SEPTEMBER 2017

Aerospace TESTING INTERNATIONAL

Inside this issue

Action stations! A400M on test

Exclusive: Expanding and proving A400M capability with the RAF's 206 (Reserve) Heavy Aircraft Test and Evaluation Squadron

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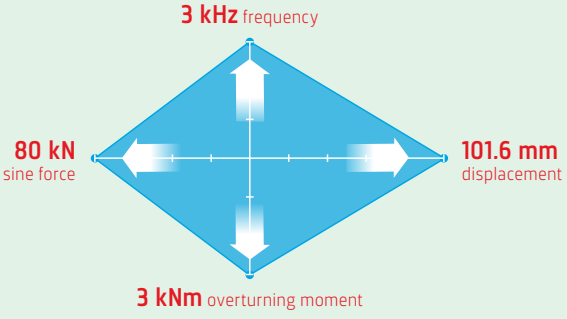

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BEYOND MEASURE

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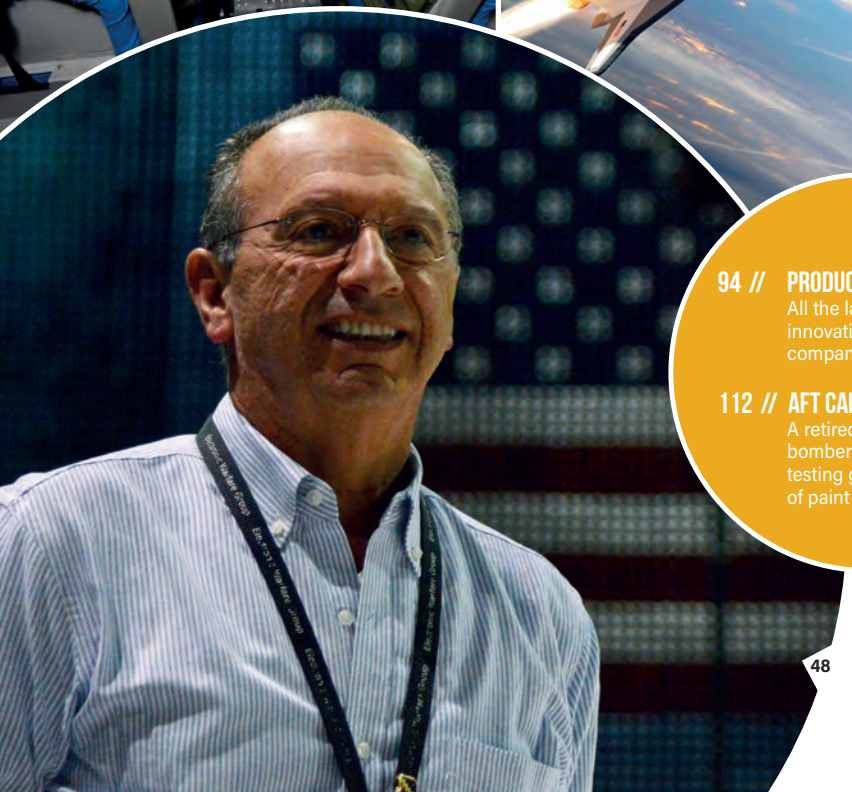

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Global briefing

Inside this issue

// No more 'chalk and talk'

I was always easily bored at school, particularly during maths or physics, when time seemed to slow to a near standstill as I tried in vain to make sense of the obscure equations and formulae on the blackboard. I wasn't alone in my struggle to remain focused, and so from time to time the teacher would suggest going outdoors to continue the lesson, and this simple change really helped to keep us engaged and switched on.

A more stimulating and fun classroom environment can work wonders, and I remember in my youth hearing of schools that had realized this and invested in novelty classrooms constructed from old buses or even aircraft. However, I can't ever recall hearing of an actual flying classroom – but that's what student flight test pilots and engineers can look forward to when enrolling at an SETP-recognized test pilot school, two of which are featured in our exclusive report on page 22.

Vocational training is very different to an academic education, with far greater emphasis placed on real-world skills, but until quite recently it was surprising just how much time a student flight test pilot or engineer would spend in a traditional classroom environment, sat firmly on the ground.

"We're making improvements in the way that we teach," says Nick Lay, operations director, Air Training Transformation, QinetiQ, which oversees the Empire Test Pilots' School, when we spoke to him about changing student and industry needs. "We are now compliant with the Defence Systems Approach to Training, which sets out modern teaching methodologies. We are also updating the way that we deliver training so that we meet the very latest standards and doctrines. When I was at school, it was all 'chalk and talk' – but we need a very different approach for the next generation of test aircrew. They need more interactivity in the way that they learn and they need easily digestible material – how I would have loved to have that when I was younger – and to be coached and mentored along the way."

Both of the schools we spoke to have invested heavily in new aircraft to ensure students are able to gain a more contemporary experience of what they can expect once they graduate. And it's not just aircraft, it's also the equipment on board that is being modernized.

"We've just outfitted one of our Avro RJs with new advanced displays that enable us to do a number of things," continues Lay. "Firstly we are transmitting and displaying flight test instrumentation outputs into the main cabin of the aircraft. This means we are now able to train, particularly for our flight test engineer students, more than one student at a time. In fact, these baseline displays ensure we can train four students at a time in the aircraft. We're also using wireless technologies to display that same instrumentation onto tablets in the cockpit, so that the student test pilots can also see the data, and the results of their flight test techniques and how effective they have been."

It's all a far cry from the stuffy, sleep-inducing classrooms that I remember at school, and it's encouraging to learn of the solid investments being made by the industry's leading institutions. The future of aerospace is hard to predict (see our feature on the latest 'copper birds' for hybrid electric aircraft on page 30, for example), but highly skilled test pilots or engineers will always have a key role to play.

Anthony James, *editor-in-chief*

// Contributors

PAUL EDEN

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

GEORGE COUPE

George is a journalist and editor with many years of experience writing for science, engineering and technology publications, as well as the national press.

