-flight, taking off from Renton Field in Renton, Washington, and landing at Seattle's Boeing Field.

During the flight a maximum altitude of 25,000ft (7,620m) and airspeed of 250kts were reached – typical of first flight procedures and sequences.

The other three 737 MAX 8 flight test aircraft are currently in different stages of final assembly and the program remains firmly on track for its first delivery to Southwest Airlines in Q3 2017.

If you are interested in learning more about the test program, read our exclusive interview with Steve Brown, lead instrumentation engineer, Boeing Test & Evaluation, which is available on our website.

READ MORE ON OUR WEBSITE!

Renton, Washington, USA

// GULFSTREAM G500 AND G600 TESTING ADVANCES

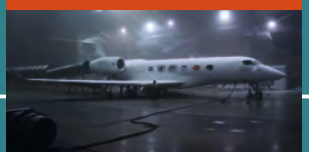
Test aircraft T1 of the Gulfstream G500 program has completed flutter testing, performed over more than 50 flights. Meanwhile, the second test article, T2, has finished climatic chamber testing at McKinley Climatic Laboratory, Eglin Air Force Base, Florida (from -40°F/°C to 131°F/55°C). A fourth aircraft (T4) was recently added to the test fleet.

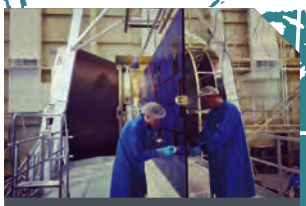
READ MORE ON McKINLEY ON PAGE 40

Since its first flight, T1 has flown more than 320 hours, reached a maximum speed of Mach 0.999 and a maximum altitude of 53,000ft (16,154m). Additional test activities include envelope expansion, air data system testing, aero performance, brakes and field performance, handling qualities and flight controls.

Back on the ground, an Iron Bird version of the longer range Gulfstream G600 has recently completed its 'first flight'. The test article is a spatially correct, dimensionally accurate structure that includes a flight deck, enabling engineers to test the flight control and mechanical systems, including landing gear, brakes and hydraulics in a ground-based lab.

Savannah, Georgia, USA





// ORION SOLAR ARRAY WING DEPLOYMENT TEST

An international team of engineers deployed an Orion solar array wing inside the Space Power Facility (SPF) at NASA Glenn's Plum Brook Station in Sandusky, Ohio, at the end of February. The deployment of the 24ft-wing qualification model was an important first step to verify Orion's power system for the spacecraft's first flight atop NASA's Space Launch System (SLS) rocket, known as Exploration Mission-1 (EM-1).

"We check to make sure everything works exactly as it should in flight," said Meg Nazario, NASA Glenn Test and Transportation project manager, after the test, which was the first of two such wing deployments planned for this year.

READ MORE ON ORION ON PAGE 74

The solar array, a component of the Orion Service Module (OSM), is based on the European Space Agency's Automated Transfer Vehicle's X-shaped array of four panels. Together, the four panels will generate 11kW of power and span about 63ft when extended. The OSM will supply Orion's power, propulsion, air and water.

Sandusky, Ohio, USA

// A321NEO TAKES FIRST FLIGHT

The first A321neo, equipped with CFM International LEAP-1A engines, has completed its first flight from Hamburg, Germany. The aircraft flew on a flight lasting about 5.5 hours, during which tests were performed on the engine speed variation (low/high) and systems behavior, and to validate the aircraft's designed flight envelope.

The A321neo will join the Airbus neo flight test fleet and perform a partial flight testing program to validate any impact on handling qualities, performance and systems for the new configuration changes. These include the latest generation engines, sharklet wingtip devices and cabin improvements. Airbus says the A321neo will undertake a partial flight test program to examine specific aspects associated with the larger type's performance.

The aircraft with Pratt & Whitney engines is scheduled for delivery to customers by the end of 2016, while the CFM-engined aircraft will be produced by the end of 2017.

Hamburg, Germany

// KC-46A INFLIGHT FUEL TRANSFER SUCCESS

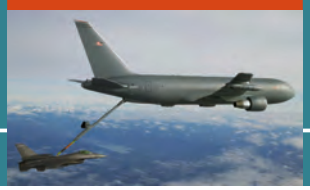
The KC-46 tanker program demonstrated aerial refueling abilities with an F-16C from Edwards Air Force Base in southern California on January 24. During that test, the Pegasus tanker passed 1,600 lb of fuel to the fighter.

All the major fuel systems aboard were recently tested after the aircraft itself was topped up by another US Air Force KC-10 tanker over Washington state.

This inflight refueling demonstration marks the third of six planned aerial contacts that support a 'milestone C' decision currently scheduled for early May. A positive outcome would unlock low-rate production funding beginning in May 2016 for batches of 7, 12 and 15 aircraft.

Still to be tested are probe-and-drogue refueling of a US Navy AV-8B Harrier II jump jet and then boom refueling of a Fairchild Republic A-10 and Boeing C-17.

Seattle, Washington, USA



// MRJ PROTOTYPE RESUMES FLIGHT TESTING

The Mitsubishi Regional Jet (MRJ) FTA-1 has resumed flight testing after more than two months undergoing a planned structural reinforcement program and software system upgrades and testing.

In late January Mitsubishi revealed details of planned airframe strengthening modifications after it analyzed static test results last year that indicated a weakness in the airframe and wing attachment. "Some components that join the wing and the fuselage, as well as those of the fuselage frame, would have insufficient strength" during ultimate load tests, the manufacturer stated. "We decided to implement the upgrades during this round of feedback upgrades."

Mitsubishi will be using five aircraft for the flight testing campaign, which collectively are expected to accumulate 2,500 hours of testing. First delivery for the MRJ is scheduled for Q2 2018 to launch customer All Nippon Airways (ANA), but the testing and delivery has experienced delays four times previously.

Toyoyama, Japan

READ MORE ON THE MRJ ON PAGE 20

// ARRIUS 2R ENGINE PASSES EASA CERTIFICATION

Turbomeca and Bell Helicopter have announced that the Turbomeca Arrius 2R engine has received EASA engine-type certification to power the Bell 505 Jet Ranger X.

In 2013 the Arrius 2R was selected to power the Bell 505 Jet Ranger X – the first Bell product to be powered by a Turbomeca engine.

Incorporating the Arrius has been on a fast development schedule, with an evaluation campaign that started in April 2014 with the first ground run. The flight test campaign started in November 2014 at Bell's Mirabel facility in Canada, and in August 2015 Turbomeca delivered the first production engine to the new Bell 505 assembly center in Lafayette, Louisiana, USA.

The Arrius 2R for Bell is designed to produce about 500shp and has dual-channel FADEC (full authority digital engine control).

Bordes, France

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F-35 fleet clocks 50,000 flying hours

Lockheed Martin confirmed in February that F-35 Lightning II aircraft operating at 12 locations worldwide had surpassed the 50,000 flight hour mark. The first flight hour was achieved by an F-35B aircraft, BF-01, on June 1, 2008. The 25,000-flight hour milestone occurred in December 2014, six years and six months later. The second 25,000 flight hours were reached far more quickly – only one year and two months later. "The next 50,000 hours will be achieved even quicker as we double the size of the F-35 fleet worldwide in the next three years alone," said Lt Gen. Christopher Bogdan, F-35 Joint Program executive officer.

Flight hours are divided into two main categories: operational flying hours, flown by 155 jets delivered to six nations; and system development and demonstration (SDD) flight test hours, flown by 18 aircraft assigned to the Integrated Test Forces at Edwards AFB and NAS Patuxent River. Of the 50,000 hours, operational jets flew approximately 37,950 while SDD aircraft flew 12,050. More than one-third of the program's flight hours were flown in 2015 alone. Among the three variants, approximately 26,000 hours were flown by the F-35A, 18,000 hours by the F-35B and 6,000 by the F-35C.

F-35s are flying at eight operating locations: Edwards AFB, California; Eglin AFB, Florida; Hill AFB, Utah; Luke AFB, Arizona; MCAS Beaufort, South Carolina; MCAS Yuma, Arizona; NAS Patuxent River, Maryland; and Nellis AFB, Nevada. Jets are also flown at two F-35 depot locations at MCAS Cherry Point, North Carolina, and the Ogden Air Logistics Complex at Hill AFB. Flight hours were also recorded at the two F-35 production facilities at Cameri, Italy, and Fort Worth, Texas. \\

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// ESA's AIM satellite will watch the DART spacecraft impact the asteroid

How do you alter the course of an asteroid?

Experts at QinetiQ Space are currently examining what it would take to save the world from an asteroid impact, under an €840,000 (US$925,000) contract that has been awarded by the European Space Agency (ESA) to define the requirements for ESA's Asteroid Impact Monitoring (AIM) mission, part of the Asteroid Impact & Deflection Assessment (AIDA) collaboration between ESA and NASA. AIDA will investigate the possibility of altering an asteroid's course to prevent a collision with Earth.

According to the AIDA mission proposal, in 2022, two years after launch, NASA's Double Asteroid Redirection Test (DART) spacecraft will collide with the 150m diameter 'Didymoon' while ESA's AIM satellite observes its effect on the asteroid's trajectory. Its proximity to Earth in October 2022 will offer an excellent opportunity to test advanced platform technologies and asteroid deflection techniques. In response, QinetiQ is examining challenges such as navigation, propulsion, power and communications, before reporting back to the ESA.

Frank Preud'homme, commercial director for QinetiQ Space, said, "The number of known accessible near-Earth objects has more than doubled in five years. However, while we are better equipped than ever to detect threats from asteroids, we are not yet able to defend our planet against them. The AIDA mission could be the first step in creating that line of defense. Our experience in developing ESA's Proba small satellites makes us uniquely placed to meet the complex technical and budgetary challenges of this study." \\

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Best of times, worst of times?

From the outside, a career in aerospace testing seems as glamorous and exciting as ever. Is this really the case? Are we in a golden age? And are those that disagree guilty of looking back through rose-tinted spectacles?

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

There has never been a better time for a career in aerospace testing. Consider the products that are currently being tested; the capabilities of an aircraft such as the F-35 are surely beyond the wildest dreams of previous generations of aerospace engineers. The challenges associated with testing a highly autonomous, supersonic, VTOL aircraft surely surpass anything faced previously; those challenges are what give aerospace testing professionals their job satisfaction.

Aside from the recent step in capability, the novel concepts currently in development can challenge the very fundamentals of testing methods and philosophies. For example, novel configurations such as tiltrotors require the development of novel test techniques for handling qualities evaluation; this isn't simple repetition of past programs, this is cutting-edge research combined with practical testing. Similarly, advances in aerospace technology are pushing back the boundaries of areas such as human factors. Can a pilot cope with the demands of flying his own aircraft while also remotely managing a swarm of UAVs? The technology is in place from an engineering perspective, but the domino effects on aspects previously considered 'peripheral' are very exciting indeed.

It could be argued that an element missing from modern testing is the burning urgency and competition associated with an arms race. However, the absence of a single, tangible adversary does not mean that current testing programs are leisurely, relaxed affairs. Indeed, ever-shrinking budgets and ever-increasing demands for safety apply pressures of their own; there is no shortage of battles to be fought.

The ultimate aim of aerospace testing is to deliver safe capability to the end user, and it is a fact that the industry is closer than ever to achieving this aim. Of the 337 English Electric Lightning interceptors produced in the 1950s and 1960s, more than a quarter were lost in accidents – many of them fatal. Owing in part to advances in aircraft test and evaluation, this figure is absolutely unthinkable today. On the basis that aerospace testing professionals are making a bigger contribution than ever to flight safety, how could it possibly be argued that there was ever a better time to be involved in the industry? \\

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

For specific products such as fast jets, the number of design iterations performed over the years is such that the industry has converged toward a very small number of solutions. Consider, for example, the vast number of different types of second-generation fighter jets in service during the Cold War, compared with the handful of fifth-generation types of the modern era.

A consequence of this is that modern test programs tend to be few in number and vast in scale, and can last for many years. Within such a construct, the scope for an individual to make a considerable contribution is greatly reduced; personality is effectively bulldozed by process. Although this may be beneficial to the end product, it can be a source of frustration to those who, in past generations, would have solved problems by sheer determination and personal flair.

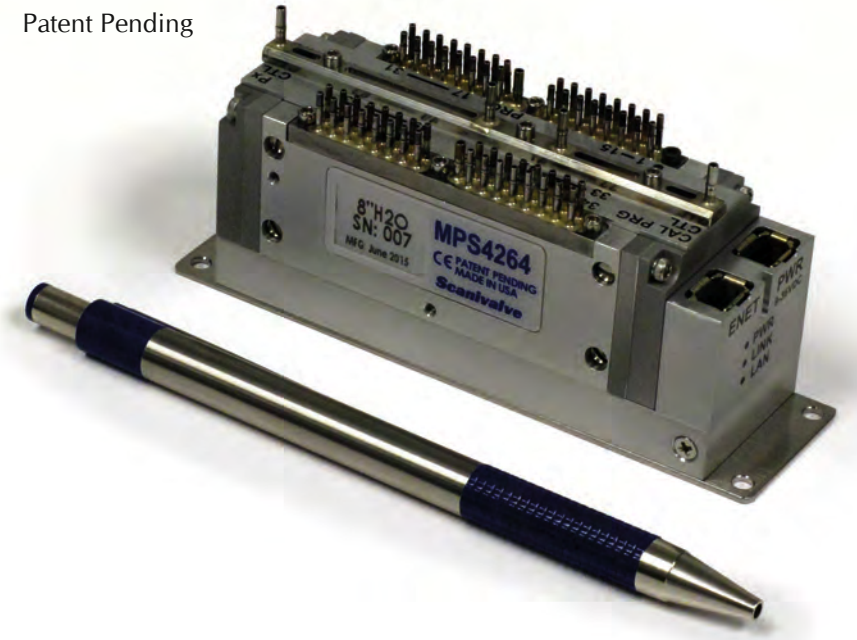
Similarly, modern testing is far more predictable than was the case in the past. The outcome of many tests is almost a foregone conclusion due to advances in pre-test activities such as laboratory demonstrations and simulation; very few modern practical testing activities are the leaps into the unknown that generate genuine excitement. This makes test programs far less reactive and therefore more methodical, with scope for planning well in advance.

Consider also the cost implications of such vast programs, and one understands the tendency toward risk-aversion. Nobody can deny that this is a good thing in the long-term, but it removes an element of excitement that was a feature of aerospace testing in the past.

It should also be noted that testing of novel aerospace concepts is anything but a modern trend. Indeed, the effect of design convergence is such that such novel concepts were far more common than they are today. Imagine the challenges faced testing the Harrier, Concorde, the Fairey Rotordyne or the SR-71. While so-called novel concepts these days may appear to be exciting and innovative, they are in fact simply variations on the aforementioned design convergence – a V-22 is just a helicopter with a party trick; a UAV is just a clever autopilot.

Today's testing is more effective in delivering safe capability to end users; something of which we should all be proud. However, it doesn't necessarily mean that the job is as much fun as it used to be! \\

Patent Pending



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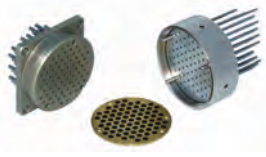

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// GEORGE COUPE

Vital signs

1 // The spray system used to put volcanic ash into the engine

NASA's Vehicle Integrated Propulsion Research (VIPR) project aims to test and evaluate an engine health monitoring system that incorporates smart sensors and advanced diagnostic techniques to measure the impact of volcanic ash

Researchers at NASA have recently completed analysis of data from a unique set of aero-engine tests, and made some interesting discoveries. Full details of the tests on the effects of volcanic ash and the ability of a new engine health monitoring system to pick up signs of degradation in performance will be published later this year.

John Lekki, principal investigator on NASA's Vehicle Integrated Propulsion Research (VIPR) program, hopes the results will make a major contribution to the decision-making process when setting safe minimum operating levels for aircraft following a volcanic eruption.

He also believes that engine health monitoring and management systems, capable of alerting on changes in engine performance in real time, have a substantial role to play in this regard, offering operators the potential for improved engine efficiencies in the future.

"We think this is going to be a really important datapoint for people who are making decisions about airspace use after a volcanic event," says Lekki.

The eruption of the Icelandic volcano Eyjafjallajökull in 2010 prompted renewed interest in the effects of volcanic ash on aircraft engines. The airspace closure due to the ash cloud is estimated to have cost the global airline industry in excess of US$1bn.

Volcanic ash consists of pulverized rock and glass, the smallest particles of which can still cause considerable damage to engines. The ash can remain in the atmosphere at low concentrations long after an eruption. Immediately after the 2010 eruption, the UK CAA set a safe upper limit for ash density at 2mg/m^3 of airspace, but revised this upward to 4mg/m^3 a month later.

Engine tests conducted in the years since 2010 have looked at the effects of high concentrations of sand and ash, the results of which have been used simply to

NASA's John Lekki

> ***"We wanted to give people some idea of what the volcanic ash would be right near the threshold of what's considered operational versus non-operational"***

83
The International Civil Aviation Organization has records for 83 "encounters" between aircraft and volcanic ash between 1935 and 2008, eight of which caused temporary engine failure

4
The number of milligrams per cubic meter of air currently considered by the UK CAA to be the upper limit of safe ash concentration for aircraft

US$ 1BN
The cost to the global airline industry of the eruption in 2010 of the Icelandic volcano Eyjafjallajökull

2 // Oil smoke billows from the right inboard engine of the C-17 while a probe collects emissions data, during Phase I of VIPR engine health monitoring tests

extrapolate the effects at these key lower concentrations, particularly those just visible to the pilot in flight.

REAL-TIME TRACKING

The VIPR tests, carried out with a range of partners including Boeing, Pratt & Whitney and the USAF, were concerned specifically with the effects of low concentrations of ash and the test and development of a system that could accurately track the effect on engine performance in real time.

"We were primarily looking at the effects of volcanic ash at lower concentrations, right around the threshold of what is visible in flight," explains Lekki. "We really wanted to be able to give people some idea of what the volcanic ash would be right near the threshold of what's considered operational versus non-operational."

The program, which began in 2011, was divided into three phases culminating in the volcanic ash tests in August last year. The researchers used two Pratt & Whitney F117 engines aboard a C-17 cargo airplane provided by the USAF. The F117 is the military variant of the PW2037 engine used on the Boeing 757.

Lekki says the program was unique partly because the researchers were able to create faults in the engines to test the range of sensors used in the engine monitoring system.

In December 2011, during a baseline test to lay the groundwork for more complicated experiments, the

3

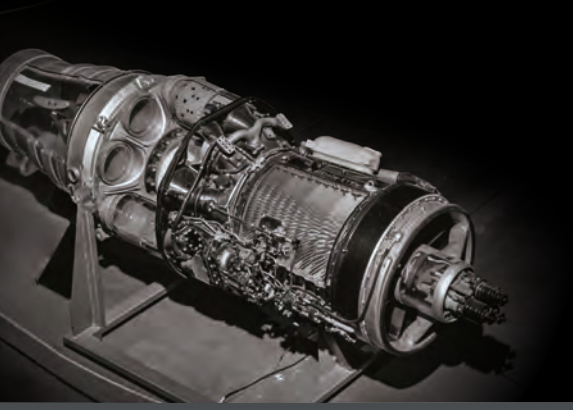
3 // A cloud forming in the intake of the engine during one engine run where there were the right atmospheric conditions

2

engine detected simulated faults including an oil leak. A second test in early 2013 verified that sensors could detect actuator faults over a range of operating conditions. Then in July last year, over a period of five days, researchers introduced increasing amounts of ash into the engine to assess how early the health monitoring sensors and their associated software can detect and report a problem.

The sensors, which were placed around and inside the engine, included emissions sensors, thin-film temperature sensors, microwave tip-clearance sensors and a range of fiber-optic sensors to monitor stress and strain in the engine and engine pylon.

After the tests were completed, the Air Force sent the engines back to Pratt & Whitney for a teardown inspection. The aim was to compare the observed effects



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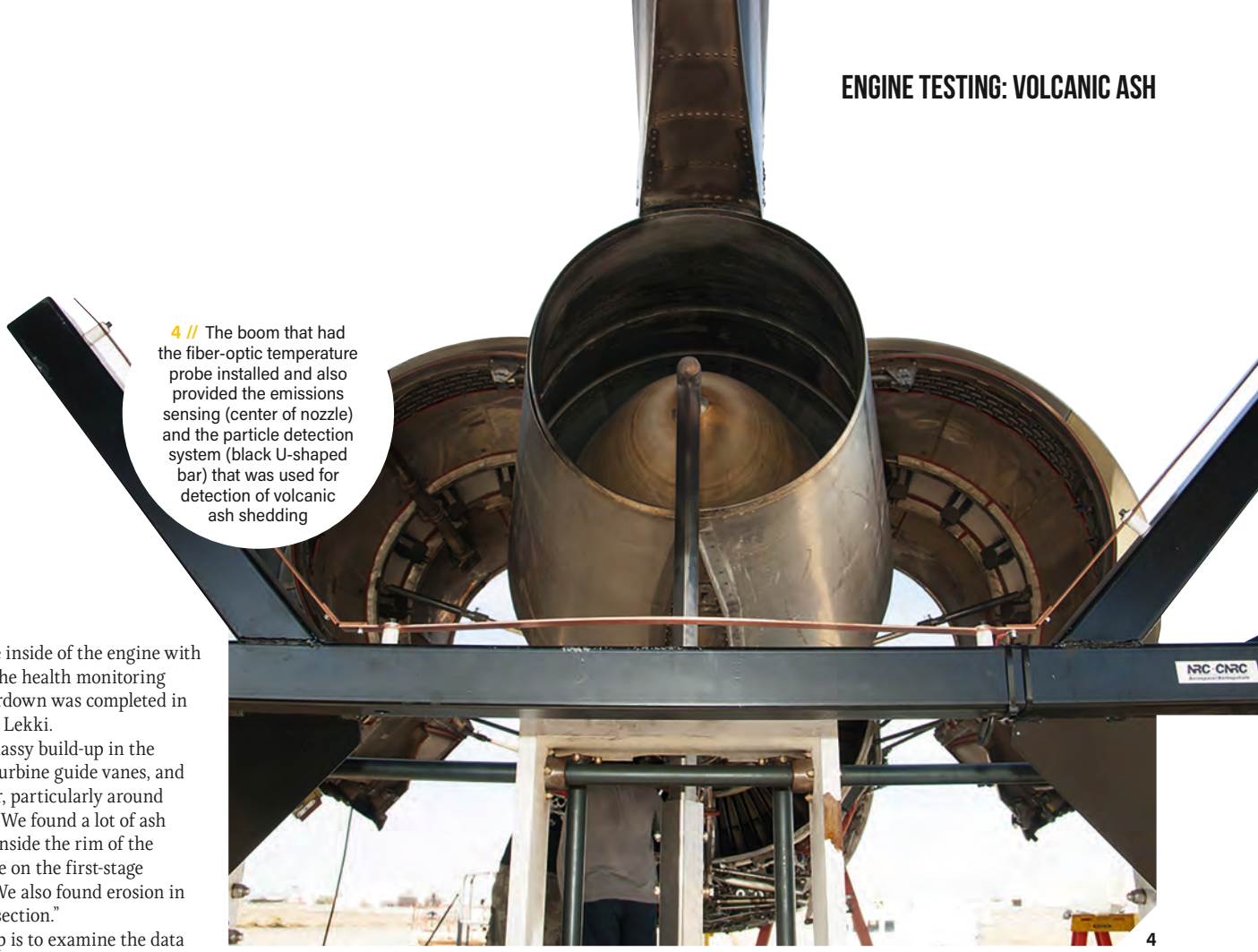

4 // The boom that had the fiber-optic temperature probe installed and also provided the emissions sensing (center of nozzle) and the particle detection system (black U-shaped bar) that was used for detection of volcanic ash shedding

of the ash on the inside of the engine with the readings of the health monitoring sensors. The teardown was completed in December, notes Lekki.

"We found glassy build-up in the turbine, on the turbine guide vanes, and in the combuster, particularly around the fuel nozzles. We found a lot of ash inside the core, inside the rim of the engine, and some on the first-stage turbine blades. We also found erosion in the compressor section."

The next step is to examine the data from the sensors to see exactly how the performance of the engine changed during the tests. The findings will be published in a final NASA report later in the summer, says Lekki, but they can already tell that the engine's performance changed not entirely as expected.

"Until now there have been a number of tests with high concentrations of sand and volcanic ash going into engines, and they produced certain results, and we extrapolated them to low concentrations to predict what the effects would be when we were running the tests. They didn't quite match what we thought they would be.

"We thought we were going to see degradation more quickly than we did, in terms of the engine's performance. That surprised us. That is the reason we do this research, because extrapolating from a high concentration case to a low concentration case doesn't necessarily work.

"We believe that these are going to be very useful findings. We don't want to say that the volcanic ash was not as serious as we thought it was. We thought the degradation would happen more quickly, but there are a lot of people who still need to weigh in on this and make recommendations. I think there are potential implications for engine design that might mitigate some of the effects of events like that."

With regard to the engine health monitoring system itself, Lekki said the researchers were very pleased with its performance to date.

HOW DO YOU SIMULATE VOLCANIC ASH?

One of the greatest problems faced by the VIPR team was how to safely introduce the volcanic ash into the F117 engine. "Just getting the delivery system to work smoothly was a huge challenge," admits NASA's John Lekki.

The key was to build a rig, nicknamed 'the spider', that could be positioned close to the engine, and spray controlled amounts of ash into the intake without the risk of it coming into contact with the engine itself.