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Rob is an engineer turned journalist, who has been writing about aerospace technology for approaching 20 years. He has recently relocated to Brittany, France.

SAUL WORDSWORTH

A regular freelancer on all manner of subjects, Saul has also penned sketches for BBC radio, while his novel *Alan Stoob: Nazi Hunter* is published by Hodder & Stoughton.

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COVER IMAGE: A400M at RAF Brize Norton

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WORLD *test update*

// SUCCESSFUL TEST FOR ORION LAUNCH ABORT MOTOR

Orbital, NASA and Lockheed Martin successfully achieved a ground firing test of the abort motor for NASA's Orion spacecraft Launch Abort System (LAS) at Orbital ATK's facility in Promontory, Utah.

The launch abort motor is a major part of the LAS designed to safely move the spacecraft and crew out of harm's way in the event of an emergency on the launch pad or during initial launch ascent. The test confirmed the motor can activate within milliseconds and will perform as designed under high temperatures.

It was fixed into a vertical test stand with its nozzles pointing skyward. Upon ignition, the abort motor fired for five seconds. The motor was developed so the majority of its propellant would be expended in the first three seconds. The motor reached 400,000 lb (1,779kN) of thrust in one-eighth of a second, as expected.

Promontory, Utah

READ MORE ON OUR WEBSITE!

// BELL 525 RESUMES FLIGHT TEST PROGRAM

The Bell 525 Relentless program has resumed flight test activity after receiving experimental certificate renewal from the Federal Aviation Administration (FAA), Bell Helicopter announced on July 7.

"Today we have resumed a key element of the Bell 525 program," said Mitch Snyder, president and CEO, Bell Helicopter. "Bell Helicopter has worked with the National Transportation Safety Board and FAA since the accident [of the first prototype on July 6, 2016] and we are confident in the resumption of flight test activity.

"The team is focused on certification in 2018 and we are committed to bringing this innovative and high-performing helicopter to market," Snyder added.

The Bell 525 is the world's first fly-by-wire commercial helicopter, designed to operate safely and reliably in austere environments with decreased pilot workload. The aircraft features a Garmin fully-integrated touchscreen avionics suite designed for helicopters.

Fort Worth, Texas

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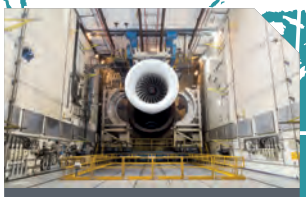

// ROLLS-ROYCE SUPPORTS £150M TESTING FACILITIES

Rolls-Royce has announced a £150m (US$194m) investment in new and existing civil aerospace facilities in the UK to support the planned doubling of engine production and delivery on its record-sized civil aerospace order book.

The investment, which was announced on June 29 and will be made over the next few years, is part of Rolls-Royce's ongoing industrial transformation and will provide additional capacity as it develops and tests the next generation of aero engines.

The majority of the investment, which is in line with the Group's ongoing planned expenditure, will provide a new facility for the testing of large civil aero engines in Derby in the UK, the home of Rolls-Royce's civil aerospace division.

The new testbed will be capable of testing a range of engines including the Trent XWB, which powers the Airbus A350 XWB and is the world's fastest-selling civil large engine, with more than 1,600 on order from 45 customers in 31 countries.

Derby, UK

READ MORE ON OUR WEBSITE!

// FIRST FLIGHT SUCCESS FOR GRIPEN E

Defense and security company Saab completed a successful first flight of its next-generation smart fighter, the Gripen E, on June 15, 2017.

The Gripen E took off on its maiden flight at 10:32am on Thursday, June 15, flown by a Saab test pilot. The aircraft (designation 39-8) left from Saab's airfield in Linköping, Sweden, and flew over the eastern parts of Östergötland for 40 minutes. During the flight, the aircraft carried out a number of actions to demonstrate various test criteria including the retracting and extending of the landing gear.

"The flight was just as expected, with the aircraft performance matching the experience in our simulations. Its acceleration performance is impressive with smooth handling," said Marcus Wandt, experimental test pilot, Saab. Flight test activities will continue, with the program on track to achieve a 2019 delivery schedule.

Linköping, Sweden

// AIRBUS A350-1000 IN HOT WEATHER TESTS

The A350-1000 test aircraft, MSN065, successfully completed hot weather testing at Al Ain International airport in the UAE.

The tests, which took place from July 4-7, involved the aircraft undergoing extreme weather conditions at temperatures above 104°F (40°C). The objective of the tests was to check systems behavior with a focus on the cabin, including cooling performance on the ground. The aircraft successfully cleared all the set parameters, demonstrating its maturity and readiness to operate in hot weather conditions.

Airbus has been using the Al Ain International Airport as its base for hot weather testing for a number of years now.

The A350-1000 is the newest member of the all-new midsize long-range A350 XWB family and more powerful Rolls-Royce Trent XWB-97 engines.

Al Ain International, UAE

// ELECTRONICS TESTS FOR KC-46A AT THE BAF

A KC-46A Pegasus entered the Benefield Anechoic Facility (BAF) for the first time at Edwards Air Force Base in California, it was reported in June.

The new aerial refueling tanker is undergoing tests to demonstrate that it meets Federal Aviation Administration certification requirements and DOD electromagnetic environmental effects requirements for systems. These tests included verifying the shielding effectiveness, emission control and high-intensity radiated fields.

The tests were to confirm that the KC-46A systems do not suffer performance degradation that would prevent mission completion when subjected to the external radio frequency environment and that undesirable emissions are adequately controlled.

The tests conducted in the BAF provide an electromagnetically controlled environment suitable for critically sensitive radio frequency measurements.

Edwards AFB, California

READ THE INTERVIEW P48

// ACTIVE ROTOR CONTROL REDUCES NOISE

Rotors are the main source of noise from helicopters under some operating conditions. The German Aerospace Center (DLR) and Airbus Helicopters Deutschland have been testing ways to reduce the noise and the simultaneous vibrations. This work led to an active rotor control on a modern, five-blade rotor which has been testing in a wind tunnel as part of the SKAT (Scalability and Risk Minimization of Technology) research project. A 30% reduction in noise resulted.