The rig was designed by a team from NASA Armstrong, who used flexible tubing to take into account the potential for the aircraft to lurch and come off its chocks. "They also did some fantastic work to make sure there would be no vibrations. We didn't want anything to go into oscillation right in front of the engine. That was a huge challenge, and the fact that it worked so nicely was a great relief. We got fantastic data for a number of important research areas."

Another challenge was how best to coordinate all the groups involved in the test program. NASA's partners included the US Air Force, the FAA, Boeing Research and Technology, Pratt & Whitney, General Electric Aviation and Rolls-Royce Liberty Works. It was also assisted by the US Geological Survey. Researchers from four of NASA's aeronautics centers – Armstrong, Glenn, Langley and the Ames Research Center – were also involved.

"I would say one of the other big challenges was just pulling together a large test capability with a lot of people on something like an Air Force base, out on the tarmac. There were researchers running the health management systems, others doing the volcanic ash system, and then we had all the aircrew and technicians supporting the tasks. We also had to make sure that everyone got enough data to be successful, but still finished on time."

"The tests have shown a number of sensor technologies to be highly durable and therefore suitable for engine health monitoring applications"

"We wanted to see how various aspects of the health monitoring systems would pick up on the degradation. From what we can tell so far, they seem to be tracking pretty nicely – what we found versus what we saw in the sensors."

Lekki says the tests have shown a number of sensor technologies to be highly durable and therefore suitable for engine health monitoring applications. Two sets of fiber optics were used in the tests: one placed in the thrust stream of the engine, and the other on the engine pylon to measure stress and strain. Another set of MEMS-based sensors were successful in picking up changes in engine emissions during the introduction of low concentrations of ash.

"During the volcanic ash testing we did see changes in hydrocarbon levels and also changes in NOx. So even when very subtle things are happening to the engine, we are getting effects in things like emissions and temperature."

While Lekki anticipates that health monitoring technologies will be adopted by the industry, he says there will have to be a strong economic reason for incorporating new sensor technology into an engine. However, there are instances where these devices could be used to improve engine efficiency and create operating economies as well as monitor engine performance.

"An example scenario is with the turbine tip-clearance system, which you can use to monitor the turbine blades and see if there is a problem, such as one of them becoming bent or broken. That gives a health management improvement. But you can also use that measurement to decrease the turbine case clearance to improve the fuel efficiency of the engine. That gives an economic benefit as well."

In the next 10 years, engine health management and monitoring will be all about data and diagnostic capabilities; adding new sensors to engine design would follow, says Lekki. "I think that health management technologies will continue to grow in terms of their implementation," he continues, "especially when there is an associated economic benefit. My anticipation is that a number of technologies will be adopted and put into practice within 5 to 10 years."

As for the findings on the effects of volcanic ash, Lekki is hoping his report in the summer will start a new debate about airspace use after a volcanic eruption. "We want people to really think about this data and have the whole aerospace community chime in. We want to get the information out there and let the discussion begin. It is just so important in terms of airspace use that we want everyone's voice to be heard." \\

5 // The volcanic ash distribution 'spider', shown here in the inlet of the engine while running, was used to send the ultra-fine particles of ash through the engine

5

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The Mitsubishi Regional Jet (MRJ) has resumed test flying, following upgrades planned before its maiden flight last November. The 92-seat MRJ90 will be Japan's first new airliner since the 1960s' NAMC YS-11 twin-turboprop

1 // The MRJ static strength test aircraft being transferred from the final-assembly factory to the strength test station, in May 2014

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First flight for the Mitsubishi Regional Jet (MRJ) on November 11 came almost 20 years after a Mitsubishi Heavy Industries (MHI) proposal for a 100-seat jetliner to be developed jointly with Bombardier. No agreement was reached, the Canadian manufacturer instead exploring a design dubbed BRJ-X before proceeding much more lately with its recently certificated C Series program.

MHI was subsequently a partner with Fuji and Kawasaki in Japanese Aircraft Development Corporation, which considered a regional-jet dubbed JSX. Later still, it developed the MRJ, which it launched in 2008.

The new model has crept slowly into the limelight, with Mitsubishi treading a cautious path – albeit one that included being the launch customer for Pratt & Whitney's PW1200G-JM geared turbofan engine. As the MRJ has progressed slowly, the powerplant has been adopted for other platforms – not least the C Series – and recently entered service on the re-engined Airbus A320neo.

Mitsubishi Aircraft Corporation (MITAC), established by MHI to manage the project, has been careful to seek outside advice. Last year it opened the Seattle Engineering Center with development partner Aerospace Testing Engineering & Certification (AeroTEC) as a precursor to US flight testing, which could begin later this year. The first flight-test aircraft (FTA-1, manufacturer's serial number [MSN] 10001) and three of the remaining four such machines are scheduled to cross the Pacific as part of a 2,500 flight-hour certification program aimed at achieving service entry with Japan's All Nippon Airways (ANA) by mid-2018, five years later than the original target date.

More than half a century after Japan's previous commercial-aircraft program, the country's aerospace industry is unfamiliar with such engineering developments (although it does produce very large sub-assemblies for other manufacturers). Nevertheless, in having suffered several delays, MITAC sits alongside some illustrious names, among them both Boeing and Airbus, which have had to adjust schedules; aerospace systems integration has become an increasing challenge to even the largest, most-experienced companies.

2
The number of Mitsubishi Regional Jet ground-test aircraft

5
The number of Mitsubishi Regional Jet flight-test aircraft

A thorough MITAC/AeroTEC program review in mid-2015 recognized the need for structural modifications and systems upgrades, which the partners agreed to introduce after initial flights as part of a rescheduled development program. Now, with that work complete on the first aircraft and underway on the remaining test airframes, the resumption of flight testing has given the project momentum that the partners will want to maintain.

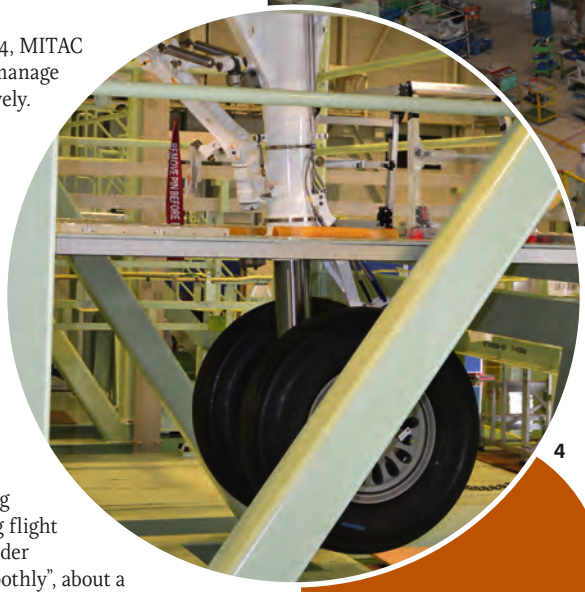
Since unveiling the aircraft at an unusual 'roll-in' ceremony at the MHI Nagoya Aerospace Systems

2

"The manufacturer elected to delay first flight to incorporate various ground-test results"

2 // An image of FTA-1, with its flaps retracted, during the third flight test that took place in November 2015 from Nagoya Airport

3 // The first, second and third MRJ flight-test aircraft at MHI's plant at Komaki South, Nagoya, Japan



4 // MRJ main landing gear loaded for functional testing to verify its durability

assembly plant in October 2014, MITAC has worked with AeroTEC to manage development more conservatively. "Reviews brought to light necessary additional tests and test-confirmation items needed through ground tests, which we carried out prior to first flight," says MITAC director and strategic-marketing head Hideyuki Kamiya. "We also reviewed future work and this increased the scale of ground tests, such as operational tests to attain more-advanced completion before first flight."

With static-strength testing and manufacture of remaining flight test articles (FTAs) (all now under construction) "proceeding smoothly", about a year ago the manufacturer elected to delay first flight to incorporate various ground-test results. MHI and MITAC hoped to "implement intensive flight testing and accelerate manufacture" to deliver the first example during the second quarter of 2017 – a target that has since slipped by a further 12 months.

WING AND A PRAYER

They also decided to schedule strengthening work, needed where the wing joined the fuselage, to follow the maiden flight. Bending tests on the static-strength test airframe in January 2015 had confirmed that the MRJ wing met limit-load requirements (by accommodating the maximum forces expected in normal operating conditions). However, further work about four months later revealed that the wing did not pass the ultimate-load test, which applies 50% greater loading. "Analysis enabled us to forecast that some components, such as those that join the wing and the fuselage, and those of the fuselage frame, would have insufficient strength," reported MITAC in late December when announcing a further program delay, the fourth in all. (Three months earlier, senior executive vice president and executive chief engineer Nobuo Kishi had said that following initial flights, modifications were planned "to expand the flight envelope" – a tacit admission of the airframe's weakness that went unnoticed by most commentators.) Kamiya declined to tell *Aerospace Testing International* how close the MRJ's wing came to meeting ultimate-load requirements. Other static-strength testing includes fuselage pressurization to check complete atmospheric sealing of the airframe and the rate at which cabin pressure is reduced during the climb and raised as the aircraft descends.

After manufacture of five flying FTAs and the static-strength airframe (MSN 90001), the seventh airframe to be built is for fatigue testing to verify airframe durability by simulating repeated stresses expected in normal operations. Major assembly of this airframe (MSN 90002) was complete before February this year, with the airframe standing on its landing gear for installation of measuring equipment ahead of tests scheduled to begin later in 2016. "MRJ fatigue-strength testing will assume that the MRJ will make 80,000 flights over a period of more than 27 years, or eight flights per day for 10,000 days," says MITAC.

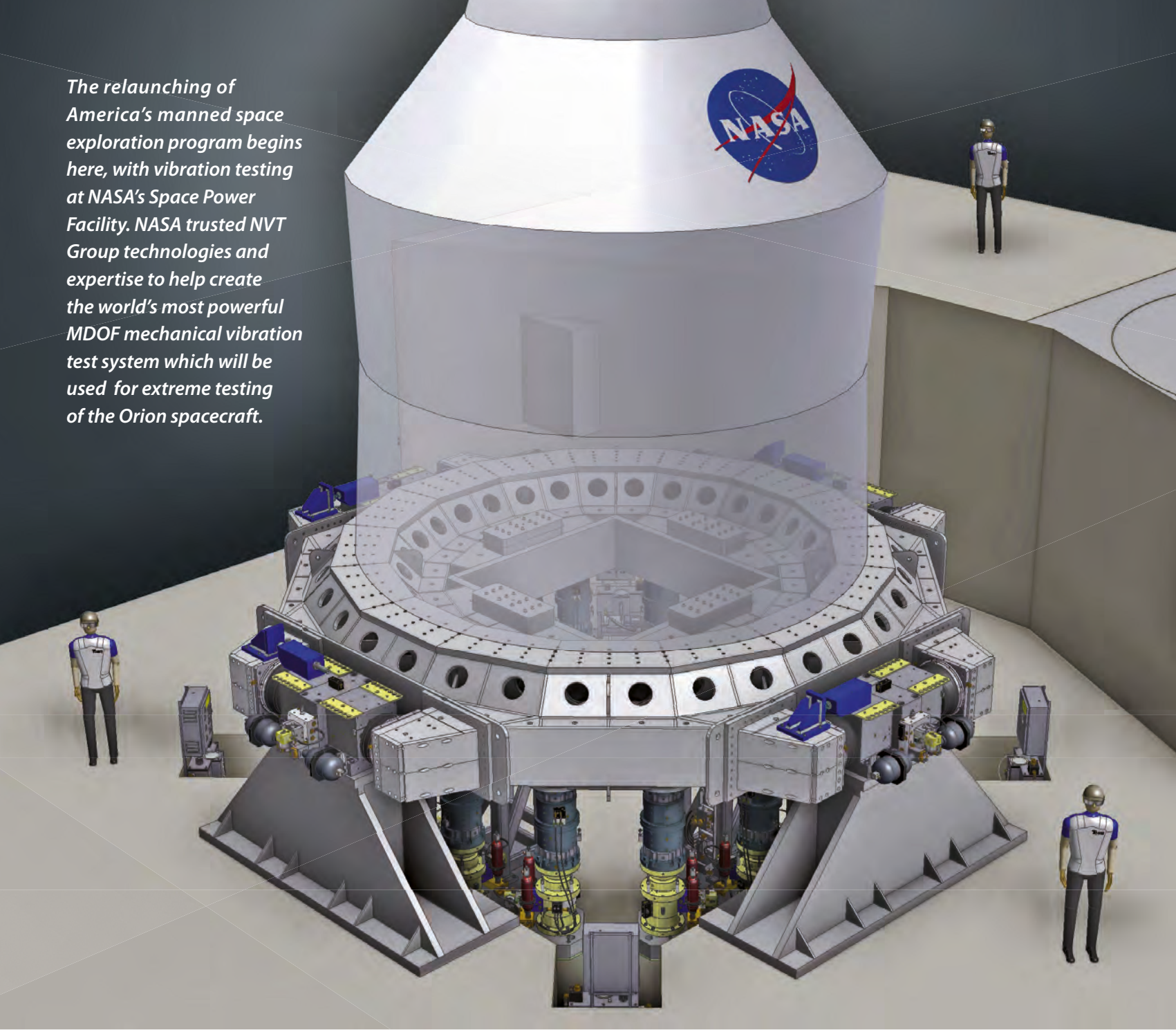
Other requirements before flight included ground-vibration (GV) tests performed in mid-2015 with FTA-2 (the second flight-test aircraft). This work plays a key role in the development of aircraft equipped with highly computerized flight-control systems, says MITAC. The GV tests confirm "whether the aircraft will achieve harmonious functioning of the structure and the fly-by-wire system to ensure flight safety".

Also in mid-2015, MITAC was scrutinizing technical data from the various test programs to assess feedback and consider possible modifications. It opened the Seattle Engineering Center and continued construction of its US flight-test hangar at Grant County Airport at Moses Lake in Washington state and another for the final-assembly line in Nagoya. (MITAC's headquarters in Japan, Seattle Engineering Center, and Moses Lake comprise the program's three engineering bases.)

A major milestone was reached in January 2015 with the running of the MRJ's first PW1200G-JM engine. Operation of the starboard powerplant

IRON BIRD FLIGHT-CONTROL TEST RIG

Since 2011 the Mitsubishi Regional Jet (MRJ) hydraulic and flight-control system test rig has been 'flying' in a dedicated experimental facility at Mitsubishi Heavy Industries. It is used to develop hardware and software and to check aircraft-maneuvering functions, which represents "one of the most important system-integration tests of the MRJ development process", according to the aircraft manufacturer. The rig, which also will be used for endurance testing, comprises a flight deck, hydraulic and flight-control equipment, on board software to be loaded on the actual aircraft, and simulation computers to 'create' the whole flight environment. Mitsubishi also uses simulators for pilot training and flight-deck engineering, and has bought a Model 7000XR engineering flight simulator from Canadian manufacturer CAE for MRJ development and flight testing.



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5

5 // Fatigue test aircraft MSN 90002 (left), FTA-5 (right) and FTA-4 (back right) – the latter two will be completed with fully fitted out airline cabins

6

6 // Launch customer All Nippon Airways (ANA) conducted its first acceptance inspection of the initial delivery aircraft this January

verified various systems including air conditioning, electrics, fuel and hydraulics. Sister company MHI Aero Engines performs final assembly of the engines.

When asked about the importance of the engine-delivery schedule and any flexibility MITAC hoped to agree with Pratt & Whitney – given the MRJ's extended development schedule – Kamiya responds, "We are moving forward with P&W in developing a safe, reliable engine. We will keep tabs on the status and remain in close contact."

Testament to the MITAC/AeroTEC partnership's careful approach and emphasis on thoroughness is that almost five months elapsed before MRJ taxi trials began with low-speed (10 knots) tests in June to confirm braking and nosewheel steering behavior. Mid-speed taxiing followed, with 13 runs that included emergency-braking and rejected-take off performance. Speeds were increased to 120 knots before Japan Civil Aviation Bureau approval for test flights (without an airworthiness certificate or installation of some required equipment) was granted on October 29.

FIRST FLIGHT

With, in Kamiya's words, "a better-integrated aircraft" following the mid-year review and additional ground testing, the MRJ made its first flight from Nagoya on November 11, followed quickly by two more. "We were able to obtain valid, reliable results through these flight tests," says Kamiya, before MITAC paused to introduce the wing/fuselage modifications and system upgrades.

In these initial operations, the MRJ achieved a "maximum altitude of 15,000ft and maximum speed of 200 knots," continues Kamiya. "Approximately 4.5 hours was logged. We are expecting certification to require around 2,500 flight-hours for all five FTAs." Mitsubishi is seeking type certification in Japan, Europe and the USA.

The MRJ's 87-minute first flight, during which the landing gear was locked down and the trailing-edge flaps set at 30° throughout, confirmed basic operating characteristics in maneuvers including ascent, descent and circling left and right. All that Mitsubishi will say regarding initial results is that the flight-tests have all gone "as planned", with basic characteristics "satisfactory" and landing gear and flap functional performances "according to specification".

Following the post-flight modifications and upgrades to the avionics, and the engine- and flight-control systems software, test flights resumed on February 10. To strengthen the wing/fuselage attachment, MITAC says that additional reinforcement plates were placed on the original parts. Kamiya says, "It was not necessary to

MRJ FLIGHT-TEST FLEET

With flight-test aircraft FTA-1 now back in the air, MITAC is incorporating the same modifications and systems upgrades in the other flight-test machines. FTA-2 is scheduled to fly during April-June this year, with the remaining units being completed at intervals of a few months. The first four will be used for testing in the USA. By early February, Mitsubishi had started to upgrade FTA-2 and install systems equipment on FTA-3, -4 and -5, and had begun functional testing on FTA-3. The aircraft will be fitted with heavy or light levels of flight-test equipment according to their planned roles. The fourth and fifth aircraft will be completed with airline-configured cabins equipped with seats, galleys and toilets.

Mitsubishi Regional Jet flight-test fleet*

Aircraft	MSN**	Livery	Flight-test function
FTA-1***	10001	Red, black and gold	Flight-envelope expansion, systems tests
FTA-2	10002	Red	Performance assessment and function tests
FTA-3	10003	Black	Detailed flight characteristics measurement, avionics tests
FTA-4	10004	Red, black and gold	System and interior test, community noise tests, icing tests
FTA-5	10005	All Nippon Airways	Autopilot tests
---	90001	---	Static-strength test aircraft
---	90002	---	Fatigue test aircraft
---	10008	All Nippon Airways	First customer delivery aircraft

**Source: Mitsubishi Aircraft Corporation **Manufacturer's serial number ***Flight-test aircraft*

7 // MITAC resumed flight testing in February: FTA-1 is seen here during its fourth flight test, a 1.5-hour trip to confirm the aircraft's recent upgrades

implement the upgrades at this stage, but we decided to implement the upgrades that are required for type certification if the MRJ is to satisfy ultimate-load requirements." The modification increases aircraft weight by "only a few kilograms" and the MRJ90's maximum take-off weight remains unchanged at "about 87,000 lb", according to Kamiya.

2,500
The number of flight-test hours expected to be flown during MRJ certification

80,000
The number of flights an MRJ could make in a service life of 27 years

Under the most recent program review, MRJ development and certification partners have extended the initial flight-testing period (but not the number of flight-hours) in Japan to increase the scale of ground tests and the time for test feedback. Flight testing in the USA, also over an extended period (again, with no increase in flying volume), is scheduled to begin between the fourth quarter of 2016 and the first quarter of 2017.

Kamiya is keen to emphasize that MITAC will continue to review all flight tests thoroughly, with results being taken account of in subsequent development work and the schedule adjusted as necessary. "We have conducted scheduling revisions as specific content has come more precisely into view. We will be managing our milestones and increasing the precision of our schedule as we progress," he says. MITAC will begin its US flight-test campaign "as soon as feasible" and will assign the roles and responsibilities of the three engineering bases "for prompt execution in all fields".

In addition, MRJ certification work will take place at other US sites, very often tied to specific tests. These tests include rejected take off, water ingestion, and high-intensity radiated fields (HIRF). Specifically, Kamiya cites three locations: Roswell International Air Center (New Mexico) – special runway testing; McKinley Climatic Laboratory (Florida) – extreme environment test; and Gunnison-Crested Butte Regional Airport (Colorado) – high-altitude take-off and landing.

As flight testing resumed, MITAC president Hiromichi Morimoto was quoted in Japan as saying that US flying could begin as early as September, since a later date would make mid-2018 delivery to ANA difficult. "But we'll be prepared for unforeseen circumstances if we tighten the schedule and aim to obtain type certification near the end of 2017."

According to the report in *Nikkei Asian Review* on February 13, Morimoto suggests an intensive US flight-test program involving MRJs FTA-1, -2, -3 and -4 each flying four times a day. Inevitably such a rate would generate an enormous volume of flight-test data, but the MITAC president is clear: "If we log about 50 hours a week, assuming that things go well, we'll be done with trials by the fall of 2017," Morimoto reportedly said.

Kamiya says that MITAC has factored in "all the risk we are aware of. We will do our utmost to advance the scheduling of each operation to create a scheduling buffer, just in case." But he cautions that program reviews may necessitate additional tests and test-confirmation items. "The upgrades will be carried out concurrently with flight testing in a timely and appropriate manner."

Meanwhile, more than five years after MRJ manufacture began with machining of a horizontal-stabilizer component, last October MITAC began assembly of the first delivery aircraft for ANA with the riveting of a port-wing structural component. Earlier this year, ANA inspected and approved work underway on what in 2018 should be the first new Japanese airliner to enter service for more than two generations. \\

8 // Right to left: FTA-1, FTA-3 and FTA-2, all of which will be involved in extensive US flight testing later this year

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N3-X hybrid wing aircraft: ©NASA/SCIENCE PHOTO LIBRARY

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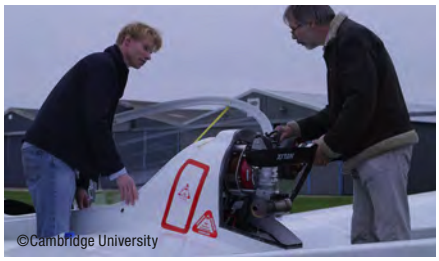
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// NIGEL PITTAWAY

Beg

1 // The A400M features a modern Defensive Aids Suite, incorporating radio and infrared frequency detectors, electronic countermeasure equipment and chaff/flare dispensers

Over 170 A400M transport aircraft have been ordered by eight nations seeking to replace their aging Hercules fleets. Airbus Defence and Space's head of flight test, Eric Isorce, discusses the latest from the testing program, as well as expansion of the aircraft's tactical roles

necessities

2 // Airbus's military airlifter received its nickname Grizzly from its flight crew immediately prior to the aircraft's maiden flight in 2009

It has been six years since the first flight of the Airbus A400M airlifter, known as the Atlas to the Royal Air Force but 'Grizzly' to its flight test crews. Over 20 production aircraft have now been delivered to five customers in Europe and Asia.

Initial flight testing focused on setting the A400M's flight envelope, but this work is now complete and the test program has shifted to role expansion, including air drop (containers and paratroops), inflight refueling and unpaved runway operations. Testing of the Defensive Aids Sub-System (DASS), vital to ensuring the safety of the aircraft when operating in a threat environment, is also underway.

Despite some recent setbacks, including an operational pause following the loss of one A400M on its first post-production test flight last May, the five dedicated test aircraft had accrued over 7,900 flight hours and 2,900 flights by mid-October 2015.

The transition of flight test away from aerodynamic testing to role expansion has already seen the retirement of two of the test fleet and a third will gain a new lease of life as an Airbus company demonstrator in the near future.

5
Total number of dedicated flight test aircraft

7,903
Flying hours achieved by the test fleet to October 19, 2015

800
Flight test hours planned in 2016

29
Number of paratroops certified in 2015 to jump from a single side door

DESIGNING A FLIGHT TEST PROGRAM

The A400M is designed and certified to civil standards, complemented by specific military requirements where necessary, but it is of conventional design. The primary structure is constructed largely of aluminum alloys, with titanium alloys used in highly loaded areas such as the wing to fuselage carry-through structure. Glass- and carbon-fiber reinforced plastics are not used in the primary structure, instead finding application in lightly loaded components such as aerodynamic fairings.

Many of the A400M's systems are based on those of the A380, and the Grizzly flight test program has been able to leverage the work performed in Toulouse, France for certification of Airbus's commercial program. In fact, aspects of the early A400M customer flight crew training were performed on the A380 simulator in Toulouse until a dedicated A400M simulator was commissioned in the Airbus Defence and Space (formerly Airbus Military) training center in Seville, Spain.

When designing the A400M flight test campaign, Airbus broke with tradition and established two test sites, one in Seville and the other at the Airbus Flight Test Center in Toulouse, to conduct simultaneous flight test activities.

"The difficulty of operating the airplanes from two bases was a concern for us before we flew, because we had to ensure that the processes and procedures we applied were consistent and we had to coordinate activities in two locations correctly," said Fernando Alonso, senior vice president Airbus Flight and Integration Tests and head of flight operations, at the height of the test campaign in 2012.

"The distance between Seville and Toulouse has not prevented us from optimizing what activities each

AERODYNAMIC EFFECTS

The unique aerodynamic capabilities of the A400M have revealed two major problems during the recent flight test campaign, one of which may have no solution at all.

The first is the 'crossover' issue, whereby paratroops jumping simultaneously from each of the A400Ms side doors may come into proximity below and behind the aircraft.

"We can drop 58 paratroops using one door, but with 116 using both doors there is a higher than desired probability of crossover as their parachutes are opening," admits Eric Isorce, head of flight tests and operations, Airbus Defence and Space. "We decided not to certify the simultaneous drop and we will need another test campaign to analyze the aerodynamic phenomenon."