The main rotor, both the source of the lifting force and propulsion on the helicopter, also creates a series of aeroelastic and aeroacoustic problems such as high levels of vibration and the source of a great deal of noise.

One way to reduce this is by active rotor control with the use of multiple swashplates. DLR researchers successfully reduced both vibration and noise emissions using a five-blade rotor and individual blade control. Noise was reduced up to 3dB – about a 30% decrease.

Marknesse, Netherlands

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Orion hits the switch!

Engineers at Lockheed Martin and NASA breathed life into the next Orion crew module when they powered up the spacecraft for the first time at the Kennedy Space Center, Florida, this August. Designed for human spaceflight, this Orion will be the first to fly more than 40,000 miles (64,380km) beyond the moon during its nearly three-week Exploration Mission-1 (EM-1), a feat that hasn't been possible before.

"Orion was designed from the beginning to take humanity farther into space than we've ever gone, and to do this, its systems have to be very robust and reliable," said Mike Hawes, vice president and Orion program manager at Lockheed Martin. "Over the last year, we've built great momentum in assembling the crew module for EM-1. Everyone on the team understands how crucial this test campaign is, and more importantly, what this spacecraft and mission means to our country and future human space flight."

The initial power-on event was the first time the vehicle management computers and the power and data units were installed on the crew module, loaded with flight software, and tested. Evaluating these core systems, thought of as the 'brain and heart' of the Orion capsule, is the first step in testing all of the crew module subsystems.

Engineers and technicians will now continue integrating the 55 components that make up the spacecraft avionics suite, connecting them with nearly 400 harnesses. Over the course of the next two to three months, as each system is installed, they will perform thorough functional tests to ensure Orion is ready to move to the environmental testing phase. \\

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// An F-35A Lightning II aircraft from Hill Air Force Base, Utah, drops a 2,000 lb GBU-31 bomb over the Utah Test and Training Range

F-35As fly in weapons evaluation

Airmen from the 388th and 419th Fighter Wings recently supported and flew F-35A Lightning II aircraft during Combat Hammer, the first operational air-to-ground weapons evaluation for the US Air Force's newest fighter jets.

Combat Hammer is one phase of the Weapons System Evaluation Program (WSEP), which tests and validates the performance of crews and pilots and their technology, while deploying air-to-ground precision-guided munitions for the F-35A.

The week-long evaluation exercise concluded August 11, 2017, and Lt Col. Timothy Smith, the 86th Fighter Weapons Squadron detachment commander who oversaw Combat Hammer, said he received positive feedback regarding above-average mission and sortie rates.

"Overall, everything went as planned and all participating units performed very well, including the 34th Fighter Squadron's F-35s," he said.

Statistical data derived from Combat Hammer will assist leaders at the highest Air Force levels in making resourcing decisions. It will also provide contingency planners with a solid understanding on weapons systems performance and the effects they'll achieve. \\

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// The dispenser structure under test at the Airbus Friedrichshafen facility

Gravity satellite ready for launch

Airbus has tested the dispenser structure that will hold the twin satellites GRACE-FO (GRACE = Gravity Recovery and Climate Experiment, FO= Follow-On) during their launch. Once the satellites are integrated in place, the assembly to the launcher or fit check test is carried out. This test is used to demonstrate the mechanical and electrical compatibility between the satellites, the dispenser and the launcher. Airbus is developing and manufacturing the GRACE-FO satellites on behalf of NASA's Jet Propulsion Laboratory.

Airbus developed this satellite dispenser for the German Research Centre for Geosciences (GFZ, Potsdam, Germany) in less than one year. This structure was developed in classical configuration with a central carbon-fiber cylinder, with the satellites held in place by four hold-down-and-release mechanisms, which each have springs, connectors and necessary harnesses.

JPL, located in Pasadena, California, and managed by Caltech on behalf of NASA, in partnership with GFZ, will send both GRACE-FO research satellites into a polar orbit at an altitude of around 310 miles (500km) and at a distance of 137 miles (220km) apart. This is a follow-on to the GRACE mission, which has been successfully operating since 2002. Both satellites will continually take very exact measurements of their separation distance, which changes depending on Earth's gravity. In this way, scientists are able to map Earth's gravitational fields. \\

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// A Boeing KC-46A tanker on the EMP pad at Naval Air Station Patuxent River

KC-46A withstands EMP test

A Boeing-led team, including US Air Force and Naval Air Systems Command representatives, recently completed KC-46 tanker electromagnetic testing to evaluate the aircraft's ability to safely operate through electromagnetic fields produced by radars, radio towers and other systems, under mission conditions.

"The KC-46 tanker is protected by various hardening and shielding technologies designed into the aircraft to negate any effects on the aircraft," said Mike Gibbons, Boeing KC-46 vice president and program manager. "This successful effort retires one of the key risks on the program."

Testing was conducted on the Naval Air Station Patuxent River, Maryland, electromagnetic pulse (EMP) and Naval Electromagnetic Radiation Facility pads; and also in the Benefield Anechoic Facility at Edwards Air Force Base, California.

During tests on the EMP pad at Patuxent River, the program's second low-rate initial production KC-46 received pulses from a large coil/transformer situated above the aircraft. The outdoor simulation was designed to test and evaluate the KC-46's EMP protection while in flight.

The KC-46A is a multirole tanker that is designed to refuel all allied and coalition military aircraft compatible with international aerial refueling procedures, and can carry passengers, cargo and patients.