The suspension of tanker trials with rotary wing receivers followed concerns that the aerodynamic effect of the A400M could place greater than desired stress on the helicopter's main rotor system, as the head of A400M program, Kurt Rossner, explains: "We have not abandoned the capability of the A400M being a tanker for helicopters but, given the aerodynamic characteristics, it will be very difficult to achieve," he notes. "We are certainly studying the matter, but the probability of achieving the technology is nearly impossible. Nevertheless we have not abandoned the task and are trying to find a resolution."

3 // High-altitude testing at La Paz, Bolivia. Grizzly 2 completed a number of flights from the airport at La Paz, which is more than 13,000ft above mean sea level

3

"The five dedicated test aircraft had accrued over 7,900 flight hours by mid-October 2015"

4 // Unpaved runway trials at Ablitas in northern Spain, where MSN2 successfully conducted 25 landings during six flights

4

airplane was doing on each day," he continued. "If an airplane was unserviceable in Seville and the tests were critical, we were able to conduct the tests with the Toulouse airplane without any problem." Today Alonso is head of military aircraft at Airbus DS.

The A400M flight test program is a collaborative effort between Airbus and Airbus DS and the crews often fly together as part of a mixed team. To assist with the receipt and collation of flight test data, the company established a telemetry network across Europe, with ground stations in Madrid (Getafe) and Seville in Spain, Bremen and Hamburg in Germany, Toulouse in France and Filton (near Bristol) in the UK.

Initial planning concluded that six prototype aircraft would be built and dedicated to the fight test campaign; however it was subsequently decided that only five would be needed and one aircraft (MSN5) was not built. The first two prototypes, MSN1 and MSN2, were heavily equipped with flight test instrumentation (FTI) and another pair (MSN3 and MSN4) had a medium FTI fit. The final test aircraft (MSN6) is only lightly instrumented and, as it was completed close to the final production standard, was used for function and reliability testing in 2012, prior to type certification in March 2013.

With the transition of the campaign to role expansion, the subsequent reduction in flight test activity has resulted in the retirement of two test aircraft, the first (MSN1) in November 2013 and the second (MSN3) in October 2014.

"MSN2 is currently dedicated to DASS flight testing, MSN4 is more focused on airdrop operations because it is the only test aircraft fitted with an operative cargo loading system, and MSN6 is used for paratroop flight test," explains the current head of flight tests and operations, Eric Isorce.

"In 2016 we aim to fly around 800 flight test hours. We plan to retire MSN2 in the middle of the year but we have the capacity to extend it in operation if we need to and MSN6 will be retained by the company for marketing purposes," explains Isorce.

"The next test campaign, to be conducted in the second quarter of 2016, will be the full performance of the RWR and MWS"

5

5 // A week-long deployment to Iqaluit, Canada in February 2013 further supplemented cold weather trials conducted in Sweden in 2011

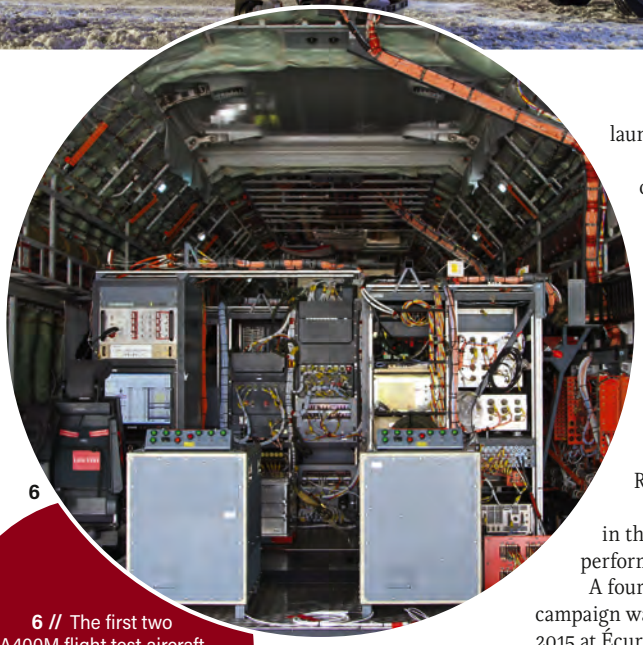
TACTICAL ROLE CAPABILITY EXPANSION

Production A400Ms delivered to the end of 2015 have a basic cargo capability, enabling customers to undertake crew training and logistics flying, while the flight testing effort concentrates on expanding the aircraft's roles into the tactical environment.

In 2014 the A400M was cleared for all flight operations down to an altitude of 150ft, in Day VMC (visual meteorological conditions) and 300ft in Night VMC in manual mode, using the aircraft's enhanced visual system (EVS) and night-vision goggles (NVG). The EVS projects infrared imagery from a camera in the nose of the aircraft to the head-up display in front of each pilot.

The next step will be to certify the aircraft using the terrain-following systems to low altitudes in instrument meteorological conditions (IMC).

During the past year a great deal of flight test work has been undertaken to expand the functionality of the A400Ms DASS system. This included a background recording campaign for the Missile Warning System Passive Element (MWS-PE) infrared sensors with additional dedicated test flights in conjunction with fighters (afterburner plume recording), and low-level flights over industrial areas in Germany, as well as the recording of the launch of flares from the A400M itself.



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6 // The first two A400M flight test aircraft were heavily instrumented, complete with a number of flight test engineer stations in the cargo bay

In all, 11 DASS test campaigns had been carried out by the end of September 2015 in Cazaux, France; Manching, Meppen, and Greding, Germany; and Moron and El Arenosillo, Spain to certify and initially qualify the DASS systems, including the Defensive Aids Computer (DAC), Expendables Dispensing System (EDS), Radar Warning Receiver (RWR) and MWS.

In parallel with this activity has been the testing of the DASS system using two production aircraft destined for the UK, as RAF A400Ms have a unique DASS fitted.

The next test campaign, to be conducted in the second quarter of 2016, will be the full performance of the RWR and MWS.

A fourth unpaved runway operations test campaign was undertaken in September and October 2015 at Écury-sur-Coole in central France, where the A400M was tested during the course of 15 flights and 40 landings on grass and soil.

The outcome of this testing has been to certify the A400M's footprint for surfaces down to CBR9 (California Bearing Ratio) and the 2016 flight test campaign will be to test the aircraft on sand-type surfaces with low CBR, possibly in the UK.

Paratroop air drop test campaigns were undertaken at Cazaux in 2014 and at Fonsorbes, France in 2015, resulting in the certification of the A400M for military free-fall jumps of up to 29 paratroops from either side

"In the tanker role, the A400M was certified and qualified in March 2015 for day and night refueling operations with two F/A-18 Hornets"

door, and up to 12 paratroops from the rear cargo ramp. The original plan called for the qualification of a total of 116 paratroops using the two side doors simultaneously (two 'sticks' of 58), but a crossover issue behind the aircraft has delayed this work until the problem is understood and a resolution is found.

Testing of airdrop loads has also continued throughout 2015, including a gravity-assisted Container Delivery System (CDS) drop of up to eight one-ton loads and one platform of up to four tons, using the A400M's automatic Electromechanical Release Gate (ERG) drop system. In the first quarter of 2016 the plan is to test the full airdrop capacity of the aircraft – up to 24 one-ton CDS drops and platforms up to 16 tons using the extraction parachute method.

Finally, flight testing of the A400M's inflight refueling system, including the role of both receiver and tanker, have been further tested in the past year. Achievements during this period include the certification and qualification in February 2015 of the aircraft's ability to receive fuel from both low-speed (C-160 Transall) and high-speed (Voyager MRTT) tankers under day and night conditions.

In the tanker role, the A400M was certified and qualified in March 2015 for day and night refueling operations with two F/A-18 Hornet fighters, using the removable underwing hose pods.

Testing to be carried out during 2016 includes the installation of the optional cargo hold tank (CHT) capability. "The tests are programmed to begin in January 2016, but this will be determined by the progress of other flight tests, because we are using MSN4 for air-to-air refueling testing and it is also the sole aircraft dedicated to cargo drop testing," explains Isorce.

One test campaign that did not produce the desired results, however, was the testing of an EC225 helicopter as a receiver behind the A400M. The aerodynamic effect of the A400M has caused a suspension of the trials and comes as a blow to Airbus DS, which had promoted its capability as a tactical tanker. See *Aerodynamic effects* on page 34 for more about the efforts toward a solution. \\

7 // Grizzly 2 underwent cold weather testing in 2011 at Kiruna in northern Sweden, where temperatures reached -21°C over a four-day period

7

8 // The first air-to-air refueling of the A400M from an A330 Multi-Role Transport Tanker (MRTT) took place in July 2014

8

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// ANTHONY JAMES

Feel the force

What's the greatest testing facility on Earth? How about the McKinley Climatic Laboratory at Eglin Air Force Base, unrivaled in its ability to create any weather to test the largest aircraft to their limits

1 // McKinley Climatic Laboratory is the world's largest climatic testing chamber, and can simulate all the weather conditions in which aircraft such as this F-35 might need to fly

Beyond the frozen, fictional realms of Narnia, where one is transported instantly into a winter wonderland simply by stepping through an enchanted [wardrobe] door, there exists an equally magical place back in the real world – the McKinley Climatic Laboratory (MCL) at Eglin Air Force Base, Florida, USA, where the temperature inside can plummet to -65°C while the average local temperature outside during summer is a balmy 25°C.

You could be forgiven for questioning why the US military decided that the Sunshine State was the perfect location to subject all manner of equipment to the worst the weather could possibly throw at it, with a particular emphasis on testing performance at extremely low temperatures.

"The reason the world's largest climatic chamber is at Eglin AFB is because of the difficulties the military experienced at its previous cold testing facility at Ladd Field in Fairbanks, Alaska, prior to World War II, due to the unpredictability and erratic duration of suitable cold periods," explains Dwayne Bell, MCL technical chief.

"There was land available here at Eglin, the bombers were stationed here, and so the decision was made to construct a large aircraft hangar that was heavily insulated and could be refrigerated to allow cold weather testing according to the military's own timeline, instead of having to wait for the right weather up in Alaska."

MCL conducted its first tests in 1947, with a B-29 bomber, C-82 cargo plane, P-80, P-51 and P-47 fighters, as well as an R5D helicopter all undergoing cold weather testing, as well as military trucks, tanks and other equipment. "This is a unique facility," explains Bell. "It is the only place in the world where you can put a full-scale aircraft inside an enclosed building, operate the engines to full power, and maintain the climatic conditions you wish to test in."

And the biggest full-scale aircraft to have squeezed inside the MCL's main hangar to date? "The largest aircraft would be the C-5 Galaxy, which is a US Air Force transport aircraft," responds Bell. "We haven't had an actual commercial 747 jet in here as yet, however we did have the Airbus A350 come through the year before last."

The problem posed by a 747 jetliner is how it would get through the door: "A 747 will physically fit inside the facility," says Bell, noting that the main chamber is 252ft wide, 260ft deep and 70ft high. "However the 747's vertical tail is about three or four feet too tall to come under the door header. We had the same issue with the C-5, but that aircraft has the ability to squat in the back to facilitate loading cargo. When in that position, the tail is low enough to come under the door header and the aircraft can be backed into the hangar. We've actually proposed to Boeing on numerous occasions that we would notch our door header to accommodate getting

"We can't create a tornado either, but we can give you a hurricane if you're willing to settle for that"

2 // During hot weather testing of the F-35, the temperature in the main chamber was steadily and incrementally increased until it reached the test maximum of 120°F (48.9°C)

BOOK NOW TO AVOID DISAPPOINTMENT

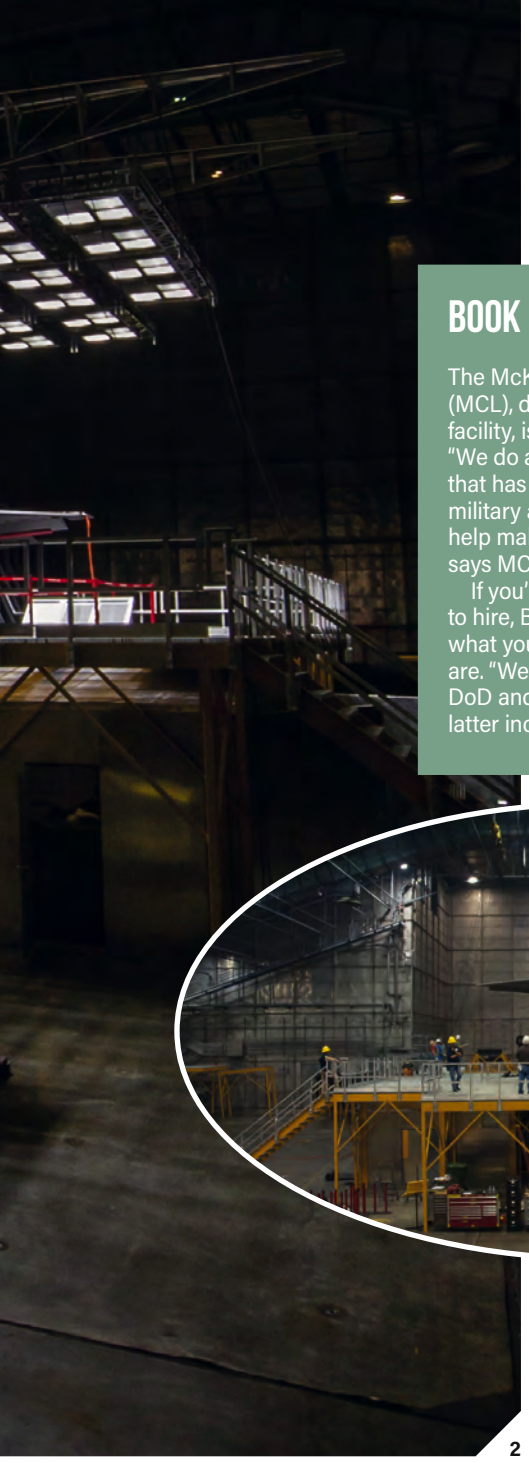
The McKinley Climatic Laboratory (MCL), despite being a military facility, is available for private hire. "We do a lot of commercial testing that has nothing to do with the military and we do that basically to help make ends meet financially," says MCL chief Dwayne Bell.

If you're wondering what it costs to hire, Bell says it depends on what you want to do, and who you are. "We have different rates for DoD and non-DoD customers. The latter includes not only commercial customers, but also government agencies such as the FAA, the Department of Homeland Security, NASA and others.

"If it's just a piece of equipment that needs a temperature test and there's not a lot of instrumentation and we don't have to fabricate any special equipment, that's probably going to cost about US$9,000 per day. However the price can jump up to US$30,000 per day if it's a complicated aircraft test with a lot of hardware to build."

Even if customers have the money, they still have to wait their turn – only the military get to jump straight to the front.

"Our main chamber is essentially booked solid for about three years into the future, all the time," advises Bell. "If somebody calls me today looking for the next available window, we are talking 2018 at the earliest, and if they can't make it on the exact month we currently have an opening, it would be sometime in 2019."



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3

3 // A 12ft-high restraint and support structure interwoven with a system of ventilation ducts secured the F-35 while operated at high power in both conventional and Short Take-off/Vertical Landing (STOVL) mode

the aircraft to come in here, but we've never got far enough into discussions for them to commit to that."

FROM SNOW TO SUN

Since opening, the laboratory has expanded its capabilities to be able to recreate a wide range of climatic conditions from severe Arctic cold to extreme jungle heat and moisture. "This facility was founded to do low- and high-temperature testing," says Bell. "If you can do that, it doesn't take long to figure out that you can also do humidity testing. And then if you fabricate some spray nozzle arrays and hang them from the ceiling, you can make it rain inside the building. And if you go and buy some snow-making machines like they use at ski resorts, you can make it snow inside the building. We also have equipment to generate sand storms and dust storms, we have an altitude chamber, and we have a salt fog chamber."

As a result the facility can simulate almost any weather on the planet, with a few exceptions: "We don't do lightning strikes here, as there is another Air Force facility that does that up in Ohio [Air Force Research Laboratory, Wright-Patterson Air Force Base]," notes Bell. "We can't create a tornado either, but we can give you a hurricane if you're willing to settle for that."

Asked to put a precise figure on the number and type of aircraft to have been put through their paces at MCL, Bell hesitates. "There is no official count. When I came to work here they were already telling people that they had tested over 300 types of aircraft, with many having been multiple times. That was 25 years ago, so I honestly don't know what the number is now, but it is many, many hundreds of aircraft."

-65°C
Chamber temperature held for a week for Google's Project Loon high-altitude balloon tests

73°C
Highest testing temperature to date for McKinley's main chamber

As for extremes of temperature, the main chamber at MCL recently ran a sustained test on a high-altitude balloon for Google's Project Loon that lasted a whole week at -65°C, while temperatures at the other end of the scale can tip 73°C (165°F). The Sun, Wind, Rain and Dust (SWRD) chamber can create wind-blown rain at rates of 25in/hr, while a dedicated altitude chamber can simulate altitude pressures as high as 80,000ft.

Maintaining such extreme conditions in a closed environment for prolonged periods is a full-time, day and night operation. "In the main chamber we are heating and cooling 3,250,000ft³ of air," explains Bell. "Whether you're holding that at -65°C or 70°C, you cannot just turn it off at four in the afternoon when you want to go home and turn it back on the next day at seven in the morning. It has to be conditioned all night and over the weekend. We literally test seven days a week."

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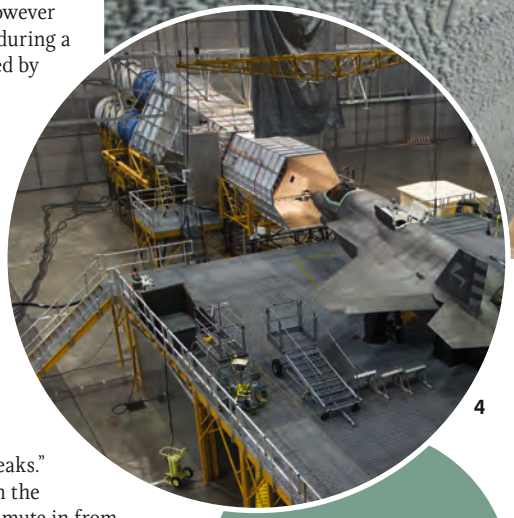
5

Each test program varies in length and focus, with the number and type of test points measured changing from one customer to the next. "There's no such thing as a typical test," says Kevin Cogan, a senior test engineer at MCL. "Every one is a little different, it's set up differently and all the items are usually a little different. I've had a customer come in and set up in a day, do one low-temperature day and be gone the next day. Two, three, maybe four days is usually the minimum, but the longest could be anywhere from eight months to a year if it's a complete aircraft program going through the full spectrum of every single condition."

NOT YOUR AVERAGE WORKPLACE

The facility employs five full-time engineers and 50 support staff, however many more personnel are on-site during a test. "The actual test team provided by the customer can vary from anywhere between two people to over 300, depending on the nature of the test being carried out," says Cogan. "The folks who work here in the facility all year round don't actually test the equipment – we just create the simulated weather. When a piece of equipment comes in for test, the customer has to bring their own people to operate it, their own engineers to evaluate the data, and their own maintenance team to fix it if it breaks."



4

4 // Nine ducted fans blow air through a single funnel, to which a spray bar is attached, capable of producing clouds of various water droplet sizes, during climatic testing of the F-35

There is no accommodation on the base itself, but customers can commute in from a range of nearby hotels. A large office space on-site for customer use can accommodate up to 40 people, while each chamber is equipped with an air-conditioned test booth, with telephone lines and internet service. "Customers can work inside the chamber when they're not testing by communicating with the office and getting their daily operations done," says Cogan.

However that's where the 'ordinary' ends in this rather extraordinary work environment, where no test is the same and test items are pushed to breaking point, particularly on military programs. "When the military test an aircraft like the F-35, they don't have to follow FAA guidelines," notes Bell. "When those aircraft come in here, the teams can operate them at full power, and exercise essentially everything on the aircraft. If you pull the right circuit breakers, the aircraft does not know it's not really flying through the air."

Bell is unable to discuss the actual test results from the F-35's time spent in the main chamber, but he can reveal some of the demanding preparations before its arrival. "From the facility's perspective, it was the largest test that has ever been accomplished here," he says. To accommodate the swivelling engine nozzle and lift-fan system of the Lightning II, a 12ft-high 'restraint and support' structure interwoven with a system of ventilation ducts had to be designed by Bell and his team to secure the F-35 and allow it to operate at high power in both conventional and short take-off/vertical landing (STOVL) mode while inside the building. A sprinkler system was integrated into the exhaust ducting to absorb some of the sound wave vibrations emitted from the engine, which can produce 40,000 lb of thrust, helping to decrease decibel levels in the chamber during testing.

"With the aircraft that far up in the air, we also needed to build a 4,000ft² platform around it so that the military maintainers and pilots could access the aircraft as if it were sitting on the ground," adds Bell. "We also had to build two double garages under the platform to accommodate all their ground support equipment for the testing. It took nine to 10 months working full time to design and fabricate all that hardware, while also supporting the 40 or so other test programs running during the same period."

5 // The chamber was cooled down in increments to -40°F while the F-35 underwent a number of cold weather test runs

A LOT OF HOT AIR

Ventilation of the exhaust is vital to maintaining a stable temperature inside the chamber. Conditioned air is

"We're able to run jet engines inside the facility but there is a certain threshold we can't go beyond"

constantly pumped in to ensure the pressure in the building is always higher than that inside the ducts surrounding the engines of the aircraft being tested and other openings on the aircraft. This difference in pressure ensures the jet exhaust flowing out of the chamber through the ducts is maintained, allowing the facility to remain at a consistent temperature. However, the bigger and more powerful the engine, the more problematic it can become.

"We're able to run jet engines inside the facility but there is a certain threshold we can't go beyond," cautions Bell. "We have two air make-up systems that take outside air, condition it and put it into the chamber to compensate for air that is being sucked out of the chamber by the jet engine and throw it down an exhaust duct to the outside world. As a result, you can't run really big engines like you get on the A350 up to full power in here. We can only put a maximum 1,000 lb mass of air per second at -65°F into the chamber for approximately one hour as those engines are exhausting out, otherwise we'll go into a negative and suck the walls in. If the engine is running at less than 1,000 lb/s, or the air is not as cold in the chamber, we can last for many hours."

Modern, large turbofan engines present a particular problem: "In a high bypass ratio engine, there is a core flow that has products of combustion in it, but there is also a large fan around the perimeter that has no products of combustion in it," explains Bell. "We are only going to put an exhaust suck that collects and reroutes the core flow from the center of the engine. If you bring an aircraft in here that's got a 10ft-diameter engine on it, we can get all the core flow exhaust out and keep up with it for air make up, but there's going to be a limit to how high you can power up the engine, as the winds it would create inside the closed building would be dangerous for the personnel conducting the test."

1,000
pounds mass of air per second that can be maintained at -65°C for one hour with test aircraft engines running

1947
First tests conducted in the McKinley Climatic Laboratory

Despite the risks of the work carried out at the laboratory, Bell cannot recall a major incident in his time working there. "To my knowledge there's never been a fatality," he says. "There are always some minor accidents – people bump their heads, catch their fingers in a door – but we've never had any fatalities that I'm aware of. There's not a single person who walks into that chamber without having had a safety briefing. We also have technicians that are assigned to be in the chamber any time our customers are out there to keep an eye on them. If they believe somebody is suffering from a medical condition relating to the extreme cold or heat, they are fully authorized to get that person out of the chamber whether they want to come out or not."

And although it is always challenging, Bell continues to revel in his role managing one of the world's most fascinating testing facilities. "One of the biggest thrills of the job is that the things that come here to be tested are nearly always the latest and greatest technology," he says. "Take the F-35. It was humbling to stand 100ft from the full afterburn with 70ft of flame out the back of the aircraft, just feeling the pure power of the engine. That's pretty exciting." \\

6

6 // Airbus A350 XWB MSN2 underwent climatic testing at MCL in June 2014, where it was exposed to temperatures as high as 45°C and as low as -40°C

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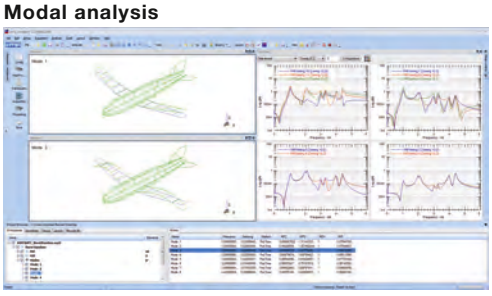
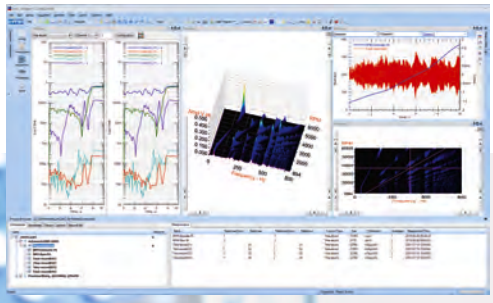
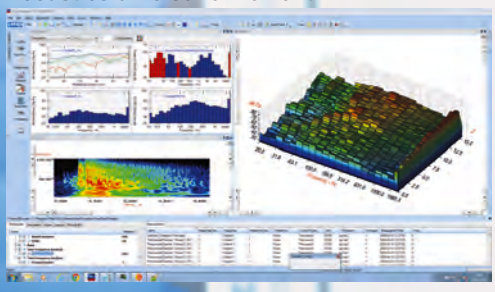


Rotational dynamics



Acoustics & noise refinement



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thin skin deep

Non-destructive testing has an essential role to play in keeping aircraft operational, but which technique has the most to offer? Two expert sources from the UK share their NDT secrets

1 // NDT is an essential frontline tool applied to RAF assets wherever they might be deployed including, as here, in Afghanistan

2 // A 71 Inspection and Repair Squadron technician performs in-theater eddy-current testing on a Tornado GR4

2

Depending on the point of view of the operator, non-destructive testing (NDT) is either a potentially life-saving, continuous trials discipline assuring airworthiness throughout an aircraft's lifetime, or a necessary evil. In most cases it requires technicians equipped with a broad skill set and a variety of deceptively simple equipment to analyze and detect issues that are more than skin deep.

NDT specialists must have the strength of personality to insist that an expensive asset – an aircraft – is grounded for as long as an inspection takes and that it remains grounded if there is any evidence at all of structural defect beyond limits. They must also balance the mobile, reactive aspects of the work, typified by testing after a lighting strike or impact with a ground vehicle, against the type of periodic test that is built into an aircraft manual. And they must have the discipline to apply precision techniques by hand, accurately, consistently and repeatably.

These basic principles of NDT are common across the commercial and military sectors; many experienced civilian technicians are ex-military and, in the UK at least, they work toward a common standard. Stationed at RAF Wittering, Cambridgeshire, No. 71 Inspection and Repair (IR) Squadron's engineers assess aircraft repair requirements beyond those of regular line operations, subsequently developing and implementing fixes and assuring airworthiness.

NDT is a key capability for the unit at the assessment stage, for continuous monitoring after repair, and when an aircraft's service life has been extended. The technique is also essential in checking the onset and propagation of fatigue in components expected to have a finite life. The squadron's NDT complement, which works to British Standard EN 4179, is spread between its Cambridgeshire HQ and four UK regional centers, while maintaining the ability to rapidly deploy its specialist, high-end capabilities globally at very short notice.

NDT is so important that it has a dedicated flight within the squadron, commanded by Flt Lt Kevin Scott, who explains the NDT techniques available and their application.

3

3 // An ultrasonic flaw detector in use with 71 (IR) Squadron

"We employ six methods, primary among them penetrant testing and eddy-current testing, then radiographic testing, ultrasonics, magnetic testing and shearography.

"Penetrant test involves pouring a dye-like liquid onto metallic structures, where it highlights faults such as cracks. It's a very basic method, almost a 'go/no go' technique that will show that you either have cracks or you don't. With eddy-current testing we pass an electric current through a component, creating magnetic fields. These are deflected by flaws in the material and shown in graphical form.

"Radiographic testing uses exceptionally powerful x-rays. It's especially good for examining 'sandwiches' of materials, where the central material often can't be reached or detected. Then we use ultrasonics, sending a ping – a sound wave – into a material. Knowing the thickness and composition of the material, we can predict when the ping's echo should return, with faults in the material causing a peak in the graphical readout.

"In magnetic particle inspection testing, we apply a fluid containing fine magnetic particles while passing a current through the material. This creates a magnetic field and the particles should be attracted to one end of

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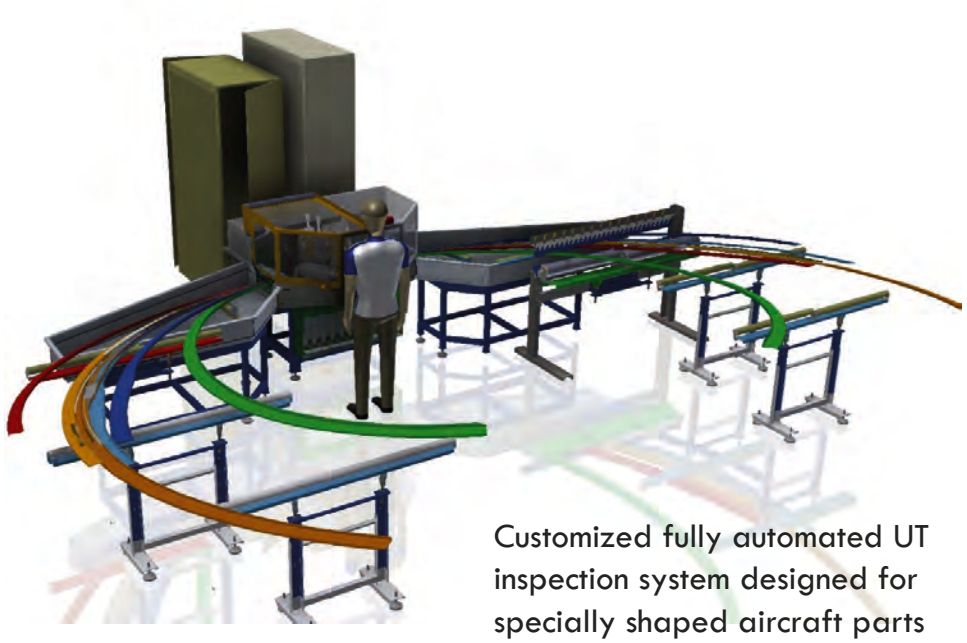

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SEVEN DAYS' NOTICE

Radiography is a powerful technique applicable across the spectrum of NDT, although as with all methodologies, it requires an understanding of the material and suspected fault. It is unlikely to pick up tight cracks parallel to the x-ray head, since there may be no measurable change in the film/plate density. For that reason, some aluminum corrosion may be visible to the human eye, yet undetectable to an x-ray inspection.

71(IR) Squadron retains radiography as a key capability at Wittering, where it usually stays, while Marshall has a dedicated x-ray pit in its NDT facility and a mobile system that can be packed into a midsize van for transport.

Radiation is potentially hazardous, the equipment heavy and awkward to maneuver, especially within tight spaces, and these factors combine to raise health and safety challenges. Following a comprehensive set of layered safety precautions, Marshall's technicians are free to perform radiography in the pit as required, but Bill Bolton says that taking Marshall's water-cooled, 160kV, 20mA machine out into the airport's hangars or on the road is a major undertaking. "We're required to give seven days' notice of our intention to do radiography, so that everyone on the airfield knows. We prefer to work in the evening when fewer people are about, cordoning areas off and locking them down. We restrict our own exposure so that it's as low as reasonably practical.

"We keep distance between us and the source, minimize exposure duration, employ local shielding, including lead shields, wear a thermoluminescent dosimeter, carry a bleeper dosimeter that goes off at a certain radiation level and use handheld dosimiters to read levels and measure around the perimeter so that we can ensure safety for all. Ionizing Radiation Regulations strictly limit exposure to radiation. For site work we have a maximum exposure limit of 7.5 microsieverts/hour and this dose rate limit determines the size of the safety cordon."

the field, but they tend to be attracted to cracks or other flaws. Finally, shearography uses lasers, initially fired at a piece of material and then again when it is under load. Comparing the two images reveals deformations due to underlying faults. It's a technique we commonly use on the large radome housing the radar antenna on the E-3 Sentry."

TRAINING REGIME

Squadron technicians are trained to three levels, with Level 1 personnel capable of basic procedures, typified by penetrant dye testing, alongside their primary engineering roles. They arrive at a 'pass or fail' result but do not interpret results. Their week-long course of instruction is followed by 10 weeks in the field and concludes with examinations. Level 2 technicians are trained as dedicated NDT personnel, learning to interpret results through a 10-week course, followed by 800 hours of consolidation per method, equating to approximately 4.5 years of consolidation. Two years of post-qualification experience, plus another round of exams are required before technicians reach Level 3. At this stage, personnel write instructions for NDT work and examine the capabilities of others.

In order to manage this complex training challenge, Scott ensures that each of his regional teams has expertise in ultrasonic and eddy-current testing, while keeping the other test methods within a quick-reaction team based at Wittering. He notes that ultrasonic and eddy-current between them account for as much as 90% of the squadron's NDT tasking.

CAMBRIDGE CALLING

Bill Bolton, a senior NDT engineer based at Cambridge Airport with Marshall Aerospace and Defence Group, says that for his technicians the primary techniques are eddy-current and magnetic particle testing, with radiography a very close third. He explains how the Marshall and RAF operations differ: "We're predominantly a depth maintenance facility, whereas the RAF technicians are responding to issues on the front line. Sometimes we do have customer drop-ins, where we're asked for immediate help. My technicians are all Level 2 or 3 qualified – as an EASA 145 organization, we're all qualified and certified to EN 4179."

Nevertheless, he confirms that ultrasonic testing, including bond testing, which uses lower frequencies for deeper penetration, or on materials with poor sound conducting qualities, is an important technique for Marshall's NDT specialists. Bolton refers to ultrasonic testing as "probably the grayest of the arts. To a certain extent, you have to have an ability to get inside components to know where the sound is going. That's why we always operate to a known reference or fault standard."

Since NDT procedures are fundamental to aircraft health, new equipment and techniques tend to be developed as new materials evolve. The increasingly widespread use of composites is a prime example of how NDT has developed in parallel,

4 // 71 (IR) Squadron has found laser shearography particularly valuable in detecting faults in the E-3 Sentry's large composite radome

5 // The Tornado has been in service for more than 30 years, with NDT employed as a constant source of airworthiness assurance

since the materials are generally non-conductive and therefore immune to many of the traditional NDT approaches, which were created around metallic structures.

The behavior of new materials under stress also has to be examined and understood; Bolton notes that Barely Visible Impact Damage (B-VID) is a particular problem with composites, for example. Unlike metals, the site of an impact may be barely visible, but delamination and other faults frequently manifest themselves below the surface, with the damage path widening as the impact energy travels deeper into the material, so the area of maximum deformation may be some distance into the component.

The inspection of composite materials presents several potential issues dependent upon the method used. Eddy-current testing is only applicable if the component/structure is conductive, while radiography is excellent for finding water egress (within the pockets of a composite honeycomb structure, for example) but not so with laminar faults. Ultrasonic inspection, including bond testing, is often the method employed where a laminar fault is expected to develop. It detects delamination within the structure as the sound reflects from the structure-to-air interface. It can be time-consuming, expensive work that relies on the experience, persistence and skill of the technician.

6

6 // RAF technician carrying out an eddy current inspection

HOT PROPERTIES

Among the new techniques particularly applicable to composite structures, Flt Lt Scott says his squadron is already looking at thermography, where heat is applied to a surface. Especially appropriate for carbon fiber, the technique uses an infrared detector that reveals deformation as areas of white light on its display. The squadron is also examining phased array, employing ultrasonics through an array of probes capable of area scanning across a surface and quickly finding faults. Through computer control of the probe firing sequence, phased arrays can also be made to steer the sound waves at angles to the surface.

With a nod toward Marshall's Advanced Composites facility at Kirkbymoorside, North Yorkshire, Bolton confirms that thermography and laser shearography are techniques in which Marshall has an interest. "We currently carry out composite inspections using bond testing, A scan, C scan and phased array ultrasonic inspections. Thermography and laser shearography have the potential to inspect large areas in a relatively short timescale. If required, backup methods may be employed to inspect areas that warrant it. As with all materials under inspection, each has one or more challenges. For example, sound attenuates very easily within some composite materials. Hence the potential use of thermography/laser shearography.

"Thermography uses an infrared camera to inspect the heat outputs of a structure or component. There are many ways of heating or cooling an item under inspection, including using a light as a source of heat, chilling a component in a refrigeration unit, or even applying a fine water spray to the surface of thin monolith, the water acting as a heat sink.

"Laser shearography and thermography are both developing technologies with the ability to cover large areas reasonably quickly. Any areas requiring further attention can be marked 'live' on the scan for subsequent examination with other NDT methods."

A variety of complementary NDT techniques and equipment is available and new iterations of existing methodologies, as well as new concepts, continue to emerge as aircraft structures evolve, but experienced and highly trained technicians form the core of successful NDT operations. Their training is long and arduous, and they face a constant round of qualification and requalification throughout their careers. Demanding and frequently misunderstood, NDT nevertheless ensures airworthiness, improves safety, enables service extension and, in the extreme, saves lives. \\

7
days' notice required before Marshall ADG's NDT personnel carry out radiography away from their dedicated pit

6
Primary NDT methods in RAF use

4
Regional RAF NDT centers

3
Levels of NDT technician qualification under EN 4179

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CT scan of
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MEET NEIL SMITH, MANAGER OF THE ENVIRONMENTAL TEST FACILITY AT THE UK MoD'S BOSCOMBE DOWN TESTING SITE – THE LARGEST CLIMATIC CHAMBER IN EUROPE

maker

1 // A RAF Wildcat helicopter is 'grilled' under the chamber's dedicated cockpit solar array

1

// WHAT IS YOUR CURRENT POSITION AND WHAT DID YOU DO BEFORE THAT?

I've been the manager of the Environmental Test Facility [ETF] at Boscombe Down for the past five years. Prior to that, I was the deputy manager. I started my career in 1986 as an electrical apprentice at the Royal Armament Research and Development Establishment (RARDE) in Chertsey, Surrey, UK. After completing my apprenticeship, I was offered a technical position in the calibration department, which was part of the Climatic Laboratories, and was made manager in 1994.

I joined the ETF, MOD Boscombe Down, in 1997. It was a temporary arrangement to help out the ETF during a busy period, after which I was supposed to return to Chertsey. However, I never went back, always managing to conjure up excuses to prolong my stay. I loved the people and the work at Boscombe Down and did not want to leave. Eventually they gave up and I was offered a permanent position – lucky really, because the Climatic Laboratories at Chertsey closed in 1999.

// WHAT ATTRACTED YOU TO THE JOB?

Ever since my first trial at the ETF, I have always loved climatic testing. I suppose it's the various types of military equipment (both land and air) that I have worked with over the past 20 years that attracted me – every trial is different and I still find it interesting. I particularly enjoyed my apprenticeship, working on vehicles such as Challenger 2, Warrior and various 'Landies' [Land Rovers].

Moving to Boscombe Down meant a change from land-based equipment to aircraft. My first major aircraft testing was a series of climatic trials on Tornado GR4/4A in 1998, including engines running. My task was to install instrumentation in the avionic bays, control and monitor the chamber conditions, and act as the trials controller. It was an awesome experience – one of the pilots involved with the trial said that it was very unnerving sitting in the cockpit of a Tornado with both engines running, while staring at a wall! I replied that it was very unnerving standing the other side of the wall while a Tornado is running its two engines! Of course there was nothing to worry about as the aircraft was secured to tie-down points in the chamber floor.

// WHAT WERE SOME OF THE KEY LESSONS FROM YOUR EARLY CAREER?

I learned so many lessons from my mentors during my career, too many to list, but hopefully I have augmented their knowledge and applied it well. I made mistakes, but adapted quickly. There are many hazards involved with climatic testing, so the experience and expertise of our people is vital to the safe and effective operation of the facility. One bit of advice I can give is not to wear contact lenses below -60°C – they freeze.

"One bit of advice I can give is not to wear contact lenses below -60°C"

// DESCRIBE A TYPICAL DAY.

My current role involves the day-to-day management of ETF staff – we are a team of eight ensuring that both chambers are serviceable and ready for action. I am also responsible for the estimation of facility cost for military or commercial trials tasks, the maintenance and repair of test equipment, and the general upgrading of the facility. The ETF is the largest climatic chamber in Europe, capable of -70°C to +70°C, so I need to ensure that all the work safety systems are in place and effective.

A typical day of testing could include a safety and pre-trials briefing, the control and operation of the climatic chamber(s) during the trial, post-trial briefing, and preparing the chamber for the next test day. When a trial is progressing, the large environmental chamber is manned 24 hours a day, seven days a week, by at least two staff. Some test days can be quite intense.

// MOST RECENT AEROSPACE PROJECT?

Strangely enough, the most recent aerospace work was another Merlin [the facility's first-ever aerospace project was an EH101]. It was the testing of an AW101 combat

search and rescue helicopter for Agusta Westland in August/September 2014. The testing was focused on the performance of a redesigned environmental control system fitted to the aircraft.

// WHAT SIZE OF AIRCRAFT CAN IT HANDLE?

The Chinook is the largest aircraft tested to date. The largest fixed-wing aircraft tested were the Typhoon and Tornado fighter jets.

// TYPICAL TESTING WORK CARRIED OUT?

Aerospace testing work carried out in the chamber includes environmental control systems, avionic control systems, APU and main engine operation.

A typical test plan often includes cold, hot/dry and hot/wet environmental conditions.

The chamber can be controlled to run diurnal cycles – a 24-hour cycle to simulate the conditions that you would see in one day in various parts of the world. Solar heating is used to simulate the heat of the sun during times of daylight during these cycles, up to a maximum of 1,120W/m^2. It is normal to run several diurnal cycles for each group of temperature, e.g. cold, hot/dry and hot/wet. We can therefore simulate the thermal conditions that you would see in a typical day in Alaska, a day in Syria, a day in Singapore, or anywhere in the world.

The facility also has what is called a true solar array. This array differs from the aforementioned solar heating system in that it more accurately replicates the full spectrum of sunlight and is used to expose and penetrate transparent materials such as aircraft cockpits to solar effects.

2 // Employees in protective clothing keep an eye on a Chinook helicopter undergoing a cold weather trial

2

The longest period that the chamber has been continually under condition was during a trial for MAN Trucks; the chamber was controlled at -46°C for a period of 4.5 weeks.

// HAVE YOU SEEN ANY CHANGES IN HOW CUSTOMERS ARE USING THE FACILITY?

The facility is now being used to test ground-based military equipment more frequently, e.g. vehicles, tents, ISO container-based systems, and various types of air-conditioning and power-supply systems. There is also an increase in the testing of UAVs and associated equipment. We do not carry out testing on animals or explosives, but human subject testing is permitted under strictly controlled conditions.

// HOW HAS THE FACILITY BEEN UPGRADED?

The facility has undergone upgrades to its data acquisition and logging systems, gas detection systems, solar simulation systems and humidification systems.

"The chamber was controlled at -46°C for a period of 4.5 weeks"

Liquid nitrogen usage has been decreased through the use of improved insulating materials. The facility is also now equipped with infrared cameras to enable the thermal monitoring of large surface areas (aircraft wings, fuselages, tailfins, etc).

The facility is quite unique – not only is it the largest environmental test chamber in Europe (and third-biggest in the world), it can also cope with high levels of wild heat. Wild heat is additional heat that is produced by the equipment under test – for example, the heat from aircraft APUs when operated in the chamber. It means that the chamber has to work an awful lot harder to maintain the temperature conditions to that specified; the normal tolerance is ±2°C.

The chamber's wild heat capacity is 250kW, which means that it can hold conditions indefinitely when this amount of additional heat is produced inside it.

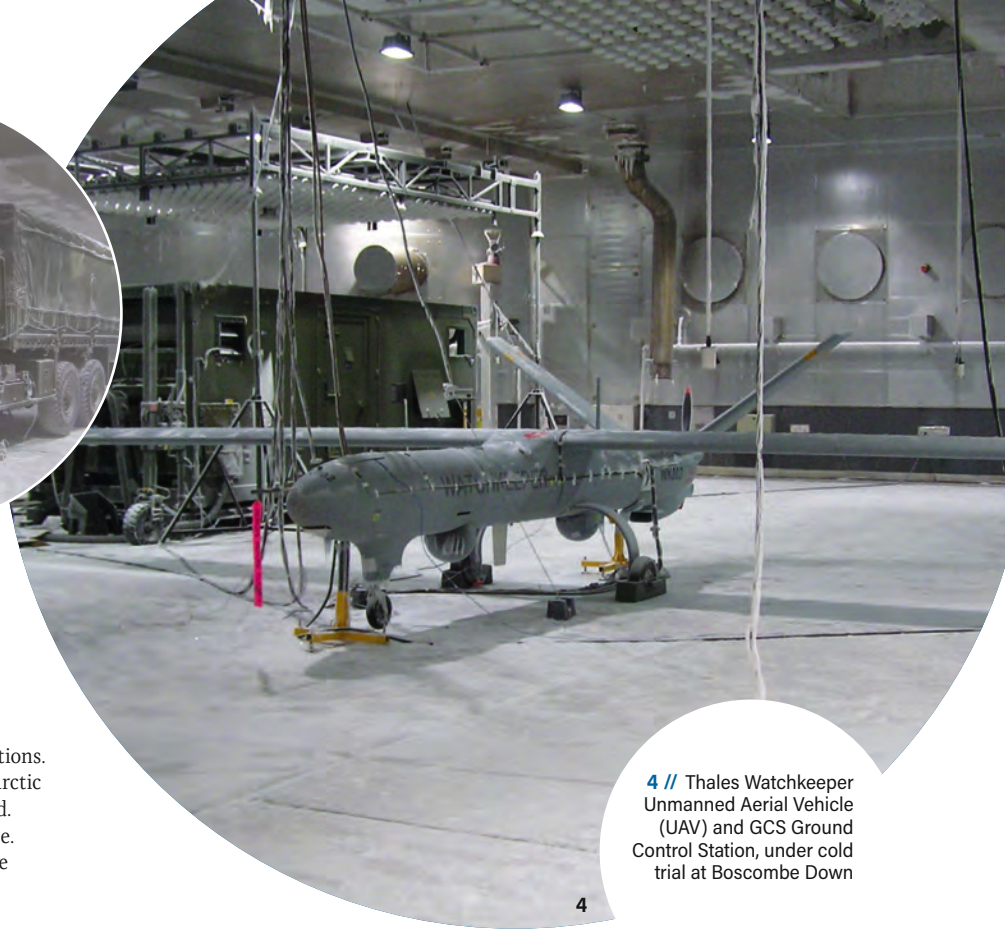
During a Merlin APU test run, the chamber maintained a temperature of -40°C for 5.5 hours. The previous record was 4 hours – testament to the upgrades made to improve chamber performance.

// WHAT IS UNIQUE ABOUT WORKING AT SUCH A FACILITY?

A high degree of skill is required to run the chamber. A suite of competences exist to ensure our eight team members possess the technical expertise to operate the equipment safely and effectively.

The facility's employees are medically cleared to work in extreme temperatures and wear a variety

3 // A MAN Truck ground vehicle was subjected to -46°C for a period of 4.5 weeks during a particularly intense cold weather trial



4 // Thales Watchkeeper Unmanned Aerial Vehicle (UAV) and GCS Ground Control Station, under cold trial at Boscombe Down

of protective clothing when working in these conditions. Suits and clothing that are designed to withstand Arctic conditions are provided for working in extreme cold. Sunglasses are provided when solar arrays are in use. Shifts are worked when trials are taking place; there is a minimum of two employees on at all times.

// HOW IS DATA CAPTURED AND STORED?

The data acquisition system (DAS) has a capacity of 20Gb and can simultaneously record 250 channels of instrumentation in real time. The instrumentation consists mainly of outputs from transducers measuring temperature, solar intensity, humidity, electrical load and pressure. There is also a high-speed DAS that is capable of measuring 16 channels of instrumentation at 1KHz. Data is normally supplied to the customer on DVD or memory stick for further analysis. All trials data is stored on backup disc and kept in a secure area for any future requirements.

// WILL CLIMATIC CHAMBERS ALWAYS EXIST?

Computer simulation could be valuable as a risk-reduction tool, but I don't think it will ever replace the real thing. I've witnessed numerous trials with equipment that has been developed via computer simulation that fail in the chamber. Commercial off-the-shelf (COTS) equipment, which has a simulated operational rating, also fails frequently.

// ANY PLANS TO EXPAND OR UPGRADE THE FACILITY IN THE FUTURE?

Yes, a future investment process is underway and includes improvements to the building, DAS, chamber insulation, medical facilities, solar arrays, compressed air systems, liquid nitrogen systems and storage areas. The customer will benefit from these upgrades through reduced running costs, improved reliability, and better conditions and services.

// WHAT COMPONENTS OR SYSTEMS ARE MOST LIKELY TO FAIL AT EXTREME TEMPERATURES?

Electronic touchscreens and batteries of all types generally do not perform well in cold conditions. Freezing temperatures can make touchscreen glass surfaces more sensitive to cracks and breaks. Batteries and their compartments are now being better insulated and gel-type batteries are becoming more prevalent.

// DO ANY NEW MATERIALS STRUGGLE WITH ENVIRONMENTAL TESTING?

COTS equipment does not generally perform well unless specifically designed to withstand extreme conditions. The facility has recently tested several types of handheld fire extinguishers – some performed well, and some didn't work at all.

// WHAT IS THE MOST REWARDING ASPECT OF YOUR WORK?

I suppose it's the variety in the type of equipment under test. I have worked on 273 trials during my time in the ETF. Each is different and my portfolio includes fast jets, helicopters, unmanned aircraft, tanks, tents and more ISO containers than I can remember.

It's very rewarding work, but none of the trials would have been possible without the assistance of my team. Recently we calculated the ETF has a total of 80 years of experience in environmental testing and it is easily the best team I have had the privilege to work with.

// ANY AMUSING ANECDOTES?