Boeing is assembling KC-46 aircraft at its Everett, Washington, facility. \\

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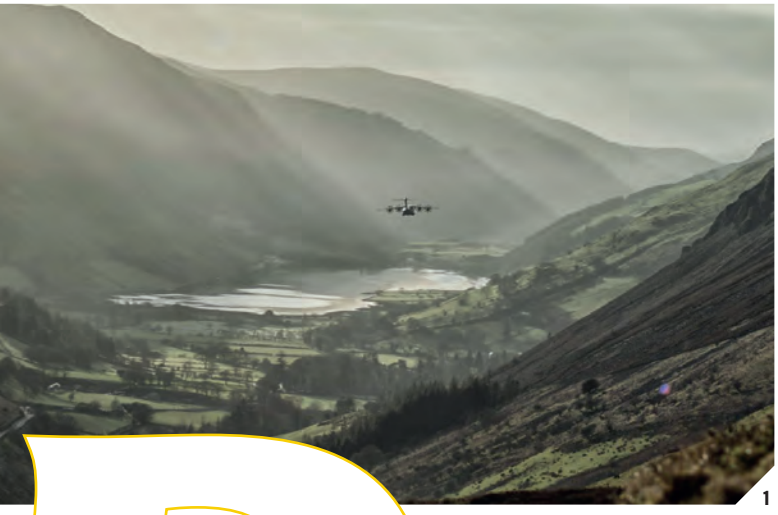
// PAUL E EDEN

Atlas on track

Based alongside the RAF's Air Mobility Force at RAF Brize Norton, 206 (Reserve) Heavy Aircraft Test and Evaluation Squadron is expanding and proving A400M capability in a carefully managed, long-term campaign that's delivering significant new capability to the frontline

// The Royal Air Force operates its A400Ms as a pooled fleet *(Photo: Paul Crouch/UK MoD)*



Development delays and technical issues are, and have always been, integral to complex military aircraft programs, and Airbus Defence and Space has worked through difficult times with its A400M airlifter. Today, the popular press perception of cost overruns and last year's grounding of the fleet due to propeller gearbox issues is not only misleading, but also masks the fact that the Royal Air Force has a thriving A400M Atlas community at RAF Brize Norton in rural Oxfordshire.

By mid-August this year, the service had received the majority of the 22 A400M aircraft on order. Although the type is officially known as 'Atlas' in RAF parlance, to its British operators it is invariably 'A400'.

While LXX Sqn (less formally known as 70 Sqn) flies the aircraft around the world in its operational role and XXIV Sqn (24 Sqn) delivers and refines Atlas crew training, 206 (Reserve) Heavy Aircraft Test and Evaluation Squadron is responsible for extending and proving the aircraft's capability according to RAF requirements and UK military aircraft certification standards.

Previously stationed at MoD Boscombe Down, Wiltshire, with detachments at RAF Brize Norton with the Atlas and Hercules Forces, 206(R) Sqn recently moved to the Oxfordshire base in its entirety. Access to the pooled A400M fleet is now simplified, and there is now daily opportunity for discussion and close liaison between the evaluators and testers, and 24 and 70 Sqn personnel, ensuring 206(R) Sqn is always serving the needs of the frontline.

The squadron draws its members from frontline aircrew who have completed either a test pilot training course (at the Empire Test Pilots' School or equivalents in the USA and France) or evaluator aircrew courses for pilots and loadmasters. These are supported by flight test engineers and trials management officers also trained at a test pilot school, or through the RAF's aerosystems course. This delivers a blend of test professionals with recent operational and engineering experience.

Officer Commanding 206(R) Sqn, Wing Commander Bruce Farquhar, has been in his post for two years and oversaw the move to RAF Brize Norton. Now settled into its new home, his unit is divided into three components: 'A' Flight, taking responsibility for the A400M, 'B' Flight, for the C-130J Hercules; and 'C' Flight, for C-17A and ISTAR. The latter has included work on the King Air-based Shadow and RC-135 Airseeker, with the P-8 Poseidon a possibility for the future.

Within the squadron's cadre of around 40 personnel, including 35 military people, 'A' Flight comprises four A400M crews. Atlas manning therefore accounts for over half 206(R) Sqn's establishment. For its aircraft needs, 206(R) bids for aircraft from the centralized A400M fleet and therefore has no dedicated technician cadre, 'borrowing' engineers from other units should it take an aircraft away from RAF Brize Norton for any length of time. The unit's one technician post is responsible for developing the aircraft role configurations required for aerial delivery capabilities, ensuring the capability is transferred to aircrew and groundcrew.

WHY TEST AT ALL?

Airbus has already extensively and publicly undertaken developmental, certification and qualification (C&Q) tests on the A400M, including unpaved, or natural surface, runway trials, held in the UK over the last two years – videos of the landings quickly became YouTube favorites among enthusiasts. So why does Britain need its own test program at all? Farquhar explains: "We're part of the international Certification & Qualification Panel that participates in the developmental, certification and

1 // Low-level testing has taken the A400M through the UK's famous Mach Loop training area in Wales *(Photo: 206(R) Sqn)*

2 // Light stores can be dropped from the rear ramp and paratrooping doors, as shown here *(Photo: Sgt Nige Green/UK MoD)*

> *"It sounds like a box-ticking exercise, but it's far from straightforward"*

3 // The Atlas is now a common sight at RAF Brize Norton as it moves closer to full operating capability *(Photo: Steve Lympany/UK MoD)*

22
A400M airlifters ordered for the RAF

81,600 LB
(36,740kg)
Maximum payload

12,000FT³
(340m³)
Cargo-hold volume

4
EuroProp International TP400 turboprops

qualification with Airbus Defence and Space, predominately in Spain. Meanwhile, the ATEC [aircraft test and evaluation] partnership between QinetiQ and the Air Warfare Centre, concentrates on specific UK requirements above and beyond those provided through the international program. We have a test pilot and loadmaster participating in the various C&Q panels, covering flying handling qualities and the cargo hold, almost full time, getting early sight of what the company's doing, considering capabilities that we're expecting in 18 months or two years' time. It's a huge opportunity for them to see what's happening and feed back knowledge of future upgrades to the squadrons at RAF Brize Norton and the A400M Project Team, based at Defence Equipment & Support in MOD Abbey Wood, Bristol.

"It also gives us an opportunity to become involved at an early stage if something's assessed as unsatisfactory in relation to the intended mission. The radio altimeter, for example, doesn't offer the fidelity we require for low-level flying but that was identified a couple of years ago. So now, when we're flying low level, we employ short-term procedural mitigations that we've developed until an appropriate modification is available."

In conjunction with the A400M Project Team, responsibility for many aspects of the post-production acceptance process also falls to 206(R) Sqn. "Every time an aircraft comes off the FAL [final assembly line] in Seville, or after the embodiment of a significant modifications package in Madrid, we deploy a crew of two, occasionally three, and they spend up to a month undertaking the inspection process. It includes extensive ground testing to ensure the aircraft is operating correctly and the build quality meets contractual requirements. We then participate in a 'customer acceptance flight', crewed jointly by the manufacturer and 206(R) Sqn representatives.

It sounds like a box-ticking exercise, but it's far from straightforward, since the frontline is relying on us to identify quality deficiencies that may become a safety risk, or a burden to engineering or operations."

While the certification, qualification, and acceptance responsibilities are a high priority for 206(R) Sqn, another good example of the long-term benefits of having its personnel embedded with the manufacturer arises with the initiation of the RAF's own natural surface testing later this year. Airbus has already provided evidence that natural surface operations are safe and qualified in accordance with the production contract, but the UK needs to develop its own detailed standard operating procedures (SOPs). This moves the squadron's operational test and evaluation (OT&E) remit, drawing on the experience of a unit pilot who flew on the 2016 trials and observed the 2017 trials at Pembrey Sands and therefore brings a raft of experience to the new effort.

Flight Lieutenant Jim Stokes, 206(R) Sqn A400M staff officer and trials manager, explains, "In July-August we're undertaking an incremental approach to natural surface operations, beginning with daylight operations and with

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CT scan of a turbine blade

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a known hard strip. Toward the end of next year we'll be doing it by night, on different surfaces and with conditions including crosswinds.

"It's important to remember that getting onto the strip is the basic objective, but we need to develop the procedures for how we're actually going to employ a capability usable by all frontline aircrew. How will we move personnel, freight and vehicles? Will the aircraft need to be reversed before taking off again? What about turning it on the ground?"

With regard to natural surface landings, Farquhar notes, "We'll be doing OT&E, but in this and other trials we do not repeat what Airbus has already done, but we will use its evidence as a baseline for our understanding. The aircraft is already authorized to land on natural strips, so we're looking at how we get into the strip as quickly as possible in a safe manner, and how personnel and cargo are dispatched prior to departure. It's very different from the Airbus work, where they were concerned with certification and qualification performance and handling qualities requirements, such as touchdown speeds, braking performance and ground handling.

"The low-level testing we've been doing is another great example of our OT&E work. The aircraft is being civilian certified by Airbus and we base the Release to Service [RTS] on that. The RTS allows us to fly the aircraft down to a particular altitude, but we've then done an extensive trials program to thrash out exactly how we should fly it at low level below that already cleared by the international program.

"A certification just means it can safely fly low, but we've come up with a robust set of SOPs describing how the RAF will employ the A400M at low level. It's a large body of work that we've just transferred across to the frontline. Now they're working up their own low-level capability, including training their aircrew and further refining procedures."

SOP development includes the smallest details, such as the procedure for looking out of the cockpit side window in a low-level turn, where a pilot – not necessarily the pilot flying – ensures the aircraft is turning around the obstacle or waypoint, as well as looking out for hazards. In the A400M's case, its high performance has led 206(R) to re-examine and modify SOPs proved over many years by the RAF's Hercules squadrons, including the low-level abort, a technique used to climb the aircraft rapidly out of harm's way.

Farquhar explains, "The A400 goes much faster than heavy aircraft have traditionally gone at low level, so things happen at a different speed – does that impact on pilot training? Also, the flight path protections (pitch, roll and load factor, for example) on the aircraft are far beyond anything we've had on the Hercules fleet.

"So you're flying along and you need to abort. Do you go full back stick? You know the aircraft will give you everything it can – full power and as much pitch as it can – then it'll pitch over at a certain slow speed to protect you. It could be a really good way of doing it.

"But the aircraft has a huge amount of thrust and if you do that it tops out at about 55° nose-up. It's great from the pilots' perspective, but does it increase your risk of mid-air collision with aircraft above you? And what's the effect on passengers? So is there a suitable middle ground in terms of the *g* you pull and the angle you climb at?

"What about if you pitch up at 30° instead, maintaining more speed? Does that give a more useful result? These are all things we've sat down and thought about so that we can take them to the frontline and say, 'Guys, here's where you start.' We're not saying these are the SOPs that'll be in

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Cruise speed

ROYAL AIR FORCE A400M SQUADRONS

XXIV Sqn	Operational conversion unit, also training crews for the C-17 and Hercules
30 Sqn	Will become the second frontline Atlas unit
LXX Sqn	First frontline Atlas unit
206 (Reserve)	Heavy Aircraft Test and Evaluation Squadron – responsible for all RAF heavy aircraft test and evaluation, including Atlas

4 // With the Atlas, UK Defence is exploring a raft of new air mobility capability *(Photo: Paul Crouch/UK MoD)*

> *"Now we're looking at the tactical side, with the low-level and airdrop work"*

place forever. We're giving them the starting point from which they can begin flying the aircraft tactically at low level."

For the time being, the low-level work is being completed by day, but an extension into night-vision goggle capability is already scheduled.

INSTRUMENTATION AID

When trials require instrumentation, high-speed photography or telemetry, the unit employs a variety of solutions, as Stokes explains: "We're about to do a trial where we require flight test instrumentation, and Cranfield University will come down and fit it. We use instrumentation on a case-by-case basis and we've done work in Spain with the Airbus instrumented aircraft. We use it for flare-release trials and similar activity."

UK-based trials are typically flown out of RAF Brize Norton, with personnel and equipment positioned elsewhere as required. "We've done some work with the aircraft's defensive aids protection systems over the Donna Nook range in Humberside, for example, where we had specialists on the ground with emulators, simulators, cameras and data-gathering equipment," continues Stokes. "It may be that they lead the trial and we just put ourselves in the right bit of airspace for them to gather their data. The exact format depends in the task, but most trials need a drop zone, a range or a strip, and we'll need support for that."