One of the more amusing tasks that we were asked to undertake was during the testing of a toilet/shower block. These units are used extensively by the military in remote locations. In essence, all waste is incinerated and potash is produced as a by-product. The problem was how to simulate the use of the WCs and the 'solids' that they would normally see. After some deliberation, the solution was wet dog food. Each of the four toilets had to have one application of dog food and toilet paper every 15 minutes for a period of one week. Apparently the units performed very well and the trial was a success. \\

cap

five carry

An accelerated test program integrates the joint-service Long Range Anti-Ship Missile with the US Navy Super Hornet

1 // Captive-carry tests of the LRASM on the Super Hornet will investigate the interaction of various underwing loads, including fuel tanks and the HARM anti-radiation missile (*Photo: US Navy*)

Where testing really takes off

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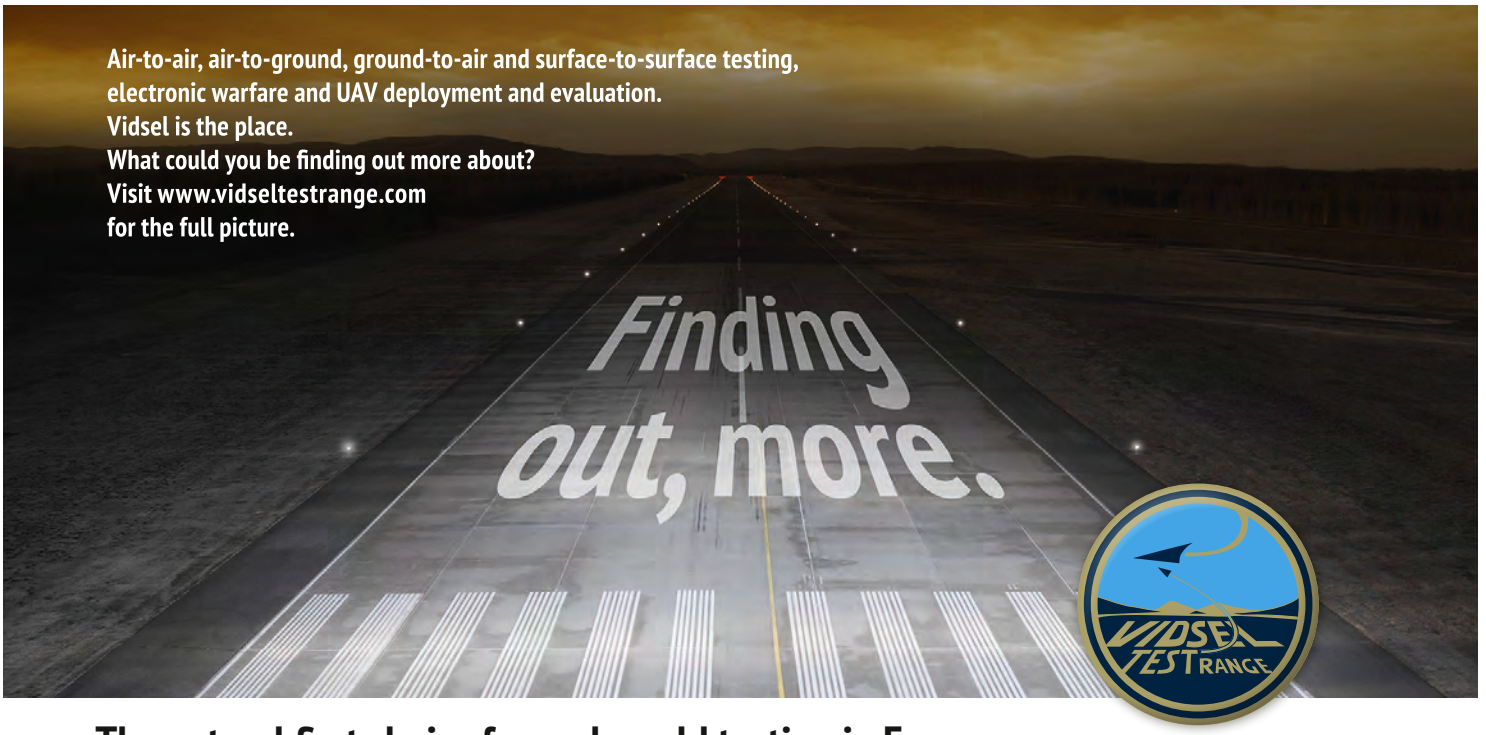

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2

2 // DARPA sponsored demonstration launches of tactically representative LRASMs from an Air Force B-1B off Point Mugu, California (*Photo: DARPA*)

The US Navy began captive-carry flight tests with the Long Range Anti-Ship Missile (LRASM) on an F/A-18E in December 2015. First-phase testing to measure loads and vibrations with inert missile shapes on the Super Hornet will run through early 2016.

Follow-on tests in 2017 will complete the aeromechanical data, with the strike fighter hauling a more representative AGM-158C missile through a prescribed flight envelope.

"We're working toward an interim flight clearance for that aircraft under these limits. That becomes part of the aircraft tactical manual," explains Capt. Timothy Hill, director of the LRASM Deployment Office within the Naval Air Systems Command (NAVAIR) at Patuxent River, Maryland, USA.

"At this point we've gone to the wind tunnel. We've looked at the full Super Hornet envelope given this weapon. We're going to look a lot more at the attack side of the envelope than the fighter side – that starts to truncate it. We will fly it faster, higher, with more *g* in testing than we ever intend to release to the fleet and then notch it back." Subsequent LRASM jettison and separation tests will lead to live launches from the carrier-based F/A-18E/F in 2018 and early operational capability in 2019.

The low-observable Lockheed Martin LRASM is Increment 1 of a joint-service effort to fill a gap in ship-killing capability pending an Increment 2 Offensive Anti-Surface Warfare (OASuW) weapon. The subsonic cruise missile with GPS/INS (global positioning system/inertial navigation system) navigation, passive RF/EO (radio frequency/electro-optical) seeker, and semi-autonomous guidance algorithms aims to reduce dependence on ISR (intelligence, surveillance and reconnaissance) networks and navigation satellites amid the jamming around capital ships.

Capt. Jaime Engdahl, program manager for the NAVAIR Precision Strike Weapons program office (PMA-201), says, "We're using some streamlined processes and running as fast as we can to get a capability fielded in 2018 for the [Air Force] B-1 and 2019 for the F-18."

3 // The Navy began initial integration testing of LRASM on the F/A-18E/F Super Hornet in August 2015 at Air Test and Evaluation Squadron Two Three (VX-23), based at Patuxent River, Maryland (*Photo: US Navy*)

3

"We had made use of all the flight test effort that was done on JASSM and JASSM-ER"

4

PMA-201 develops, buys and sustains Navy air-to-ground weapons. F/A-18E/F testing through mid-2019 is required to document loads, noise and vibration, flying qualities and carrier suitability with LRASM underwing. "This is the first major weapons integration program that we in PMA-201 have done for a couple of years," notes Capt. Engdahl. "It's a rapid, accelerated acquisition program to integrate it on the F-18 and get an OASuW capability in the Pacific theater specifically in 2018."

Talks with Pacific fleet commander Admiral Robert Willard in 2008 led the Defense Advanced Research Projects Agency (DARPA) to team with the Office of Naval Research to investigate LRASM technologies. DARPA routinely demonstrates high-risk technologies and transitions them to the military services for development. A Broad Agency Announcement in 2009 drew nine industry contenders proposing OASuW solutions to cover ranges greater than 200 nautical miles (370km).

Lockheed Martin Missiles and Fire Control in Orlando, Florida, won the DARPA demonstration contract in 2011 with an LRASM based on the 2,000 lb (907kg)-class Joint Air-to-Surface Standoff Missile – Extended Range (JASSM-ER) platform. JASSM-ER has an acknowledged range greater than 500 nautical miles (926km) with a 1,000 lb blast-fragmentation warhead. It entered full-rate production in 2014, but neither JASSM nor JASSM-ER is in service on the US Navy Super Hornet.

1,642
The number of Joint Air-to-Surface Standoff Missiles (AGM-158A JASSM) delivered by January 2016

94
The number of JASSM-Extended Range (ER) missiles delivered as of January 2016

85%
Commonality between JASSM-ER and LRASM missiles, based on total parts count

4 // The JASSM/JASSM-ER, which has a high aeromechanical similarity to LRASM, has been integrated on the B-1B bomber at Dyess Air Force Base, Texas (*Photo: US Air Force*)

Lockheed Martin is developing versions of LRASM for both aircraft and surface-ship launch. The company's air-launched LRASM program director, Mike Fleming, notes, "LRASM shares the same outer mold line as JASSM and JASSM-ER, and the aerodynamic properties are very similar between the three variants. LRASM's weight and center of gravity are the same as JASSM-ER's. Loads and vibration tests on the F/A-18E/F are part of the required airworthiness testing for any integration effort on a new platform."

Joint-service development of the JASSM stretches back to 1995 with the cancellation of the Tri-Service Stand-off Attack Missile (TSSAM). The resulting AGM-158A has been integrated on the B-1B, B-2, B-52, F-16 and F-15E for the US Air Force, plus legacy F-18 Hornets for international operators. The AGM-158B JASSM-ER with a turbofan engine and more fuel for greater range is certified for internal carriage on the B-1B and it is currently being integrated on tactical fighters. The ship-killing AGM-158C LRASM benefits from the JASSM lineage. "We had made use of all the flight test effort that was done on JASSM and JASSM-ER, so there is no need for dedicated testing in terms of aeromechanicals," says Capt. Engdahl. "That truly takes years off the development program and the risks of discovery on the

B-1. We understand the weight, the moments, the vibrations. We can concentrate solely on the performance aspects of LRASM."

Unlike the JASSM and JASSM-ER land attack missiles, LRASM is meant to search out and attack specific ship targets in crowded littoral waters. The missile sensor suite that was developed by BAE Systems integrated a targeting datalink and RF and EO sensors and flew on a Sabreliner business jet in 2012. A tactically representative LRASM launched from a B-1B hit a ship target off Point Mugu, California, without mid-course updates in August 2013. Two more DARPA-sponsored shots from B-1Bs in November 2013 and February 2015 exceeded the required OASuW range and demonstrated low-altitude navigation and obstacle avoidance. The NAVAIR LRASM Deployment Office was set up to speed the missile integration and testing. According to Capt. Hill, "We looked again at what nominal development would be, and it would be an 8- to 10-year effort. We're going to be close to 4.5 or 5."

Current work on the B-1 LRASM integration focuses on data exchange between the launch aircraft and the missile. "We'll do that same kind of work on the Super Hornet as well," explains Capt. Hill. However, DARPA demonstration shots from the Air Force bomber dropped missiles from an internal weapons bay. The Navy F/A-18E/F carries LRASM externally next to a range of underwing ordnance.

"You can imagine that with an aircraft like the Super Hornet there are thousands of combinations, so we have input from the fleet as to what combinations we're going to look at," continues Hill. Test configurations will include fuel tanks, targeting pods and air-to-surface weapons next to LRASM.

"We're able to leverage a lot from the aeromechanical flight clearance testing that's already been done on B-1," says Capt. Engdahl. "We already have the weapon design and the aircraft design – we're will couple those two together and to go out though the flight envelope and survey the underwing environment and make sure it's matching the models in the design."

LRASM flight testing on Patuxent River F/A-18s was preceded by wind tunnel testing last year at Arnold Air Force Base in Tennessee. Mike Fleming explains, "Tunnel testing provides accurate aerodynamic properties and stores separation data that would normally be available only through actual flight testing. There are major cost and schedule savings achieved by using wind tunnels to conduct this testing. Lockheed Martin has conducted extensive wind tunnel testing in the past to complement the mature flight testing program for JASSM and JASSM-ER."

The LRASM Deployment Office also has flexibility in its flight test plan to expedite early operational capability. A general plan with scheduled sorties over time can be shortened based on flight test data. "If things correlate well with the wind tunnel, we'll knock it off and be done," says Capt. Hill.

HANG ON AND FLY

LRASM tests on the Super Hornet are flown over the Atlantic Test Range (ATR) by test squadron VX-23 based at Patuxent River using early F/A-18E Engineering and Manufacturing Development (EMD) Super Hornets E3 and E6. E3 is the primary test platform for LRASM captive carry tests.

"It was one of the original load airplanes for Super Hornet," observes Capt. Hill. "It has a whole host of instrumentation – much more than we actually need. It runs the gamut from nose boom capability to load sensors on the pylons, a lot of which we're not using at this point."

VX-23 STRIKE TEST

Air Test and Evaluation Squadron Two Three (VX-23) at the Naval Air Warfare Center Aircraft Division, Patuxent River, Maryland, is the US Navy's largest flight test squadron, with more than 40 F/A-18A-D Hornet, F/A-18E/F Super Hornet, EA-18G Growler, F-35B/C Lightning and T-45A/C Goshawk aircraft assigned. The dedicated fixed-wing strike aircraft test unit also supports development of the Northrop Grumman X-47B Unmanned Combat Aircraft System Demonstration (UCAS-D).

As part of the Naval Test Wing Atlantic, the 'Salty Dogs' test flying qualities and performance, shipboard suitability, propulsion systems, tactical aircraft mission systems and ordnance. VX-23 testers last year, for example, completed aeromechanical testing of an infrared search and track (IRST) pod for the F/A-18E/F.

Current tests of LRASM are flown on the third and sixth Boeing Super Hornets built for the F/A-18E/F Engineering and Manufacturing Development (EMD) program. Boeing originally instrumented F/A-18E-3 with strain gauges, accelerometers and other sensors to measure maneuvering loads, buffet loads and vibration levels during EMD. A solid-state digital recorder stores data on board, and a telemetry system transmits data in real time to monitors on the Atlantic Test Range (ATR). A Telemetry Data Center at the ATR collects real-time test information from up to nine aircraft at a time for test teams.

5 // Air Test and Evaluation Squadron Two Three (VX-23) completed the first phase of LRASM inflight load testing in January 2016 with inert mass simulators. More complete missiles will be used for the second phase of aeromechanical testing (*Photo: US Navy*)

5

"We make sure we survey the entire envelope of the aircraft just to make sure we don't have problems"

Lockheed Martin is meanwhile responsible for building and instrumenting the LRASM test missiles used at Patuxent River and has a team on site to conduct real-time load data evaluation. The missile contractor also receives recorded data for post-flight evaluation. The LRASM simulators with representative mass, center of gravity and moments of inertia were assembled and instrumented at the same facility in Troy, Alabama, where JASSM and JASSM-ER missiles are produced. "They're dumb shapes," notes Capt. Hill. "They're instrumented to get data with respect to loads, *g*-forces, etc, but they have none of the guts of LRASM." Later tests will use more complete vehicles, and Lockheed Martin will provide support at Patuxent River, according to Fleming.

Flight tests take the Super Hornet and LRASM through a broad envelope to verify stores clearances as the aircraft flexes. "They're doing test points up to 25,000ft Mach 0.95 and low-altitude and high-speed testing," says Capt. Engdahl. "It's all standard flight test maneuvers, such as wind-up turns and high-*g* test points, They're looking at aircraft loads up to 7.5g, to the standard limits of the aircraft." He adds, "We don't need to fly LRASM up to 7.5g or to some of the end points in the environment, but we make sure we survey the entire envelope of the aircraft just to make sure we don't have problems."

Capt. Engdahl explains, "In generic terms, this is Phase 1 of captive-carry testing for noise, loads and vibration. There is a Phase 2 with more heavily instrumented captive rounds. Then we go to jettison and separation test vehicles – jettison tests are without wing deployment. Then you get wing deployment as well to make sure neither scenario causes a problem." Jettison and separation tests will be performed by squadron VX-31 at China Lake, California, in 2017.

Carrier suitability testing for a Super Hornet with LRASM on board will include launches from a standard TC7 catapult and traps with Mk7 arresting gear at Patuxent River in 2018.

"We're not planning on doing anything unique for this weapon," says Capt. Hill. The Naval Air Warfare Center Aircraft Division at Patuxent River also has electromagnetic environmental effects testing facilities to supplement work done by the Navy at China Lake and by Lockheed Martin in Orlando, Florida, and in pTroy, Michigan.

LRASM on the Super Hornet promises the Navy a powerful anti-ship weapon in the near future and NAVAIR additional test work if the Navy chooses to integrate the missile with the low-observable F-35C strike fighter also in development. Capt. Hill concludes, "Any weapon you want to integrate on any aircraft needs to be tested." \\

6

6 // Air Test and Evaluation Squadron Two Three (VX-23) completed the first phase of LRASM inflight loads testing in January at NAS Patuxent River, Maryland. *(Photo: US Navy/ Liz Wolter)*

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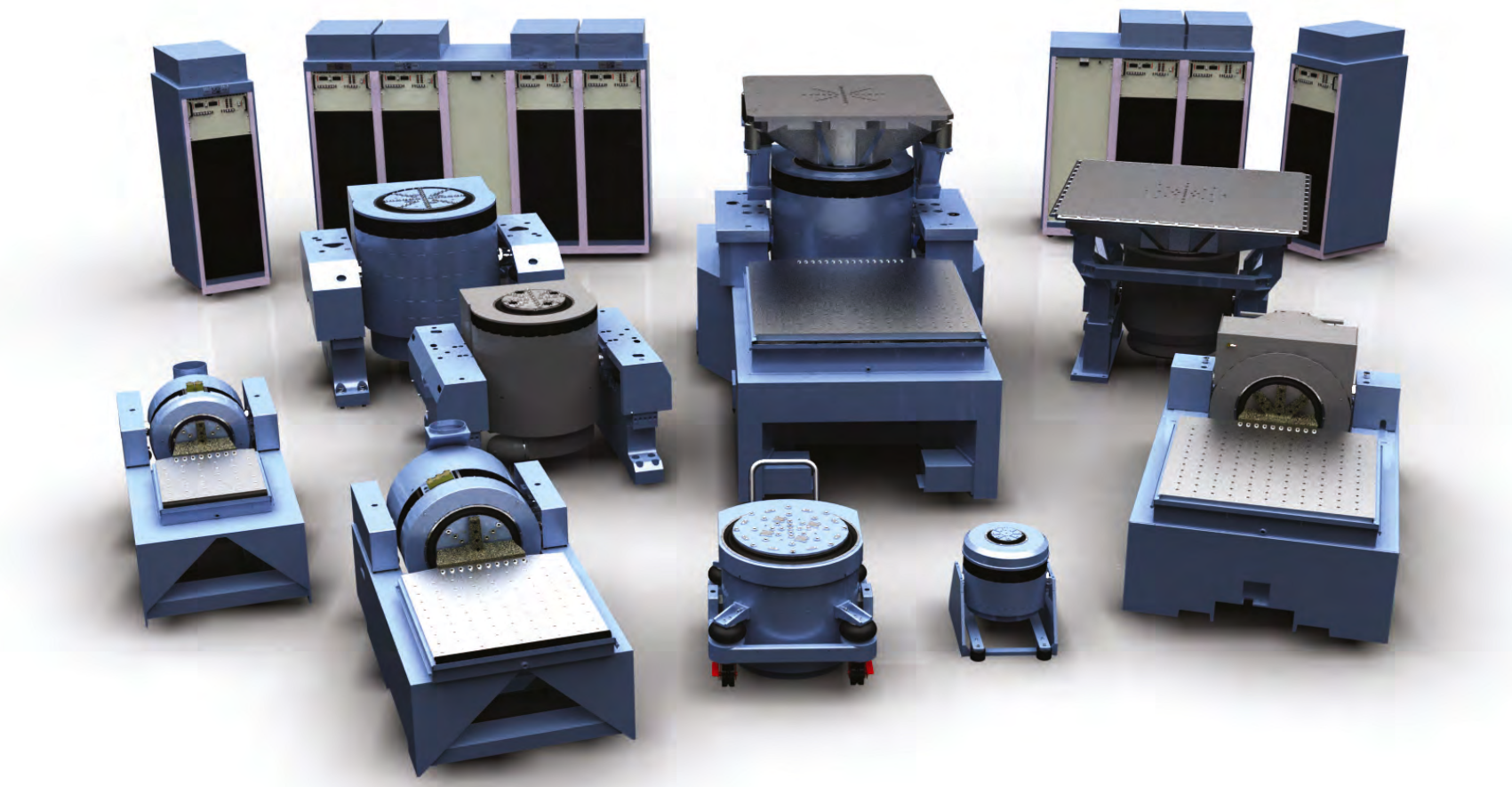

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// CLIVE SIMPSON

Shake, rattle and roll

A critical piece of NASA's new Orion spacecraft – the service module – is undergoing a series of crucial tests to determine whether it can withstand the rigors of space flight

1 // The vacuum chamber at the B-2 Space Power Facility (SPF) at NASA's Plum Brook Station in Sandusky, Ohio, USA

2 // The vibration table at NASA's SPF will verify that Orion's crew module can sustain the vibrations of not only launch, but also a launch abort

Satellites and human-rated spacecraft are expensive to build and launch – and once in orbit they cannot be fixed. During launch, rocket boosters and their payloads are subject to intense acoustic environments, which induce high levels of vibration in structural elements and equipment.

So extensive ground testing during each phase of space hardware development to simulate launch-induced vibration and investigate structural dynamic characteristics has proved to be a vital contribution to the success rate of spacecraft programs all around the world.

All launch vehicle organizations (and satellite insurance companies) across the world (from the USA and Europe to Russia, China, India and Japan) now specify spacecraft vibration tests for payloads.

In the past, surveys of workmanship defects in commercial spacecraft acceptance vibration tests have revealed a variety of typical failures. These include: electrical shorts due to abrasion of wiring harnesses, intermittent shorts in cable harness pin connectors, molded graphite-epoxy dish bonding failures, screws and bolts backing out, loss of solar array alignment, solar array failure to deploy due to binding, debris lodged behind and within other mechanisms, floating nuts, plumbing leaks, material failures due to faulty processes, and swaged ball joint failures due to faulty manufacturing.

Consensus within the expendable launch vehicle payload community is that spacecraft vibration testing is a crucial component of any spacecraft verification program. Tests provide qualification for essential mission components and are effective at detecting workmanship defects. Analysis, static load and acoustic testing have proved no substitute for the spacecraft vibration test, particularly at low-to-mid frequencies.

The Cassini probe – a joint NASA, European Space Agency (ESA) and Italian space agency mission to Saturn – experienced a radioisotope thermoelectric generator (RTG) electrical short to its spacecraft mount after

6.7M
The Mechanical Vibration Facility (MVF) at NASA's Space Power Facility uses a large aluminum table approximately 6.7m (22ft) in diameter with a 0.61m- (2ft) wide annular mounting surface centered about a 5.5m (18ft) nominal diameter

34,000KG
(75,000lb) Maximum test article mass specified by NASA for the MVF

EYE IN THE SKY

There's often a fine line between success and failure – and a routine, relatively inexpensive test would have caught the error that initially crippled the US$1.5bn Hubble Space Telescope (HST) after its launch in April 1990 into orbit 340 miles (547km) above Earth with failing eyesight and an optical system that was hardly better than ground-based telescopes. The test, involving the reflection of light off the telescope's mirror, would have been far simpler than an ambitious effort to test the Hubble as a total optical system before launch at a cost of US$100m. A smaller test, costing no more than several million dollars, would have found the flaw – a spherical aberration that occurs whenever a mirror in a telescope is not ground to the right shape – but the telescope was running hundreds of millions of dollars over budget and NASA cut back on its testing to save money.

The story had a spectacular and happy ending after astronauts flying on the US space shuttle were able to recapture the telescope on a mission in 1993 and fit a correction lens.

3 // Qualification model of Galileo dispenser fitted with one Galileo engineering model on each side, for testing on the QUAD shaker at the ESTEC Test Centre

vibration wore isolation coating off the mount in a system random vibration test. Major degradation in spacecraft electrical power could have resulted, so the mount was redesigned prior to the probe's launch in 1997.

Deep Space 1, a NASA asteroid and comet fly-by mission, experienced several workmanship problems during system random vibration test. A hydrazine liquid service valve opened prematurely; the spherical Langmuir probe fell off the bottom of the remote sensing unit; two screws in the star reference unit fell out and another backed out part way; and fasteners loosened in the star tracker bracket, leaving chatter marks on the shear panel. Any one of these problems may have seriously degraded the mission.

More recently, prelaunch testing of NASA's Mars Exploration Rover (MER) found that fundamental modes of the rover in spacecraft random vibration tests were 20% greater than predicted in all three axes. Fixed-base modal tests had been performed separately on the rover, lander and cruise stage before they were combined, when it was found that the stiffness of the lander attachment to the rover was too low. Vibration tests also revealed improper torque for bolts on some tanks.

The majority of ESA spacecraft are tested at a dedicated center at its European Space Research and Technology Centre (ESTEC) site in Noordwijk, the Netherlands, the largest of its kind in Europe. "Its role is to help project teams evaluate prototypes and verify that instruments and equipment operate as intended," says Gaeten Piret, head of ESTEC's testing division. "All projects rely on this critical verification activity and the center enables satellites to go through all necessary tests – particularly the non-standard ones that industrial companies cannot do by themselves – in a single location with quick response times."

Satellites are typically exposed to the severe vibration and tremendous acoustic noise experienced during take-off using ESTEC's shaker tables and acoustic chamber. "In the space simulation facility, test engineers also expose the satellite to the vacuum conditions and the extreme temperatures of space for weeks at a time," Piret adds. "These activities check whether the satellite will continue to function properly in these conditions. Intensive testing goes on for months until engineers are

"Vibration tests also revealed improper torque for bolts on some tanks"

MERCURY RISING

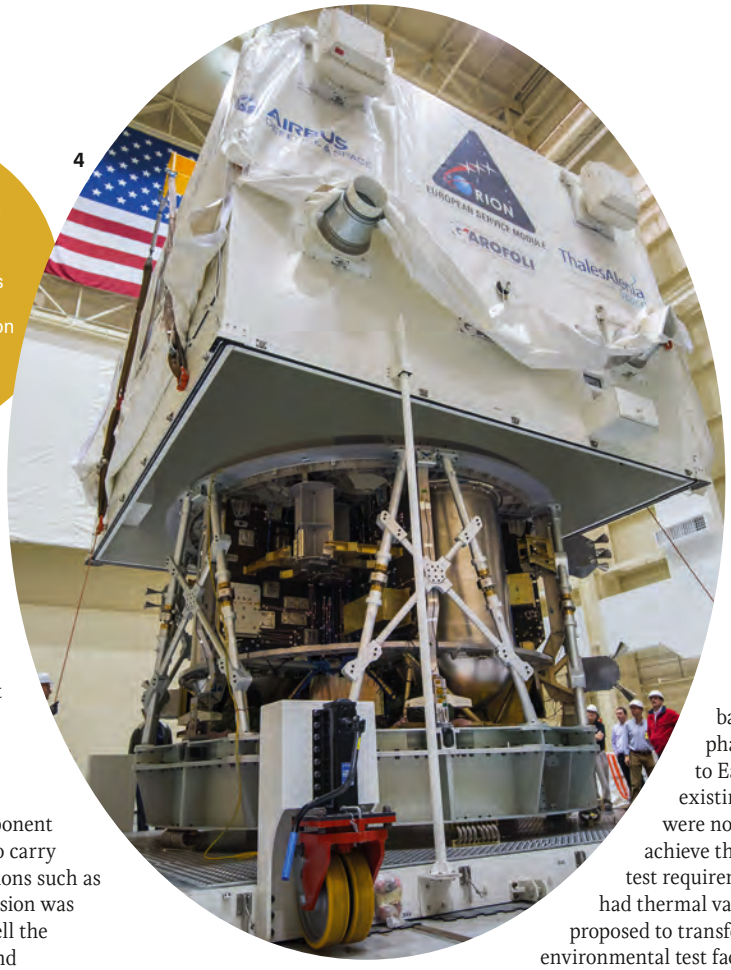
If ESA's Mercury orbiter of the BepiColombo mission seems to stand at an unusual angle above its test chamber floor during a series of EMC, radiated emission and susceptibility testing in December 2015, it was entirely intentional. Testing took place inside the Maxwell chamber of ESA's ESTEC test center in Noordwijk, the Netherlands, where shielded metal walls and doors form a Faraday cage to block unwanted external electromagnetic radiation, while internal walls are covered with anechoic radio-absorbing foam pyramids to mimic boundless space.

"We performed two types of compatibility testing," says Marco Gaido, assembly, integration and test manager at BepiColombo. "First, we checked that the craft is electrically compatible with the electrical field generated by the Ariane 5 launcher that will deliver it into orbit, with no possibility of interference with BepiColombo's receivers.

"Second, we tested for any risk of incompatibility between the different subsystems of the spacecraft itself when it orbits Mercury. In particular we want to check that its trio of antennas on top can communicate properly with Earth. So it was deliberately oriented to simulate a worst-case scenario for test purposes."

The orbiter was positioned to allow deployment of its medium-gain antenna in terrestrial gravity. The high-gain antenna reflector meanwhile was deployed in a worst-case position, supported by a dedicated fixture.

Tilting was achieved by means of a large platform while the high-gain antenna was supported by a tower made of wood and transparent to radio waves. All test cables used were shielded to reduce potential interference.



4 // The European-built Orion Service Module arrived in Cleveland in November 2015 and was transported to NASA Glenn's Plum Brook Station for testing in the SPF

convinced the satellite is capable of performing well for the whole of its planned life."

In the USA, the Space Power Facility (SPF), run by NASA's Glenn Research Center at the Plum Brook Station in Sandusky, Ohio, is one of the world's leading test facilities and offers the ability to conduct most or all required full-scale end-assembly space simulation tests at a single location.

ORION UPS THE GAME

ESA's Orion Service Module is a crucial component of NASA's next crewed spacecraft designed to carry astronauts to the moon and deep-space locations such as asteroids and Mars. Last November a test version was delivered to the SPF to begin tests on how well the system will withstand the intense shaking and thrust associated with a launch, as well as the heat and pressure extremes it will encounter in space.

Back in 2006, when Orion – known then as NASA's Crew Exploration Vehicle (CEV) – was being conceived as a replacement for the space shuttle, initial decisions were also being made about the required facility capabilities necessary for environmental testing of such a spacecraft.

Those requirements were based on analysis of the flight phase environments from launch to Earth orbit – an assessment of existing test facilities concluded there were no existing facilities that could achieve the mechanical vibration or acoustic test requirements. At that time the SPF only had thermal vacuum capabilities, so it was proposed to transform the SPF into a space environmental test facility.

To prepare for testing Orion, NASA decided to add two major new facilities to the SPF's Space Simulation Vacuum Chamber, built in 1969 – the Reverberant Acoustic Test Facility (RATF) and the Mechanical Vibration Facility (MVF), both of which were completed in 2011. The RATF simulates extreme noise and the MVF simulates the intense shaking a spacecraft experiences during ascent into space. The RATF is the world's most powerful spacecraft acoustic test chamber, while the MVF is the world's highest capacity and most powerful spacecraft shaker system.

At the same time, the ability to perform reverberant-mode electromagnetic interference and compatibility testing was added, meaning the whole facility is now capable of performing a full suite of testing services simulating a complete space mission from launch to deep space environments – all under one roof.

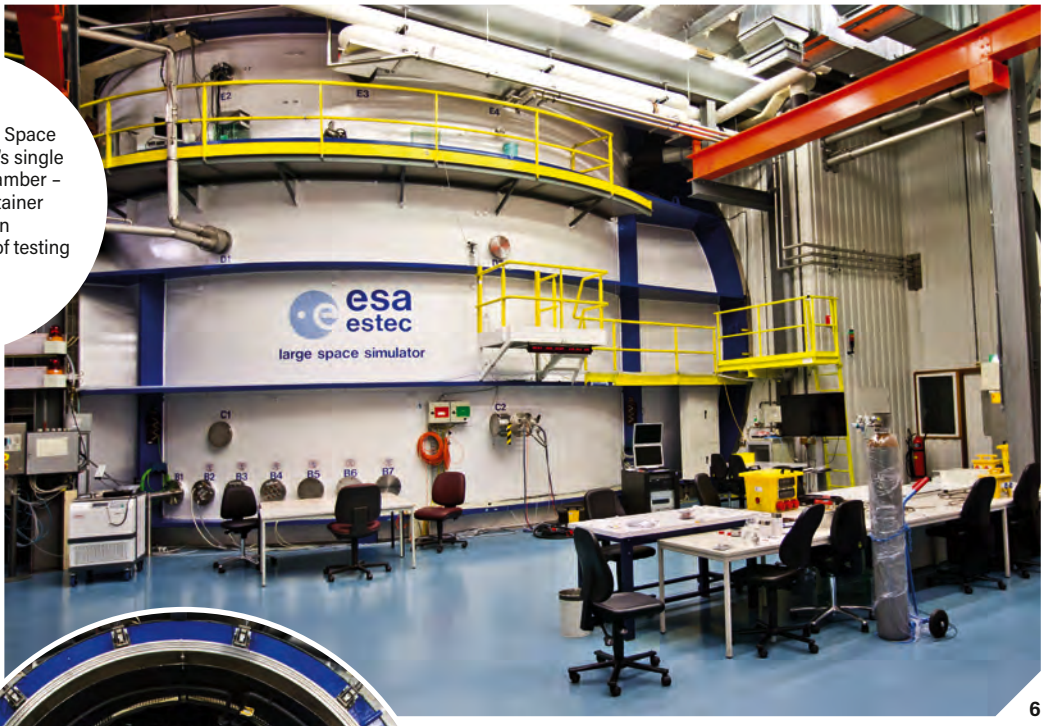
Rick Sorge, SPF test manager, tells *Aerospace Testing International*, "The test facilities here are all world class. The acoustic chamber is the most powerful in the world, capable of producing 163dB overall sound pressure within its 101,000ft³, and the chamber is large enough to house most full-scale spacecraft.

"The vibration system is also the world's most powerful servohydraulic shaker system, capable of

5 // The Reverberant Acoustic Test Facility (RATF) is the world's most powerful spacecraft acoustic test chamber

16
Vertical actuation of MVF's table is provided by 16 hydraulic cylinder actuators attached to the reaction mass, onto which 16 double-spherical couplings are attached

23.5M
(77ft) Maximum test article height specified by NASA for the MVF



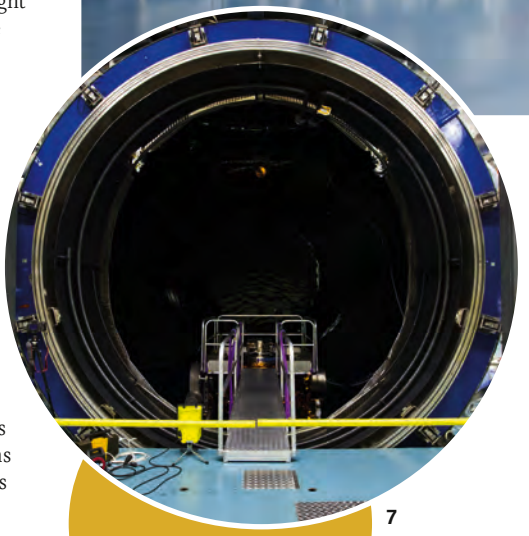
6 // ESTEC's Large Space Simulator – Europe's single largest vacuum chamber – is a cylindrical container 15m high and 10m in diameter, capable of testing full-size spacecraft

6

accelerating masses of 75,000lb at 1.25*g* in the vertical axis and 1.0*g* in the lateral axis. The 19ft-diameter table is large enough to support full-scale test hardware."

At 100ft in diameter, 122ft in height and with a volume of 800,000ft³, the vacuum chamber is also the world's largest. "This size permits full-scale testing of deployment mechanisms, rocket fairing separations and large ground vehicles," explains Sorge. "The 40ft cylindrical thermal shroud system, capable of temperatures from -250°F to +170°F, can fully surround large spacecraft. The chamber can reach vacuum pressures of $1x10^{-5}$ Torr in less than eight hours, and maintain conditions indefinitely."

Among tests the service module is now undergoing are acoustic stress and mechanical vibration simulations of the launch environment, as well as shock tests to mimic the vehicle's separation from the rocket. The SPF vacuum chamber is being used to mimic the vacuum environment in space and the facility will also fire pyrotechnics to test the temperature resilience of the vehicle's solar arrays.



7

7 // The Large Space Simulator has an overall volume of 2,300m³

"Because Orion will carry astronauts, testing requirements are very extreme to ensure the safety of the crew," says Jerry Carek, SPF manager. "We have to build in margins by testing to vibration and acoustic levels that are much higher than we expect during a mission to confirm that hardware will not fail. These extreme testing environments can only be produced by the new facilities within the SPF."

The European-built service module serves many purposes for Orion, according to Mark Kirasich, NASA's Orion program manager. "It acts as the propulsion system, provides steering and avionics for the spacecraft, and during the ascent from Earth it gives the spacecraft an abort capability, should it be necessary," he says. "In addition, it has solar arrays that are used to collect energy and power all the equipment on board Orion, including radiators that keep the temperature ideal for both the equipment and the passengers, as well as carrying oxygen, nitrogen and water for crew life support."

"Testing requirements are very extreme to ensure the safety of the crew"

After the series of tests is completed later this spring, the service module will be disassembled. Some of the remaining parts will be refurbished and undergo further testing, with some being sent to Kennedy Space Center in Cape Canaveral, Florida, and other returning to Europe, where additional iterations of the service module are being constructed.

Orion, which will launch atop NASA's new Space Launch System (SLS) rocket, underwent its first test flight in December 2014, but during that test the craft was not fully equipped for a trip into deep space. NASA plans to launch Orion on a fully integrated test flight, known as Exploration Mission-1, sometime in 2018, which will take the uncrewed vehicle around the moon and back. \\

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SPACE IS THE PLACE

New records, new exhibitors, new format, new venue – Space Tech Expo, co-located with Aerospace Electrical Systems Expo, launches in Pasadena, California, May 24-26, 2016

OPENING HOURS

Tuesday, May 24
12:00–6:00pm
(Drinks reception in the exhibition hall, 4:00–6:00pm)

Wednesday, May 25
9:00am–5:00pm

Thursday, May 26
9:00am–3:00pm

VENUE DETAILS

Space Tech Expo is co-located with Aerospace Electrical Systems Expo and takes place at Pasadena Convention Center, 300 E Green Street, Pasadena, California 91101, USA

Space Tech Expo – co-located with Aerospace Electrical Systems Expo – looks set to host its largest event ever, with 230+ exhibiting companies and 1,700+ participating companies joining the show in Pasadena, California, from May 24-26, 2016.

Pasadena, home of the world-renowned California Institute of Technology (Caltech) and Jet Propulsion Laboratory (JPL), is the new home for Space Tech Expo and Aerospace Electrical Systems Expo. Its reputation as a major center for science continues to attract great minds eager to make the next big discovery.

Indeed, many new exhibitors are joining the fold this year, including BAE Systems, AeroVironment, TTTech, Emcore, Falcon Electric, Honeywell, NASA AFRC and JPL. The latter also features in the Space Tech Conference proceedings, with deputy director General Larry James presenting a keynote address.

Space Tech Expo already holds the reputation of being the USA's meeting place for space technology and engineering, and Aerospace Electrical Systems Expo is fast becoming known for the same reason. In 2015 the event saw a 45% increase in attendance and a 25% increase in exhibitors, and this year looks set to beat that impressive growth.

"It's been a great show for us. We've had a booth here and had some sponsorships," said Arnie Streland, director of strategy and business development at Orbital ATK, after last year's event.

TESTING ZONE

There will once again be a dedicated exhibit area to showcase companies providing testing capabilities, and give attendees the opportunity to meet the wider aerospace sector, including the commercial and general aviation, military aerospace and space industries.

There will also be sessions covering themes concerned with the full cycle of testing, evaluation and inspection applications for civil/military aerospace, airborne defense systems, launch vehicles, satellites and space platforms.

Finally, GE Aviation will once again be a key supporting partner, with a feature exhibition space and dedicated free sessions with its expert speakers, as well as hosting invitation-only small-business meetings, with NASA confirming participation.

SPACE TECH CONFERENCE

This year's conference will focus on examining how military and government organizations can deliver space missions by working closely with the commercial sector, leveraging the latest innovative technologies and business models. The conference also takes a deep dive into the rapidly evolving space-to-space market, and offers specific sessions examining the plethora of emerging on-orbit services and technologies.

One session not to be missed is the Keynote Panel: Commercial, Defense and New Space – Understanding the Roles and Value Proposition of the Space Funding Inflection Point, featuring Larry D James, deputy director of JPL (NASA), to be held on Day 1 of the conference. Other confirmed speakers include Claire Leon, SES, DAF, director – Launch Enterprise, Space and Missile Systems Center; Michael Gazarik, vice-president of engineering, Ball Aerospace; Steve Stich, deputy manager, Commercial Crew Program, NASA; Mark Rawlins, chairman, Space Data Association, and director of communication system operations, Eutelsat; and Jim Keravala, COO, Shackleton Energy Company.

KEY TOPICS FOR 2016

- Commercial, defense and new space – the inflection point
- Launch market trends – reusability and affordability
- Simplifying and improving ground systems architecture
- Commercializing new technologies
- Driving innovation with new space players
- Cross-sector collaboration in space situational awareness
- Enabling space-to-space commerce and on-orbit services

FREE SESSIONS

Featuring 30+ presentations over three days, the free-to-attend sessions in the expo hall will explore space engineering, electronics, aerospace manufacturing, and design and test innovations.

The Free Sessions Program features speakers from ULA, JPL, GE Aviation, NASA, BAE Systems and Honeywell. Topic presentations cover technologies and design, electrical systems and test, and government/military/prime requirements.

One session not to be missed is Using High-Performance SpaceVPX Computing Modules for Next-Generation Onboard Processing, to be given by Joe Marshall, senior principal systems engineer, BAE Systems.

On the last day of the expo, a series of free-to-attend requirements presentations will bring together representatives of leading government, military and prime contractor organizations. Speakers will outline their current and future projects, highlighting where there are opportunities for the space supply chain, and also share details of specific opportunities for small businesses. Confirmed speakers include representatives from NASA JPL, NASA Armstrong and SMC.

Modular compliant connectors

Visit ECT at Booth 1025

Boasting five decades of experience in developing compliant connectors, Everett Charles Technologies (ECT) is well placed to welcome questions from the military, medical, aerospace, test and measurement, transportation and industrial sectors this spring in Pasadena.

With an expanding suite of intellectual property, and a legacy in spring probe and compliant interconnects, ECT focuses on the most demanding customer applications while supporting small and large volumes.

The company will be showcasing its connectors at this year's Aerospace Electrical Systems Expo.

The SC1 line of modular compliant connectors meets the demanding requirements for a broad range of applications. The architecture is based on ECT's standard contacts and offers economies of scale to customers. For example, the row count, column count and tail of the probes can easily be configured. However, for customer-specific applications, ECT can design and manufacture connectors to exact stipulations.

Moreover, ECT connectors meet application-specific demands, whether the need is for sealed, self-cleaning connectors for material and chemical-sensitive industries or for shock and vibration-tolerant connectors for rugged environments. ECT excels at fulfilling the mid- and low-volume needs of customers who require design-intensive, high-compliance, long-life connectors. For more information, please visit ect-cpg.com/compliant-connectors.

Genasys switching subsystem

Marvin Test Solutions (MTS) has confirmed that it will showcase the expanded product line of the GENASYS platform at Aerospace Electrical Systems Expo this May in Pasadena.

The GENASYS system has been selected by two major military-aerospace primes to support the manufacturing test of high-value, complex products.

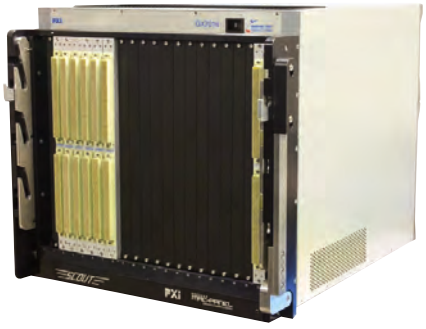
Among those being showcased is the GX7016 GENASYS Switching Subsystem, which offers a new level of high-performance, high-density signal switching for board and system-level functional test with an 'any resource to any pin' architecture.

This incorporates a modular switch matrix and multiplexer architecture with the MAC Panel 6U Scout receiver, providing up to 4,608 multiplexed, hybrid I/O pins without cabled connections.

Also being showcased is the newest addition to MTS's portfolio of PXI digital instrumentation – the GX5296. This switching subsystem features sub-nanosecond edge-placement resolution and PMU per pin capabilities. It offers features and capabilities that have only been available previously in proprietary ATE systems.

Finally, the company will be showcasing the advanced ATEasy-Lite test executive and development software for OEM users and digital test subsystems. This is currently being deployed with J-Testr test systems manufactured by Eiger Design, Interlaken, Switzerland, and offers comprehensive support for all J-Testr bus-controlled devices.

Visit Marvin Test Solutions at Booth 4027



Visit JTAG Technologies at Booth 2032

Boundary-scan technology

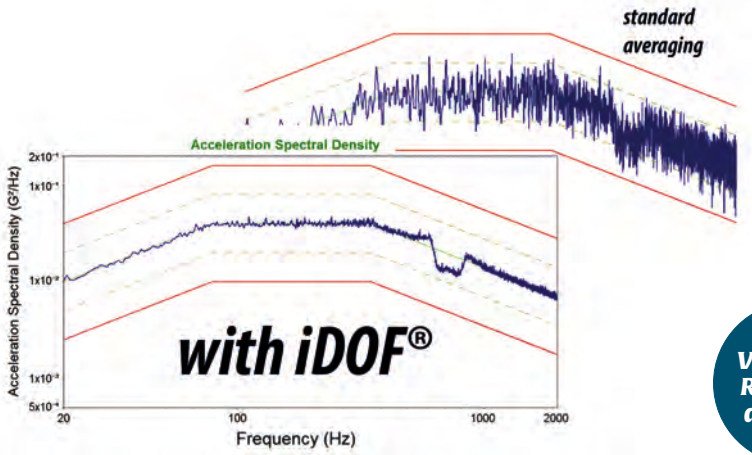
Boundary-scan company JTAG Technologies will be showcasing its extensive range of products in Pasadena, enabling visitors to see why its products can be found in design labs and factories in over 50 countries around the globe.

Attendees will be able to visit JTAG Technologies at its booth and find out how the company's low-volume, high-value circuits and systems, as found in military and aerospace systems, are ideally suited for testing using boundary-scan technology.

The company's products help achieve maximum fault coverage and provide pin-level diagnostics with in-system programming of PLD/CPLDs, FPGAs and flash memory devices.

JTAG's tools can be used in standalone configurations or integrated with other test setups such as functional test systems, in-circuit testers and flying probe testers.

Embedded test capabilities are supported. Furthermore, with the company's patented TAP Communicator technology, remote testing and programming via the target's communication interface can be supported independent of the distance between the tester and the target system.



Visit Vibration Research at Booth 3022

Random vibration test tool

Vibration Research will present iDOF, its latest patent-pending innovation designed to rapidly and accurately estimate the PSD of a random vibration test. This technique solves the age-old problem of being able to accurately display short-term frequency spectrum deviations.

Traditionally, presenting a smooth PSD estimate required long-term averaging, which can mask short-term, but highly important, deviations. On the other hand, presenting a rapidly updating display of changing conditions required minimizing the averaging, which resulted in a rough PSD estimate with a lot of variance. This variance can mask deviations and make it difficult to apply tight tolerances.

Now iDOF improves your PSD display by confidently removing estimation error from the PSD estimates, enabling the test engineer to see the PSD of the signal accurately and clearly in a short amount of time. This clarity of information enables the tester to quickly determine if a test is within tolerance, or to quickly abort if the actual vibration deviates above the allowed levels, thereby avoiding costly over-testing.

Stop by Vibration Research's booth at Aerospace Electrical Systems Expo for a hands-on demo to see clearly what this innovation can do for you.

Visit Thermo Fisher Scientific at Booth 2024

Lightning test simulator

Thermo Fisher Scientific is the world's leader in servicing science, and a supplier of ESD, EMC and TLP test equipment. It will be demonstrating its multifunction lightning test simulator (LTS) at the expo in May.

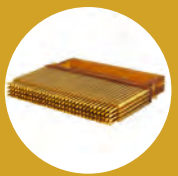
The company offers the most complete product line in the industry. Sold under the Thermo Scientific brand, testers are available to meet every test standard requirement.

The LTS is a modular test platform that delivers reliable, repeatable results that meet multiple avionics standards, including RTCA DO-160, Boeing, Airbus and EUROCAE.

The ECAT LTS performs pin injection, cable bundle and ground injection testing with single stroke, multiple stroke and multiple burst modes from one module, to match the performance standards of the aircraft's most critical systems.

Waveforms and functions are selected with the push of a button rather than by reconfiguring test equipment, moving around bulky generator boxes and wiring.

The ECAT LTS system features proven modular construction, so it can be upgraded in the field by the user or in the factory as requirements change. \\



AEROSPACE ELECTRICAL SYSTEMS EXPO

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May 24 - 26, 2016 | Pasadena, CA, USA

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new for 2016

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- ***New Attendees:*** 45% increase in attendees in 2015 and still growing!
- ***New Format:*** High-quality, free-of-charge speaker sessions
- ***New Exhibitors:*** 230+ companies showcasing products and technologies
- ***New Opportunities:*** Exhibit your capabilities and services and meet with pre-qualified decision makers

exhibiting companies include Jet Propulsion Laboratory and:

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Honeywell
BAE SYSTEMS INSPIRED WORK
Multi-Contact MC STÄUBLI GROUP
CRANE AEROSPACE & ELECTRONICS
DIT-MCO International
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Featuring **30+ presentations** over three days, the free-to-attend sessions in the expo hall will explore space engineering, electronics, aerospace manufacturing and design and test innovations.

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- **GE-hosted technology sessions featuring speakers from NASA**
- **Cubesat applications and opportunities**
- **Next-generation electrical systems for aircraft and spacecraft**
- **Using design thinking in aerospace systems innovation**

Entry to the free sessions is included within your **FREE** expo hall pass.

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Joe Marshall
Senior Principal Systems Engineer
BAE Systems

Speaking on: *Using High-Performance SpaceVPX Computing Modules for Next-Generation Onboard Processing*

ZODIAC AEROSPACE

Craig Damlo
Director of Innovation & Business Development
ZODIAC AEROSPACE

Speaking on: *Using Design Thinking in Aerospace Systems Innovation*

Glenair.

Dr Ronald Logan
Chief Technologist
Glenair

Speaking on: *Examining the Use of High-Speed Photonic Transceivers for Spacecraft Fiber-Optic Interconnects*

NHR
NH Research, Inc.