Developmental trials are an important component of 206(R)'s A400M work, taking UK-specific requirements and proving the new airlifter against UK-specific requirements. The squadron recently completed a light stores aerial delivery task, essentially trialling the behavior of the aircraft and items of light cargo using a static line parachute. Farquhar details the work: "It was the first time we'd taken UK equipment and assessed it on the A400M. We did it as a developmental trial with the ATEC. It involved cameras and ranges as we worked to gather evidence for RTS recommendations so that it can be cleared for service.

"Under ATEC we operate with QinetiQ, providing the aircrew while they provide subject matter experts and ground expertise, and sometimes flight test engineers who fly with us, although for some trials we use our own RAF flight test engineers. For the light stores task, they had aerodynamic and load experts, for example, and we provided the operational aircrew experience. It creates a powerful, technically and tactically experienced team."

The RAF's A400M program is making carefully programmed progress as the service gradually opens up its considerable capability to the frontline. Farquhar says, "The aircraft will be in service for many years, allowing us to tweak procedures, so right now we're working to use its natural capability to get it into service in the most efficient and safest manner, and as operationally effective as possible, delivering what the frontline need when they need it."

Summarizing progress to date, Stokes says, "We've done a lot of the strategic work, so we have an understanding for how it gets around the world and what sort of freight you can put in the back. Now we're looking at the tactical side, with the low-level and airdrop work, defensive aids subsystems, natural surfaces and so on. In conjunction with the Project Team and the RAF's Air Capability team, I've written a full trials program out to 2020, but it could move beyond that if further requirements or equipment emerge."

It's a considerable span of time for an aircraft already well tested but, as Farquhar confirms, the A400M represents a serious capability: "It's massive, hugely challenging and rewarding. Its importance shouldn't be underestimated, since it will be the bedrock of the RAF's tactical and strategic air mobility fleet for the foreseeable future." \\

TRIALS MANAGEMENT

Flt Lt Jim Stokes explains the organization of individual A400M trials: "Trials are tasked via the ATEC for activities supporting the safety case and the RTS, and the Air Warfare Centre for OT&E, but the procedure in any case is broadly the same. We're given the task and those of us with expertise in that subject define what the aim is and what we need to achieve it. From that we assess the associated risks, do peer and specialist review, and then put the documentation in place. Then there are the engineering implementations, and hardware and aircraft requirements.

"It all comes together over a trials planning period, at the end of which we should have all the documentation to support that trial. Out of that we generate the test cards describing what we're physically going to do. We bring everyone involved together and brief thoroughly, not only on the risks of the trial, but on the specific risks of that day's work, what the test points are, and what represents success, or what we're looking for.

"There'll be milestones in place where we assess: 'Are we doing what we're supposed to be doing? Are we getting the results we expected?' And we'll stop if needs be, have a think about it and perhaps redo it. There's always a post-flight report on each test point and then we think about how to hand it on to the frontline so they get everything they need to develop a course for teaching it."

5 // RAF Brize Norton has seen considerable infrastructure development work accompany the A400M's arrival into service *(Photo: Paul Crouch/UK MoD)*

5

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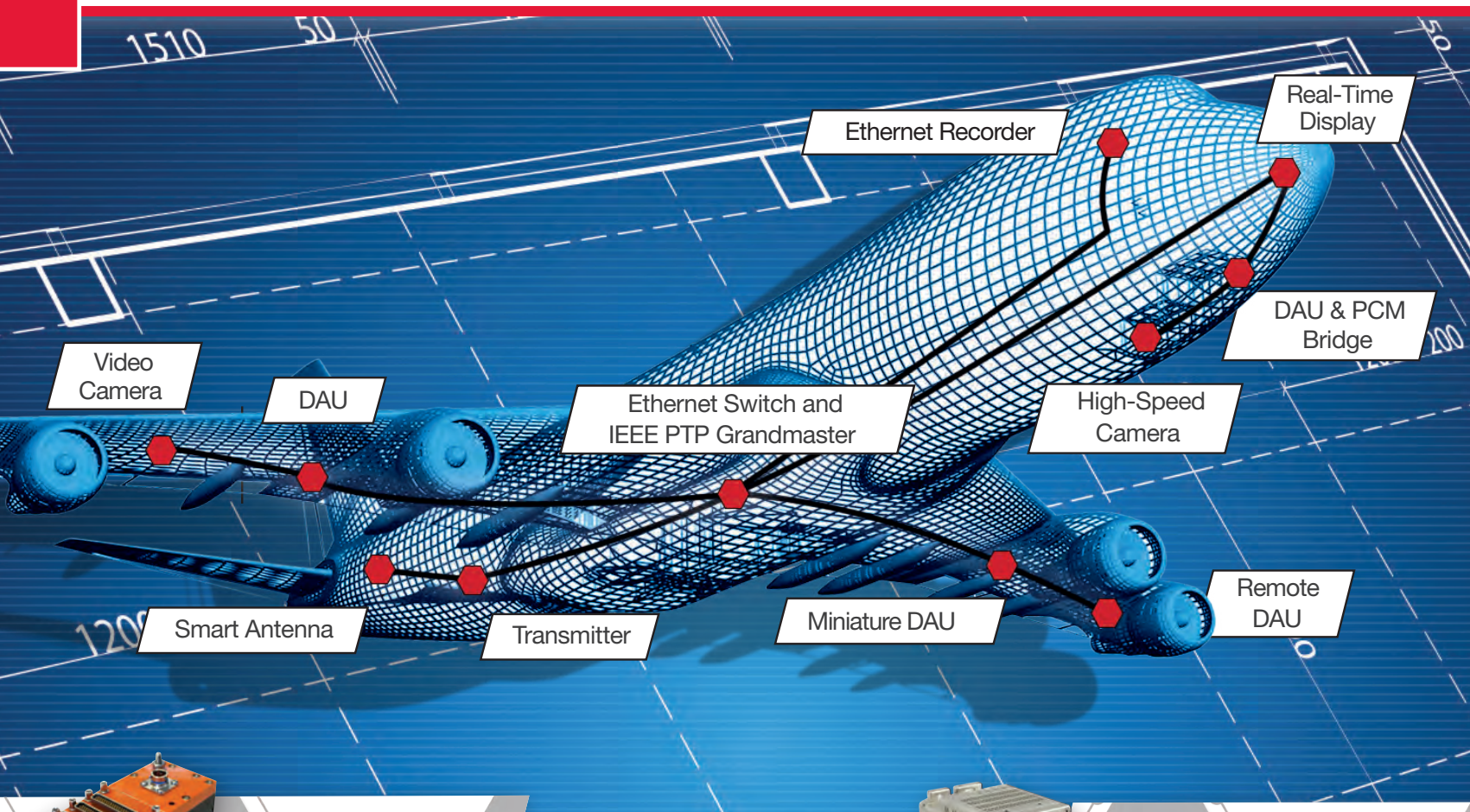