Martin Weiss
Product Director
NH Research

Speaking on: *Distributed Power Testing Approaches: Simplifying Testing and Achieving Better Results*

Averna

Jeffrey Halnon
Technical Lead, Systems Engineer
Averna

Speaking on: *Ensuring Flawless Performance for Mission-Critical PCBs*

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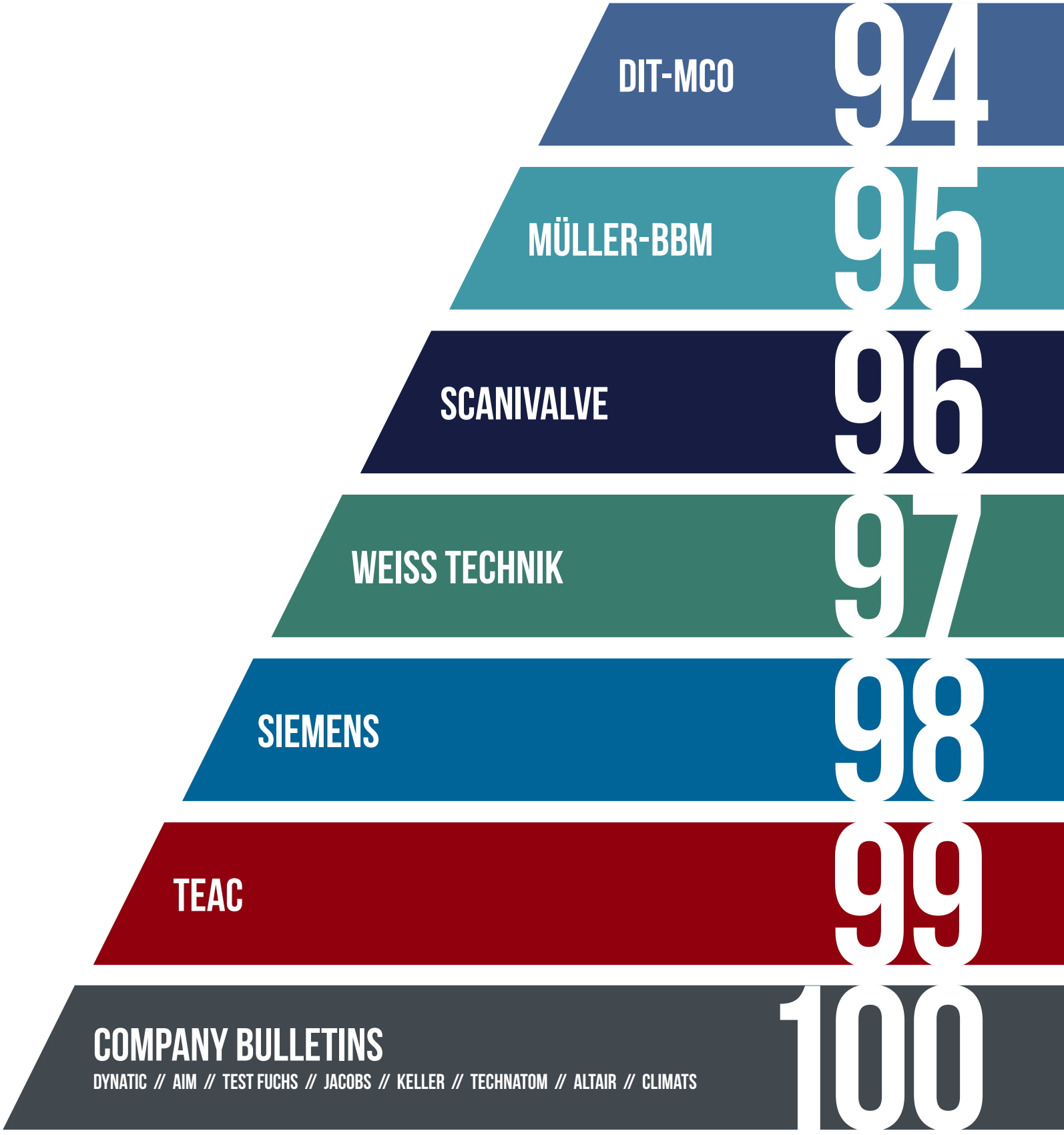
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SIMPLIFIED WIRE HARNESS TESTING FOR FIELD TECHNICIANS

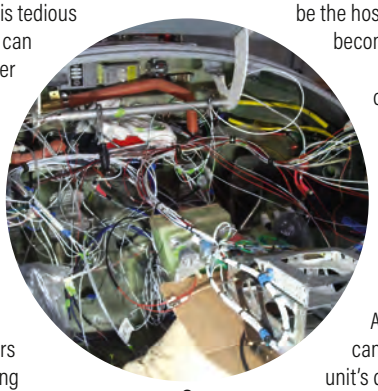
A cable and harness tester with ease of training and use, speedy operation, data logging and multi-unit expandability

1

Developers of the DIT-MCO HT-128 handheld cable and harness tester have designed a product to meet four key criteria: portability, ease-of-use, expandability and precision.

Today's maintenance, repair and overhaul (MRO) technicians use schematics and multimeters to perform field-level testing of wire harnesses. Basic tools that provide ease-of-use, universal accessibility and low training requirements, but simplicity that often has costly time trade-offs.

Testing installed harnesses normally needs at least two technicians, who switch focus between the schematics and each connector point across the entire wire harness being tested. This tedious and error-prone process can take up to five minutes per wire depending on the harness accessibility and complexity. For a 500-circuit wire harness, this 'ring-out' time can easily exceed 16 man-hours with the associated labor and overhead cost.



2

Since most multimeters do not have data recording capability, continuity measurements must be hand-logged or not recorded at all, leaving future doubt about the overall condition of the harness. While continuity testing may be straightforward, testing with a multimeter for shorts between each circuit can prove to be nearly impossible. Tracing crossed wires, probably the most common wiring error, can be tedious and difficult.

The DIT-MCO HT-128 addresses these issues by combining the portability and precision of a multimeter with the utility of a factory-level wire harness test system, automatically testing for opens, shorts and miswired connections. Each HT-128 handles 128 test points, exceeding the coverage requirements of most connectors. Additional testers can be added if more test points are required and up to eight units can be linked wirelessly, allowing operators to test multibranch harnesses quickly and easily.

Using snap-in adapters, technicians can configure multiple HT-128 units to interface with every connector across a wire harness. One MRO technician can then wirelessly link the HT-128s for complete wire harness test coverage. Any of the units can be the host, with all others becoming remotes.

A basic understanding of Microsoft Excel will enable users to program the HT-128 within minutes. A single technician can test a 500-circuit wire harness in less than three minutes. After testing, the results can be viewed on the unit's display or downloaded to a PC through the USB interface.

Any new testing approach has trade-offs. The HT-128 requires an initial investment in adapters to access wire harness connectors and requires programming, whereas ordinary ringing-out out of harnesses requires virtually no up-front investment.

However, the initial investment can pay off quickly when measured against the cost and time for manual testing and consequent equipment downtime.

Improving aircraft maintenance processes and reducing maintenance man-hours are two primary objectives for aviation maintenance. Fleet managers must avoid new wire harness testing solutions that are so complex they create ongoing training problems. As the complexity of technology increases, technicians either avoid adopting it or waste valuable time periodically retraining themselves in its use.

The HT-128 takes advantage of smartphone familiarity by using a touchscreen display and menu-driven user interface that lowers training time to less than one hour.

Viewed against the labor cost of manual ringing out, plus the much larger cost of an aircraft out of service, the initial investment makes economic sense. \\

1 // A connection cable can be configured with many snap-in adapters for testing harnesses

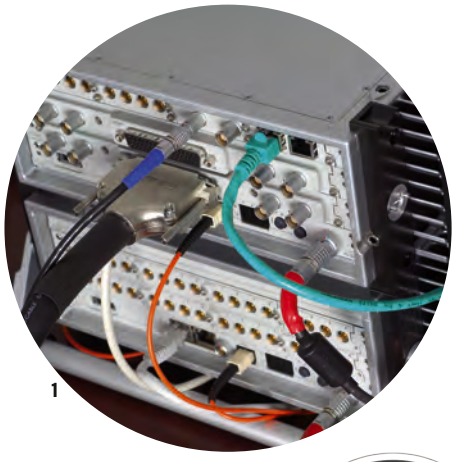
2 // A challenging, time-consuming wire tracing and testing environment

3 // The HT-128 can handle 128 test points or more with multiple units

3

SMART DATA ACQUISITION WORKFLOW

Using Müller-BBM's PAK MKII hardware, the PAK capture suite gives a smartphone or tablet full setup control over data acquisition tasks, including manual and condition-based start/stop triggers



1

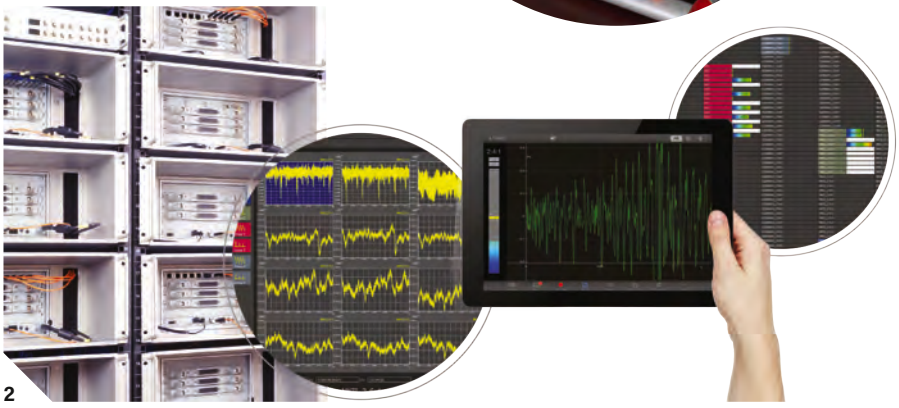
Test preparation can be a long and tedious process. Setting up a device under test (DUT), including the calibration of transducers and signal checks, often takes longer than the actual measurement. When performed correctly, improvements in the workflow not only save time but also reduce the stress and pressure that engineers face daily while using cost-effective means to perform the test.

In 2014 Müller-BBM Vibroakustik Systeme (Müller-BBM) released PAK Capture Suite, a product that covers the modern test engineer's needs for a simple yet reliable approach for data acquisition and the test workflow. Running on Müller-BBM's proven PAK MKII hardware platform, the PAK capture suite delivers the setup configuration for each test to the engineer's fingertips through a smart device such as iOS and Android phones and tablets.

Once the test setup has been completed, the data can be recorded by either a simple start/stop procedure or intelligent event-based triggering. The system continuously acquires data, simply waiting for processing commands (manual or conditional). All data is stored on an internal solid-state drive, adding safety through redundancy while minimizing the risk of data loss in the case of an unforeseen infrastructural fault, e.g. network interference or power loss. Data acquisition has never been easier and more secure.

The reduced workflow effort is reflected in the short time needed for the calibration and signal-quality checks. Single-user operation reduces the need for additional test personnel. Engineers are not required to run back and forth between the test cell and the control room, potentially hundreds of feet apart. Simple signal checks, tap tests and other testing methods can be performed in the proximity of the DUT with instant feedback on a tablet or a smartphone running the PAK capture app.

Once the test scenario has been properly configured, the measurement chain accurately calibrated and signal checks successfully performed, the test operator has the choice of two operational modes for data acquisition. A start/stop procedure is available in manual recording mode.



2

A more elegant test data capture can be done through the user-configurable, conditional start/stop triggers, which start and optionally can stop the recording when a required event occurs. For example, a trigger can be set to start a measurement when a bandpass level on a chosen channel is exceeded. When running a test on rotating machinery, rpm-based conditions can be set to start and stop the test in a given speed range. A combination of conditions can also be used to cover more sophisticated scenarios. Once the trigger conditions have been set, the system is ready for the event-based recording. This is a very useful feature when the front end has to be switched off and moved, but as soon as the system is powered up again it instantly changes into trigger mode, enabling immediate test operation or continuation without human interaction.

In all cases, a user-definable circular buffer can be used to record a continuous time history prior to the triggering event or manual test execution.

After the test has been performed, the operator can quickly check the data validity directly on the tablet or phone. The recording can be played back and listened to, to identify any issues prior to further analysis. If the data is considered valid, a simple yet effective PC-based tool can be used to retrieve the data for more in-depth analysis with PC-based software. The data is retrieved through either an Ethernet or an available wi-fi connection.

3

1 // PAK MKII hardware platform forms the front end for running the PAK Capture Suite

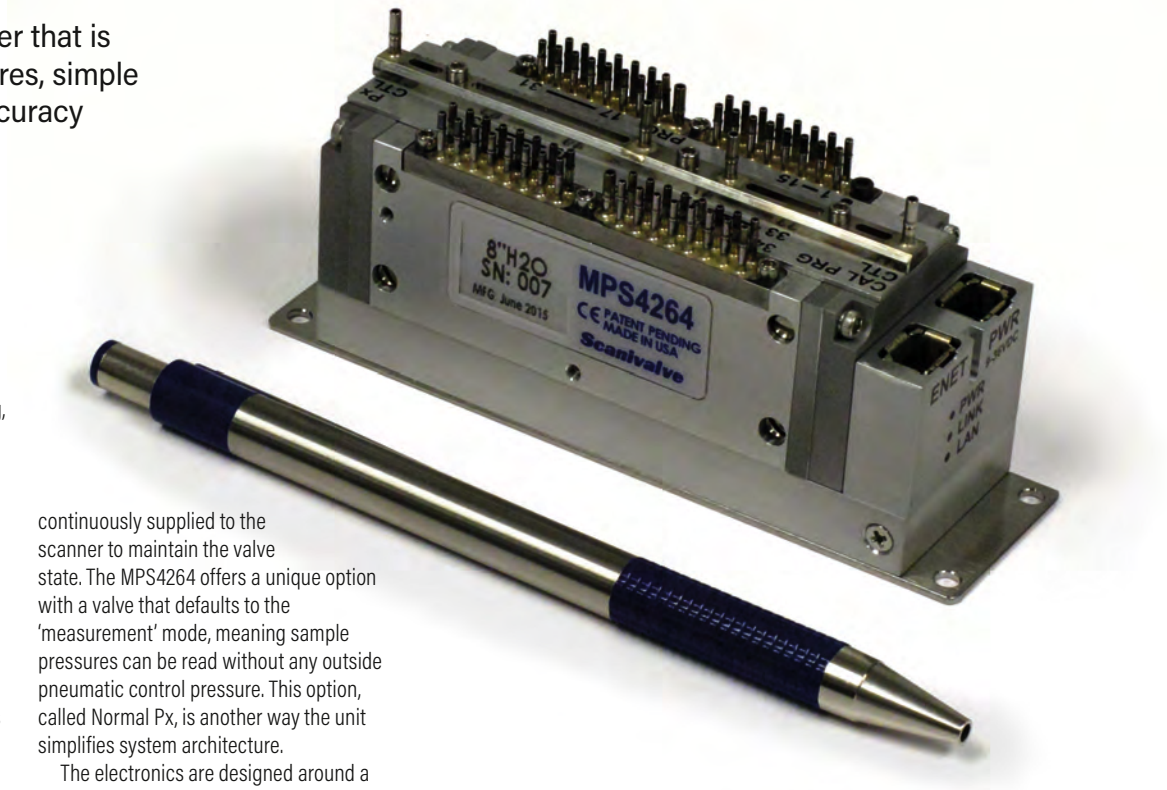
2 // The scope of the acquired channels viewable by the user on a tablet or PC

3 // With a tablet, users can calibrate sensors with the PAK Capture Suite

In addition to providing local data storage, each of the PAK MKII data acquisition front ends is capable of distributing the same information to one or more connected PCs for additional processing. For example, PAK 5.9, Müller-BBM's versatile data acquisition and analysis suite, is able to listen in to the data stream and record the calibrated feed in a completely independent procedure. The software solutions, all running on a standard PC, are individual streaming clients that process, record and analyze the data on demand. This enables versatile, scalable and application-specific testing environments that accelerate and simplify the overall workflow prior, during and after the test. \\

NEXT-GENERATION MINIATURE PRESSURE SCANNER

A miniature pressure scanner that is accurate, packed with features, simple to set up and has higher accuracy than previous products



// MPS4264, a 64-channel miniature pressure scanner offering engineering unit data directly through an Ethernet connection

The MPS4262, a next-generation miniature pressure scanner (MPS) developed by Scanivalve, has 64 pressure channels, TCP/IP Ethernet connectivity and other innovative features.

The market demands a scanner that is significantly smaller (28mm wide, 95mm long, 38mm high), faster, maintains higher accuracy, and is substantially simpler to integrate than any previous products. The MPS4264 meets all these requirements.

To achieve the highest accuracy sensor, Scanivalve engineers evaluated known causes of non-repeatability in piezoresistive pressure transducers. By designing a double isolation method of bonding the sensors to the base substrates (patent pending) they found it minimizes the mechanical influences of assembly and thermal expansion. This dramatically improves the stability and the resulting accuracy of the sensors.

The engineers also developed a proprietary means of maximizing sensor stability for span and offset. This technique (patent pending) of 'dynamic zero correction' greatly improved the sensor's stability over time and temperature. The increase in overall sensor stability reduces the need for zero-offset and span calibrations, resulting in significantly reduced testing interruptions and downtime.

Accuracy is further improved by increasing the sensor signal resolution. To accomplish this, 16 24bit A/D converters reside in the pressure scanner. This provides greater resolution than any other currently available pressure scanner, reduces signal noise by eliminating long cables and provides a simpler system architecture.

The MPS has an optimized internal pneumatic control valve. Existing pressure scanners require outside pneumatic pressure as a force to switch the valve logic. In most applications, this 'control pressure' must be continuously supplied to the scanner to maintain the valve state. The MPS4264 offers a unique option with a valve that defaults to the 'measurement' mode, meaning sample pressures can be read without any outside pneumatic control pressure. This option, called Normal Px, is another way the unit simplifies system architecture.

The electronics are designed around a high-performance digital signal processor (DSP) to produce 64-channel data in excess of 850Hz (readings per channel per second). 'Fast mode' can achieve rates of 2,500Hz.

The onboard flash memory holds the pressure-temperature matrix that converts raw analog/digital counts to precise engineering unit data over a wide range of temperatures. The power conditioning circuits allow for a wide power supply range and minimize module self-heating.

Communication to the MPS is through a miniature Ethernet connection that supports an impressive array of protocols. The user can connect using a web browser and this graphical interface enables the operator to change settings, view data on the screen, and save binary or ASCII data to a file on the host machine with a click of a mouse.

Data can also be streamed to an FTP server. ASCII commands may be issued via a Telnet client connected to the MPS Telnet server. A multicast protocol is employed that allows multiple MPS devices to all start scanning in concert with a command to a single device. The unit also supports a binary server that is optimized for a LabVIEW interface. Example LabVIEW VIs are available.

The MPS uses the latest Precision Time Protocol (IEEE-1588v2) standard to time-correlate data, which allows any 1588 slave device to synchronize its time to sub-microsecond accuracy without the use of external trigger signals. PTP can synchronize any physical measurement device or a computer to a common Grand Master time.

The MPS4264 effectively simplifies and improves every aspect of high-speed, multipoint pressure measurement. Whether using a single 64-channel module or a 1,000-plus channel system, the architecture is simpler, smaller, faster and easier to set up. \\

ICING TEST CHAMBERS

Climate chambers provide flexible testing of critical equipment through environmental simulation

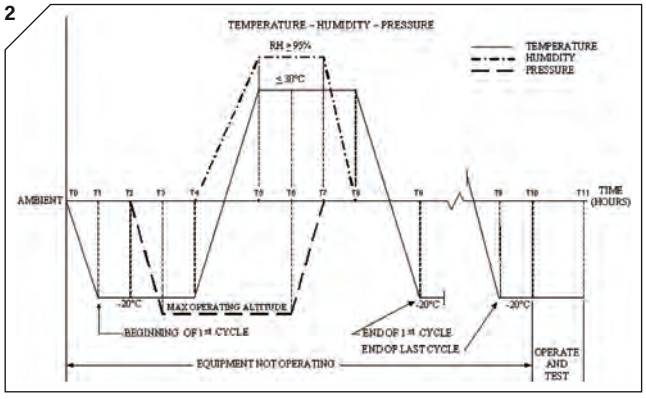
1 // A Weiss Technik specialized climate chamber provides combinations of altitude, temperature and humidity for critical equipment

For obvious safety reasons, determining the effect of temperature, altitude and humidity on critical equipment is of utmost importance. To be certified, aircraft systems and equipment, depending on the nature of the application - civil or military, must undergo design and qualification tests as per DO-160 standard, Environmental Conditions and Test Procedures for Airborne Equipment, or the US military test method standard MIL-STD-810. These norms describe combined testing procedures that have to be strictly followed to ensure the proper functioning of the specimen in any environmental conditions it could potentially encounter during its lifetime. Simulating these conditions on earth requires special altitude chambers from Weiss Technik.

PRIMES, the Platform for Research on power Electronic Integration and Management of Energy and Storage devices, part of the ENIT engineering school in France, acquired such a chamber to perform severe CTAH (combined temperature, altitude, humidity) test cycles on electronic power components and assemblies.

The CTAH chamber was initially designed for the CEPIA project (Advanced Integration for Power Electronics Converter), an initiative to develop a comprehensive approach to the predictive reliability issue for power assemblies used in embedded applications. "Our industrial partners, among them Alstom Transport and Technofan, had to ensure and prove the reliability of their electronic components for the whole range of possible environments they might face when embedded in airplanes or trains" says Dr Paul-Etienne Vidal, researcher and lecturer at ENIT in France.

The chamber, integrated in a larger test bench, allowed testing and ageing of equipment such as power converters and avionic integrated systems.



2 // A sample of the cycle described in the DO-160 standard for testing beginning at -20°C, rising to 95% humidity (around 30°C) before falling again. The cycle is repeated 25 times before testing begins

José Ferrao, PRIMES operations director, said, "Now that the CEPIA project is finished, and as the chamber is still fully operational, we are planning to make it available for industrial projects. We are even thinking about upgrading the chamber's performances to respond to the highest technical requirements of our customers," which may include a major European aircraft manufacturer to test innovative sensors they are developing.

The test cycle for power converters and avionic integrated systems starts by stabilizing equipment at -20°C. This temperature is maintained while chamber pressure is decreased to simulate the operating altitude for the standard flight conditions required for the specimen. Then, temperature is decreased while relative humidity is maintained above 95%.

This phase simulates conditions similar to those encountered when flying through warm, humid cumulonimbus clouds which instantly condense and freeze on cold equipment. Pressure and relative humidity levels are then brought back to room ambient, while temperature is maintained during a sufficient period of time to melt all frost. The cycle is repeated 25 times before finally starting specimen operation and testing.

Weiss Technik France's engineers solved several technical issues such as controlling temperatures at low pressures (91mbar, as per DO-160 standard) where convection is not optimally efficient due to the lack of air and using radiation panels would have significantly increased the chamber's cost.

The second challenge is producing high relative humidity at low pressure. This was solved with a specific mechanical design and required hours of tuning and testing PID controllers before commissioning. Customer training was also mandatory to ensure the longest service life of the chamber.

Weiss Technik supplies an extensive range of aerospace testing equipment covering many applications, from standard and icing altitude chambers, to kerosene conditioning units and space simulators. \\

ROTORCRAFT TESTING

Analyzing the noise and vibration performance of a helicopter

1

Look at a noisy machine and imagine wearing futuristic acoustic glasses and seeing a colored picture highlighting acoustic hot spots. Acoustic beamforming can actually do this by using an array of microphones to capture sound from a number of locations. An LMS star-shaped array (a few meters from the helicopter) and an LMS SCADAS measurement system can capture the sound pressure at each microphone within a few seconds.

This data is processed with LMS Test.Lab software to analyze time delays between the microphones and, in a few minutes, the dominant noise sources are located on the helicopter image with their corresponding acoustic power.

Identifying and ranking acoustic sources drastically improves noise engineering efficiency and provides guidance for possible noise reduction measures.

Analyzing noise inside the cabin is more challenging. When performed during flight, the noise measurement has to provide results in a short time to minimize flight testing costs and capture potential transient noise sources. Beamforming best addresses these challenges. This application uses a spherical array with microphones distributed on its surface. It captures noise sources in the entire cabin simultaneously and avoids the lengthy measurements typically necessary with conventional intensity-based measurement tools.

Sound source localization results can be analyzed immediately by an in-cabin operator. Autonomous measurement can also be achieved for an entire flight, with later analysis to identify localized noise sources.

Vibration inside a helicopter can be harsh and cause potential fatigue failures of sensitive equipment. The cockpit VHF radio is exposed to high tonal and broadband vibration excitations and should be properly designed and mounted to withstand the long-term fatigue that might cause damage during its life.

2

The 'mission synthesis' or 'test tailoring' technique is often used to calculate the equivalent short-duration excitation signal, which can be used for qualification of a product. This signal is intended to be representative enough to avoid over-testing, but sufficiently severe to ensure that the products that survive the test will also do so in the real world.

Mission synthesis has several steps implemented in the software LMS Test.Lab. First step is the mission definition; that is, the definition and duration of the environments that the VHF radio is going to encounter during its life. The second step is to characterize the vibrations related to each of these environments. Accelerometers placed at the attachment points of the radio in the cockpit and connected to an LMS SCADAS data acquisition system record the vibration levels for each event.

Data is analyzed for damage potential, which creates a 'damage equivalence model' that characterizes how damaging for the radio each of the environments is in terms of maximum response spectrum (MRS) and fatigue damage spectrum (FDS).

The final step in the process combines the damage spectra of all the environments and derives a short-duration excitation signal that is representative of the fatigue damage that will be experienced by the radio through its entire life. In tests, it has been found that the vibration excitation at the blade passing frequency (BPF) of the main rotor is particularly damaging for the radio due to a high excitation level, but also due to the presence of a structural resonance of the attachment system.

This technology can be used to develop specific qualification spectra for test items, which need to be qualified against vibration environments. It is an alternative for (often overly conservative) generic spectra coming from standards. \\

3

1 // Exterior sound source localization on the ground using an LMS star-shaped array to record levels

2 // In-flight noise and vibration measurement using an LMS 3D Solid Sphere Array

3 // Exterior sound sources: blades, exhaust and cooling systems sources are localized and quantified (Sound power at 5kHz with 10dB dynamic range)

DEPENDABLE DATA RECORDING FOR AEROSPACE TESTING

An instrument data recorder for failsafe, reliable backups featuring multichannel capabilities, storage to RDX server-grade disks, and a high dynamic range

1

The WX-7000 series of instrument data recorders is designed to provide multichannel, high-bandwidth recording solutions for the testing and monitoring requirements of aerospace, defense and industrial acoustics/vibration-based applications. TEAC has been providing data recorders for the aerospace testing market since the reel-to-reel tape era and continues to develop and provide machines that use the latest technologies.

In the past, PC storage capacities were small and data transfer rates were slow. In aerospace testing many signals are recorded at high sampling rates, but earlier computers did not have high enough performance levels to record the volumes of data. Instrument data recorders were therefore the main data acquisition system and the files created were analyzed on a computer after the tests. Now the PC is the front-end of the acquisition system, analyzing the data in real time, while the instrumentation data recorder has become the backup system.

The TEAC WX-7000 series has many features to provide reliable data recording with protection from catastrophic data loss, including a wide dynamic range and high resolution. A unit can have 128 channels and synchronization between two units enables 256 channels to be recorded. The WX-7000 offers a longer recording time than is possible with a tape recorder.

Connection to sensors is eased by support for the TEDS (transducer electronic data sheet) standard, while data is stored on a reliable recording medium using an RDX server-grade removable disk. The operational interface is intuitive and uses a 3.5in color LCD for user-friendly operation.

To ensure failsafe recording, the WX-7000 closes the data file after every minute while recording. Even if an unexpected or mistaken power outage occurs, the recorded data is saved from the minute before the power loss and is available for playback.

TEAC WX-7000 data recorders have been used for developing the Japanese LE-X rocket engine. Vibration testing and analysis is one of the most important parts of developing any rocket engine. If levels exceed certain thresholds, vibrations might lead to decreased engine efficiency and damage. The test data collected can be used to increase the reliability and durability of components, but these tests have to be performed under the same conditions as encountered in flight, such as extremely low temperatures, high nozzle pressures and high rotation forces when the rocket is launched. The large amount of time and cost involved in this kind of testing requires dependable and secure data recording.

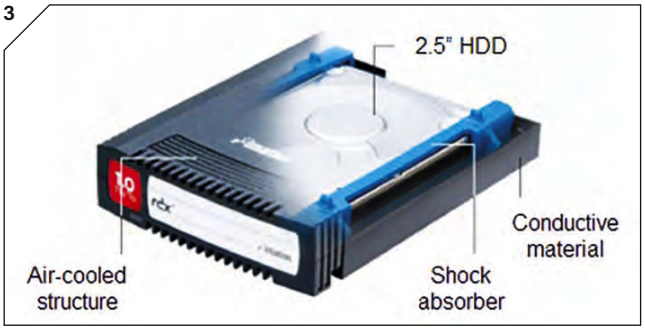
Turbomachinery and jet engine manufacturers use the data recorders when testing for rotational balance to lessen shaft vibration, and they are also used during inspections. These applications employ the WX-7000 series with a PC front-end system running real-time analysis software. The recorded raw data is transferred to a PC via gigabit Ethernet in real time and to the WX-7000 to ensure safe data backup. \\

2

1 // The WX-7000 main unit, shown with 16 channels, is configurable to 128 channels using eight 16-channel input/output cards

2 // The interface is intuitive and uses a 3.5in color LCD display

3



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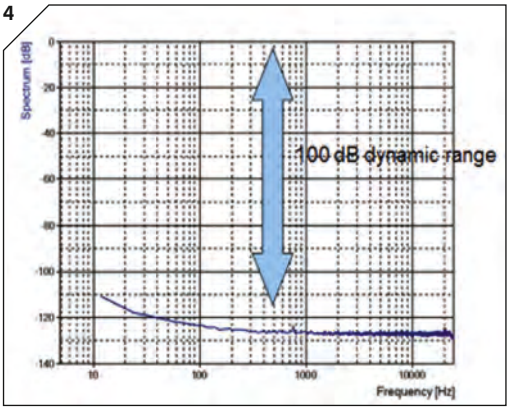

3 // Data is stored on an RDX server-grade removable disk

4 // The dynamic range of the WX-7000 is over 100dB

RUGGED, MODULAR, STANDALONE DATA ACQUISITION SOLUTION

Data acquisition systems are relied upon heavily in the aerospace industry, from the design through to the final production stages. Yet those instruments often introduce many challenges to the testing cycle, due to the need for cumbersome wiring or an inability to function correctly during transportation or following impact.

The Allegro Mercu data acquisition system from Dynatic Solutions eliminates these issues by offering several features that are critical to success in countless common testing processes in the aerospace sector.

The Mercu's modular acquisition slices offer up to 128kHz sampling rate per channel, while also allowing for ample interchangeable input options (IEPE, charge, strain) that can be tailored according to application or project specific demands.

Additionally, the instrument's 2 x 2in chassis is designed to withstand up to 500*g*, making it optimal for use in tests associated with extreme blast, shock or vibration, as well as minimizing space constraints. The built-in high-capacity lithium battery and 8Gb flash memory, both expandable upon request, complement these features by enabling the Mercu to work as a completely standalone data acquisition system. \\

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DYNATIC SOLUTIONS

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NEW SAFER CREW ESCAPE SYSTEM FOR TEST PILOTS

New aircraft development involves rigorous testing – both on the ground and in the air. At the sharp end are test pilots, who routinely take high risks to verify that all the aircraft technology works as intended. Aircraft under test often undergo testing to the extremes of their performance envelope. It is during these critical phases of flight that test pilots are most at risk.

It is essential that test pilots can exit the aircraft quickly and safely during a critical maneuver should control be lost. In traditional escape systems, pilot seats were pulled by cable into the exit position. This was not considered safe enough. A new business jet manufacturer enlisted TEST-FUCHS engineers to design a new crew escape system for use during testing of their aircraft.

The resulting design greatly increases escape safety for test pilots. If a loss of control occurs during a test flight, the pilot's seat is pulled to the ideal escape position with a hydraulic system, enabling easy and rapid exit from the aircraft. Safety devices guarantee that unintentional operation does not occur. Testing has already proved the new system to be more reliable than cable-operated versions.

Other European aircraft manufacturers have shown substantial interest, and TEST-FUCHS has a second contract to design and produce a two-seat retraction system. \\

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TEST-FUCHS

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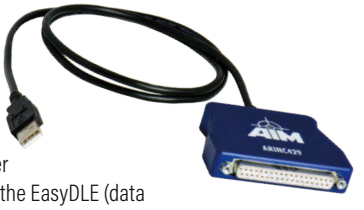
EASY DATA LOADING



AIM has introduced a new solution for data loading of airborne computer systems using the ARINC615-3/4 protocol over ARINC429. The baseline is the EasyDLE (data loading engine), which is available as a software library for Windows and Linux operating systems.

Standard AIM ARINC429 interface devices, which come in a wide variety of form factors, support the EasyDLE library. The library is able to simulate multiple data loader instances at the same time and can handle concurrent load processing on different ARINC615 buses (ARINC429 Tx/Rx pairs).

Each bus can be configured with a unique set of response timeouts for the various protocol handling stages. Users can configure the protocol parameters, such as the number of retries and the timeout values. This provides a high level of flexibility and adaptation of the EasyDLE to match that of any unit to be loaded.

Users are free to write their own loader applications in C/C++ or by using the library's object-oriented Python programming interface.

AIM has extended its PBA.pro databus test and analysis software tool to support the EasyDLE, enabling users to quickly set up, configure and perform 615-3/4 data loading via a GUI. The PBA.pro extension is attached to the PBA.pro ARINC429 component, which also supports engineers in investigating loading failures by capturing, decoding and visualizing the ARINC615 and resulting ARINC429 bus traffic. A standalone 615-3/4 data loader application is also available.

AIM has offices in the UK and the USA and its main design and manufacturing facilities are in Freiburg, Germany. \\

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AIM

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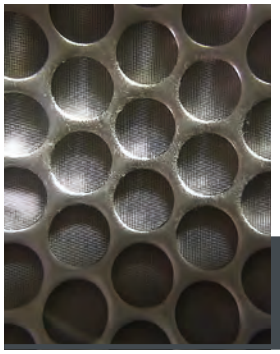
WIND TUNNEL TREATMENT

US aircraft engine companies have used the 9x15 Low Speed Wind Tunnel (LSWT) at NASA Glenn Research Center (GRC) for testing propulsion systems since the 1980s. More stringent noise standards and more efficient engines mean lower background noise levels are needed. In aeroacoustic wind tunnels with low background noise levels, natural boundary layer noise from the flow along the test section surfaces is a limiting factor. In 2012 Jacobs performed an evaluation of the LSWT to develop acoustic solutions to reduce the background noise in the test section. Jacobs determined that the overall sound pressure was dominated by 'self-noise'.



The recommended modifications reduced boundary layer self-noise by improving the test section surface. The acoustic treatment is stainless steel wire cloth bonded to stainless steel perforated plate. The surface Jacobs developed is acoustically transparent to backing absorption material and aerodynamically smooth. The generation of boundary layer growth and self-noise are minimized, reducing the impact on aerodynamic flow quality and background noise levels. \\

INGENIOUS SENSOR DESIGN

KELLER AG is setting new standards for pressure measurement with its M5 series. Highly dynamic pressure measurements require a direct connection between the sensor and the measured medium. The M5 series is a micro-mechanical solution (with an M5 thread) without a media isolation diaphragm, its associated damping effect, capillary tubing, sealants or adhesives to fit in tight installation spaces.

A silicon sensor is secured flush to the front of the pressure connection, enabling dynamic measurements from 0-50kHz and giving excellent decoupling of mounting forces and structure-borne vibration. The M5 has wide compatibility and durability from anti-oxidation coatings. Measurement ranges (absolute) are available for 3 bar, 10 bar and 30 bar (with five times overprotection). Operation is from -40°C to +180°C with a total error band of ±1% (i.e. including temperature errors).

The sensor's analog signal is adjusted in real time to retain its dynamic range, with microprocessor electronics and amplified to 0-10V. The remote signal converter electronics enclosures operate from -40°C to +125°C.

The sensor and signal converter are calibrated at the factory to meet customer-specific needs. \\

REUSABLE STRAIN SENSOR

Think modal analysis with a strain sensor can't be done? Think again! PCB Piezotronics' unique Model 740B02 reusable Piezoelectric ICP Strain Sensor has unparalleled 0.0006με resolution with an amplified ±5V output and a 100kHz upper frequency response. Test engineers can now verify high-stress locations and modes with micro-excitation, without risk of structural damage from artificially high shaker forces, ensuring a linear response. At 0.5g, this sensor is far lighter than typical high-sensitivity accelerometers, thus reducing localized mass loading for thin, lightweight test articles. It installs in one minute, can be removed in 10 seconds and can be reused multiple times just like an ICP accelerometer.

PCB's Model 740B02 dynamic strain sensors differ from resistive strain gauges in two ways. First, they can be mounted and reused using a quick-bonding cyanoacrylate gel, which makes the bonding procedure much faster and more compatible with the instrumentation timings and efforts that are required for a GVT test campaign. Nonetheless proper mounting is critical to good sensor performance. As with traditional strain gauges all surfaces must be clean, dry and free from oil before applying the adhesive. Since the 740B02 strain sensor can be reused multiple times, the lifetime cost and labor cost for each installation is dramatically reduced.

The second difference from resistive strain gauges is that the 740B02 piezoelectric strain sensor combines a quartz sensing element and a built-in microelectronic ICP signal amplifier within its titanium housing. The calibration of the strain sensor is not performed on-site as with foil gauges, but in a controlled metrology lab where the sensors are dynamically calibrated using a cantilever beam excited to its first resonant mode. Each sensor is mounted to the beam and calibrated using resistive foil reference gauges. \\

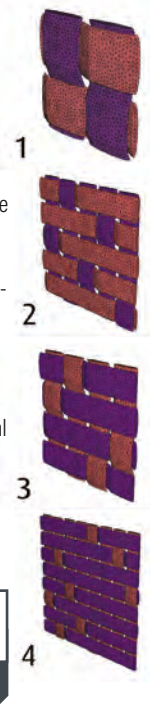
MATERIALS DESIGN & ANALYSIS

Many materials are composed of more than one constituent. While modeling these materials as homogeneous material systems works for predicting stiffness and stability, it is not sufficient to predict strength, damage onset and damage progression. The issue is that damage occurs at the micro level, usually at the interface of the distinct materials or in the weakest material, and then propagates in a complicated fashion that is difficult to predict. Many of these materials are now in use on airplanes, which has prompted the need to characterize these materials properly and understand how they will perform in the full structure.

Altair Engineering's Multiscale Designer provides a complete environment for the design and analysis of engineered parts from heterogeneous materials including continuous fiber composites, long and short chopped fiber composites, metals, reinforced concrete, soil, bones, honeycomb and others.

Multiscale Designer uses a systematic model reduction technology that reduces complex unit cells, having hundreds of thousands of finite elements, to a manageable number of deformation modes and state variables. This enables us to model what is happening at the micro-scale within a macro-scale model with little impact on total run time. Applications include material design, material allowables generation, coupon and component ultimate failure simulation, fatigue, fracture, impact, crash, environmental degradation, and multiphysics simulations.

Multiscale Designer contains plug-ins to macro-scale commercial FEA solvers that provide practical validated multiscale modeling capabilities. \\



NON-DESTRUCTIVE AERO INSPECTION

Spanish engineering company Tecnatom has opened its technology to the aerospace industry by providing NDT solutions for the life of aero-components – inspection cells for quality assurance during manufacturing and NDT equipment for maintenance, repair and overhaul activities.

At JEC WORLD 2016 Tecnatom will present its wide range of inspection equipment, including automated-robotized systems and in-house hardware/software technology, which enables the integration of the complete inspection process – probe programming, trajectories generation, 3D simulation, acquisition, evaluation, reporting and control – in a unified environment that can be operated by a single person.

The systems apply several ultrasonic techniques: through transmission ultrasonic, and conventional or phased array technology. Tecnatom also has expertise in laser ultrasonic (LUS) technology. TecnaLUS, Europe's first industrial LUS inspection system for aerospace production, is a non-destructive inspection system based on laser ultrasonics and Tecnatom robotic technology for small and complex-shaped aeronautical components. Other contactless techniques, such as air coupling and dry-probes, are already included in some of the most recent developments. Complementary to the UT techniques, thermography and artificial vision sensors are also implemented in some systems.

M2M, one of the group's French subsidiaries, will also present the new Multi2000 software version 8.0, released last October, and compatible with 64-bit operating systems up to Windows 8. It provides high-speed composite inspection. An improvement of the inspection speed up to 400mm/s has been obtained with a high pixel resolution of 0.5mm x 0.5mm including full Ascan storage. \\

ENVIRONMENTAL STRESS SCREENING

To simulate the environmental stresses that aircraft components need to survive, a wide temperature range is required and the rate of speed change (average or linear) must occur very rapidly.

Electronic components might be very sensitive to humidity migration, which is why any environmental chamber must ensure a perfect control of humidity to prevent damage to the components under test.

To support aerospace testing applications, Climats designs standard and customized chambers, enabling engineers to set up and achieve demanding test standard profiles with a high accuracy (+/-0.1°C on a soak cycle) and very high traceability with measurement sampling every second.

Model 585VRT 70/22 is a good example of the high-performance solutions manufactured by Climats. Designed for a major aircraft manufacturer, this chamber reaches an average temperature change speed of 20°C/min from +100°C down to -55°C while loaded with 100kg of electronics boards that can generate 1kW of heat dissipation load.

The embedded control and HMI (human machine interface) software suite, Spirale 3, is a multi-tasking Windows-based system displayed on a 15in touchscreen. This operates real-time humidity measurements managing the air dryer, while communicating with the customer's test bench.

With these Climats ESS chambers, the aircraft manufacturer can qualify a complete electronics system, fulfilling the desired standards and achieving the highest quality levels for testing. \\

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From first to final flight

The Boeing 727 was the most successful jetliner of the modern era, introducing millions to air travel. After a long service life, retirement and restoration, the first test airplane has just made its final flight

When the first 727-100 (registration N7001U) rolled out of the Boeing factory on November 27, 1962, the airplane maker had just 80 pre-orders for the aircraft (40 each from United Airlines and Eastern Air Lines) – well below the estimated 200 needed for break-even and the 250 it hoped would be profitable. The financial risk to the company for a new jetliner was great, as start-up and production costs for the 707 were still burdensome.

The airlines were not clear about their needs. Some wanted four engines, others suggested a twin-jet configuration, others were happy to continue with prop airplanes. However, in December 1960 the three-engine 727 design was announced, with N7001U making its inaugural test flight on February 9, 1963, and continuing in the testing program until its delivery to United Airlines in October 1964. The first of 1,832 Boeing 727 Trijets, N7001U remained with United for its entire service life – 27 years – accumulating 64,495 flight hours and 48,060 landings. The airline paid US$4.4m for its first 727, which generated revenues of more than US$300m while carrying an estimated three million passengers.

Delivering the first test aircraft for revenue service to a 'kick-off' customer, rather than keeping it for further testing, was not repeated until the introduction of the Boeing 777.

In 1984, Bob Bogash, a recently retired Boeing employee, was instrumental in getting United Airlines to donate the airplane for preservation on its retirement. In 1991 it was flown to and parked at Paine Field in Everett, Washington, USA, pending 'something' happening.

After 25 years in essentially the same spot, the process of bringing the airplane back to life was coordinated by Bogash, now 727 prototype project manager (volunteer) for the Museum of Flight (MOF) in Seattle at Boeing Field.

An intensive restoration kicked off on January 8, 2016, with the MOF using a professional 'aircraft on ground' maintenance contractor, other professionals and a host of volunteers. Although several days later the airplane was brought inside a hangar for the first time in over a quarter of a century for some heavy repairs, much of the other repair work took place outdoors in the winter.

Safety was the key criteria for the 727 prototype's restoration and final flight to Boeing Field. The challenge was to find and replace the parts that had been salvaged for spares by United after it donated the aircraft. The list was extensive. Federal Express provided three Pratt & Whitney JT8D engines from its spares. The parcel carrier had received the last Trijet built by Boeing in 1984 and had its own fleet.

At the end of February restoration was complete. An FAA inspection gave a one-time approval to fly. On March 2, 2016, N7001U made its 17-minute final flight to Boeing Field. The first ever 727-100 will now reside inside the new covered pavilion, along with the first 737-100, the first 747-100, the third Boeing 787-8 and a Concorde. \\

(Photo: Boeing)

(Photo: Museum of Flight)

FEB 9,1963
First flight

727-100
Model number

108FT
Span

133FT 2IN
Length

170,000 LB
Gross weight

632MPH
Top speed

570MPH
Cruising speed

3,110 MILES
Range at full load

36,100FT
Ceiling

14,000 LBF
Thrust of each of the three P&W engines

131
Passengers – one class maximum

Read more on the 727-100's restoration blog:
WWW.RBOGASH.COM/727/REFURB/REFURB_STATUS.HTML

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ACOUSTOGRAPHY ULTRASONIC COMPOSITE INSPECTION

Acoustography is a full field, ultrasonic inspection technique similar to radiography, but without the hazard. At the heart of the Acoustography method is a novel two-dimensional (2-D) super high-resolution proprietary ultrasonic area detector, called an Acousto-optic (AO) Sensor that converts ultrasounds directly into a visual image, which can then be electronically captured using a digital camera, allowing for digital archiving and image enhancements.

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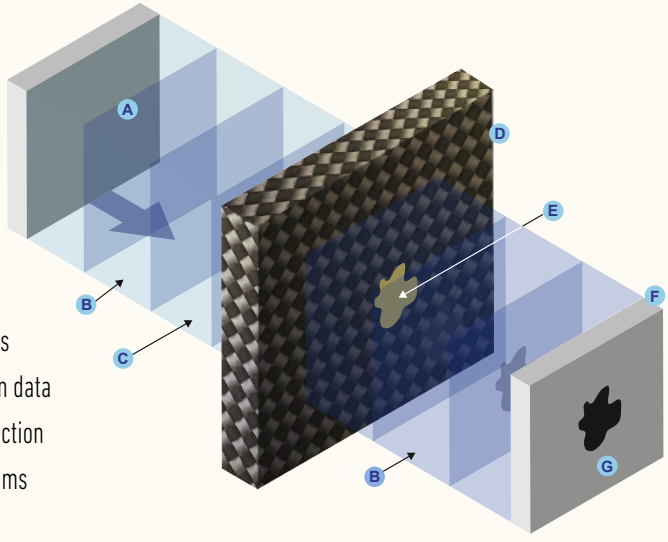
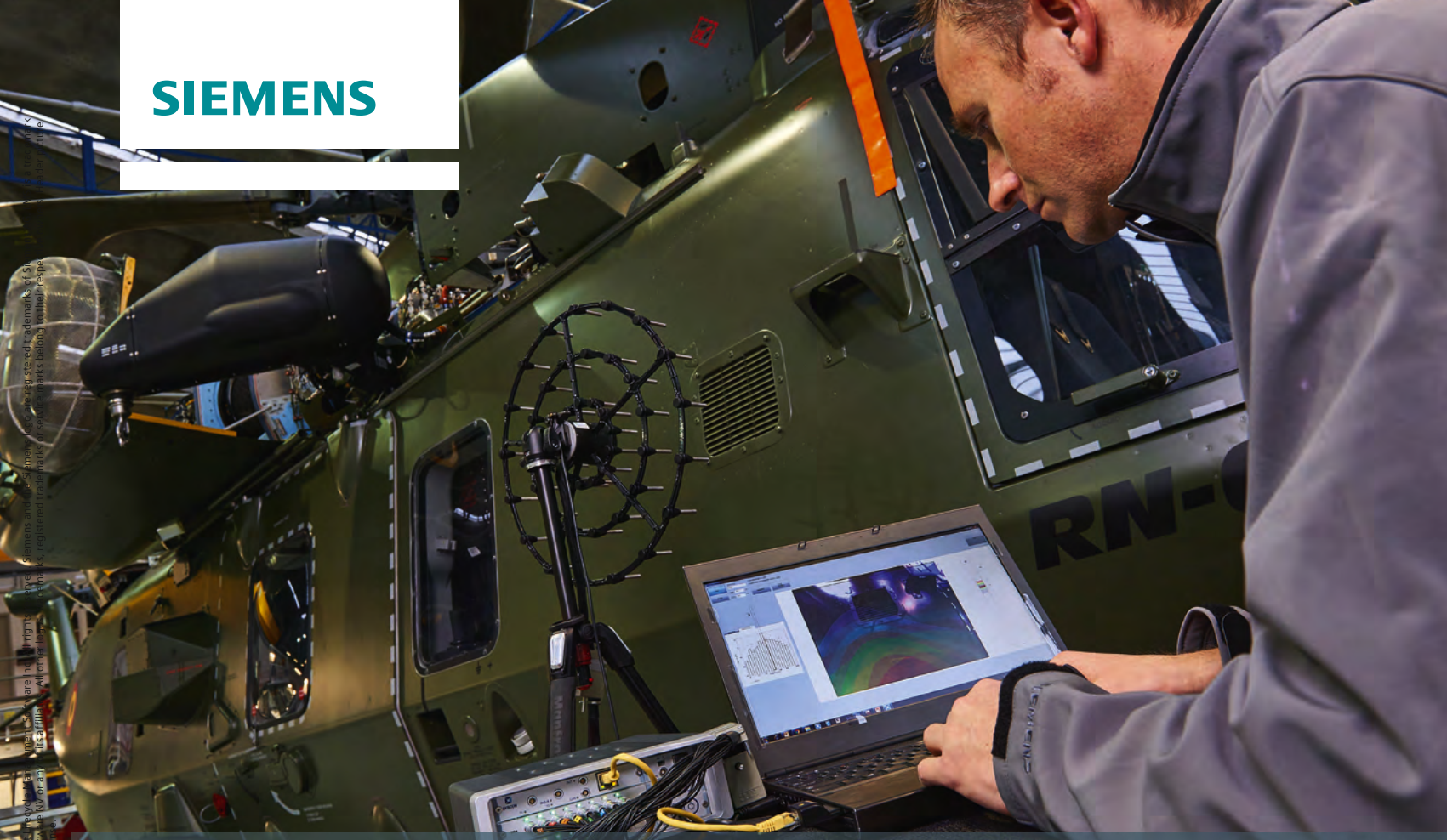
- Practical method for Complex-geometry Part Inspection
- Upgradable to existing UT C-scan Immersion Systems
- 3"x3" up to 12"x12" Area Coverage



A. Sound Source | **B.** Acoustic Coupling Medium | **C.** Ultrasonic Wave Fronts
D. Specimen | **E.** Imbedded Flaw | **F.** AO Sensor | **G.** Flaw is Revealed

Inspection time of less than 5 sec with image processing; only one shot required with 5"x5" FOV; Red circle shows defect in the tight radius

SIEMENS



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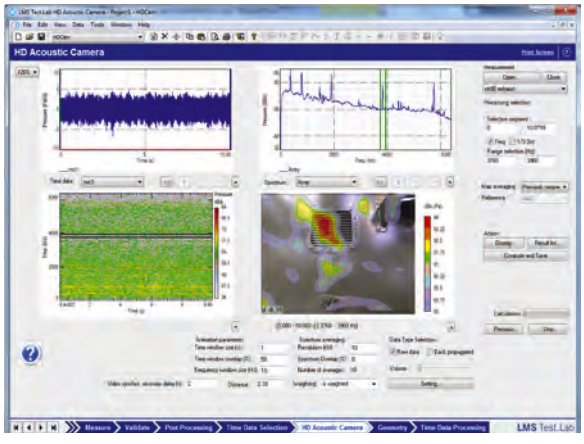

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