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// ANTHONY JAMES

Two leading test pilot schools continue to invest in aircraft, equipment and new approaches to better meet the changing needs of industry

school re

1 // The ETPS announced in February 2017 that it had ordered four Airbus H125 helicopters

vision

"We were the first civilian test pilot school in the world recognized by the SETP"

2

3

2 // The NTPS's Northrop T-38 Talon – a two-seat, twin-engine supersonic jet trainer

3 // The NTPS has recently refreshed its rotary-wing fleet with the Airbus H145

There seems to be a university degree for just about every conceivable subject these days, from golf management to surf science. But if you want to be a test pilot or flight test engineer, your best bet is to attend a course offered by one of eight schools officially approved by the Society of Experimental Test Pilots (SETP).

These include the UK's Empire Test Pilot School (ETPS), the US Naval Test Pilot School, the US Air Force Test Pilot School, the French Test Pilot School (EPNER), the International Test Pilots School (Ontario, Canada), the US National Test Pilot School (NTPS), and the two most recent additions, the Indian Air Force Test Pilot School and the Brazilian Test Pilot School.

COMMERCIAL PRESSURE

Aerospace Testing International spoke with two SETP-approved schools: the ETPS at MoD Boscombe Down, Wiltshire, UK, founded in 1943 as the first such institution of its type in the world, now run by the UK Ministry of Defence (MoD) and defense contractor QinetiQ; and the NTPS, a not-for-profit institution established in 1981 as the first civilian school of its type, based in Mojave, California, where it has access to one of the finest flight test areas in the USA, namely the R-2508 Complex also used by Edwards AFB and China Lake NAWS.

Both were quick to highlight a strong industry need for a greater number of qualified test pilots, particularly for work in the growing commercial aviation sector.

"ETPS is currently moving to a model whereby it can support not just the military need for test pilots and flight test engineers, but also address the emerging markets for civil flight test professionals, particularly civil test pilots," explains Nick Lay, operations director for QinetiQ's Air & Space business division.

"We have taken as our starting point not just the needs of our principal customer, the RAF's Air Warfare Centre [AWC], but also the recent regulatory requirements introduced by the European Aviation Safety Agency [EASA], which require civil test pilots to have a flight test rating along with a commercial pilot license," continues Lay.

4

4 // ETPS test pilots at MoD Boscombe Down, UK

5 // ETPS Flight Test exercise on RJ100

As a result, the ETPS has radically revised its course structure, moving to a more modular approach to better meet changing civil requirements: "We are turning from a very tailored and specific set of courses lasting either six months or a year, to a more modular approach that is going to enable us to deliver not just our existing courses, but also new courses to reflect the changing needs of our customers," explains Lay.

"This will enable us to look at avionics systems, for example, with much more consideration of systems as opposed to the traditional focus on handling qualities and stick-and-rudder stuff."

Meanwhile, as the world's only civilian test pilot school, the NTPS has long recognized the needs of the commercial sector. "We are different because we are a total flight test education and training organization that is dedicated to providing the worldwide flight test community with the flight test education and training that they need," says Dr Allen Peterson, president and CEO, NTPS.

"We were the first civilian test pilot school in the world recognized by the SETP, but it's much more than that," he continues. "Because we are a total flight test education and training organization, we provide a wide range of courses and services to meet the needs of the worldwide flight test community and we are also extremely customer focused. We were the first test pilot school in the world to be certified as a flight test approved training organization (ATO) by EASA. We were the first test pilot school in the world to offer a master's degree in flight test. We were the first test pilot school in the world to devote a significant portion of the curriculum for all students to systems testing. And we were the first test pilot school in the world to put an extensive emphasis on civil certification regulations testing."

5

INVESTMENT DRIVE

The greater emphasis on commercial aviation needs has seen both schools invest heavily in new aircraft, as well as working hard to achieve EASA certification.

The ETPS was recognized by EASA as an ATO, certified to train test pilots to civil standards, this February. The accreditation means that ETPS is just one of three schools in the world able to provide test pilots with course completion certificates needed to obtain civil flight test ratings in compliance with the new EASA regulations.

"All civilian test pilots in Europe, such as those working in-house for aircraft manufacturers or graduates seeking commercial work, must now receive training from an accredited school," explains Paul Shakespeare, head of the ETPS at QinetiQ. "Our ability to provide this vital training will be greatly welcomed by our existing customers, and will create growth opportunities in new international markets as companies and individuals react to the new EASA rules."

The accreditation supports the school's continuing modernization program, under which QinetiQ and the MoD are investing £85m (US$109m) to transform its courses and the air fleet used to deliver them. The program is part of a £1bn (US$1.3bn) contract, announced in December 2016, which ensures QinetiQ will continue to manage the ETPS until at least 2028.

Implementation of the modernization program began in January 2017 with the purchase of two Pilatus PC-21

COMMUNITY SPIRIT

The National Test Pilot School (NTPS) in Mojave, California, is a firm believer in giving back to the local and flight test communities, having initiated two major innovations in this area. "Our STEM-focused Flight Test Camp for the local high school students, which is the only program of its kind in the world, lets these young people experience hands-on what it is like to be a flight test engineer," explains Dr Allen Peterson, president and CEO, NTPS.

A further innovation is the NTPS's three-year Graduate Assistant Flight Test Engineer program, which sees the school sponsor young engineers on a work-study program so that they can earn master's degrees in flight test engineering and also earn their Flight Test Engineer Professional Course diploma. "This is the only program in the world that is putting test pilot school trained flight test engineers into the flight test community workforce at no cost to the members."

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fixed-wing aircraft, destined to carry out duties currently performed by an aging fleet that includes Hawks and Alpha Jets.

"We have introduced new civil registered types that have modern glass cockpit displays, with complex systems that enable us to deliver on the new elements of our courses," explains the ETPS's Lay. "On the fixed-wing side we are going to be retiring our two Short Tucanos [a two-seat turboprop basic trainer], our one remaining Hawk and our Alpha Jets. All those types will be retired at the end of 2018. In their place will come two Grob G 120TPs and two Pilatus PC-21s. We're also going to be using aircraft from other suppliers and partners to make sure we get the breadth of experience that the students need to graduate."

QinetiQ has also coughed up £15m (US$19m) for four Airbus H125 helicopters to replace the ETPS's existing Airbus Gazelles, which will be retired at the end of 2018. The deal will see Airbus Helicopters' UK design team upgrade the Garmin G500-equipped aircraft with, among other capabilities, a three-axis autopilot, dedicated communications equipment and traffic awareness systems. This is in addition to a flight test instrumentation suite, which is used to test and evaluate aircraft design and performance – a critical part of a test pilot's or flight test engineer's training.

"We have listened to our customers and refreshed our approach to focus more on the things that matter to them," adds QinetiQ's Shakespeare. "While we continue to deliver the military training for which we are renowned, civilian trainees will benefit from shorter and more flexible courses, enabling a better balance between learning and working. Newer, more advanced aircraft and updated teaching methods will keep the ETPS at the forefront of test aircrew training, reasserting the reputation for excellence we have maintained for nearly 75 years."

7

However, the NTPS's Peterson is quick to point out that the Mojave-based school was actually the first to achieve EASA certification, becoming a Part-ORA ATO for Part-FCL flight test training in June 2016, at which time it was the only test pilot school in the world to be certified by EASA to provide flight test ratings. "We were the first test pilot school in the world – and the only civil school – to attain certification by EASA," he says proudly.

EQUIPMENT CHECK

The NTPS has been equally busy buying more modern aircraft. "We have recently purchased an EC-145

6 // The NTPS's Merlin 'flying classroom'

7 // Control room exercise taking place at the NTPS

8

8 // Pilatus PC-21, announced in January 2017 as the first purchase for the ETPS's new fleet

9 // An Agusta A109 twin-engine, multi-purpose helicopter is put through its paces at the NTPS

9

helicopter, two Aero L-39 Albatross trainer jets and two King Air C90 twin turboprops," continues Peterson. "All the aircraft we chose to purchase or lease are evaluated for several factors that we think are important for an aircraft on one or more of our courses."

But it's not just aircraft that have caught Peterson's eye. "We have or are in the process of updating all our instrumentation systems on the aircraft to include the DAQ 9000 data acquisition system from Nginuity in the UK," he says. "We stay in close touch with our customers and with the flight test community through the SETP and the Society of Flight Test Engineers (SFTE), to make sure we are buying the right sort of equipment."

The ETPS has also ensured that its new aircraft will feature suitably sophisticated onboard systems. "We worked very closely with Pilatus, which is supplying us with an instrumentation suite for the PC-21," confirms Lay.

"The suite is based on the flight test instrumentation system designed as part of Pilatus's original development program but incorporating dedicated displays in the cockpit that can draw on the information available on the avionics buses to give our students immediate feedback during the tasks they are performing and whether they've carried out that input correctly or not. That's a real time saver. Previously we had to land the aircraft, take out the memory unit, get it calibrated, read and then re-expressed for analysis. Now we can do it in the air almost instantaneously. It's this sort of investment that is really going to move us forward in terms of the ability to get the most out of every flying hour."

Despite the increasing sophistication of cockpit technology and flight test equipment, the fundamentals of flight testing remain the same.

"The skills required to be a good test pilot really do not change, but the tools they use to evaluate the aircraft and systems change with technological advances," says Peterson. "A good test pilot should be above average in all things but most especially in flying skills, analytical skills, writing skills, decision making and judgment. They must also have integrity and moral courage."

MAKE THE GRADE

Students are taught academics in the classroom and laboratories, and numerous flight test techniques are honed in aircraft, simulators and laboratories. "The students are evaluated through written and oral examinations, written and oral reports, and graded flying exercises," confirms Peterson.

"Students are required to plan, execute and report on flight test exercises," he continues. "They must be able to plan how the flight should be conducted to acquire the data and then fly the required points and collect all the required data. Once collected, the data must be analyzed and conclusions drawn so that the reports can be written. Students are also required to present oral reports to students and faculty."

It's extremely rare for any students to fail, although some have faltered in the past: "Most students pass the courses," says the NTPS's Peterson. "NTPS students and customers come from a variety of backgrounds including military organizations, the aerospace industry, governments and certification agencies. Some are even private citizens. The students are normally vetted very seriously before they come, because the organizations want to send the best people who have the best chance of success. That being said, we do occasionally have students who cannot successfully complete the courses, because they are indeed very challenging." \\

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Nginuity design and manufacture a wide range of airborne protocol conversion units and power supplies typically suitable for system upgrades to ensure compatibility can be maintained with legacy systems. Conversions from and to many analogue, synchro, discrete and digital data bus formats are available including ARINC-429 and MIL-STD-1553B.

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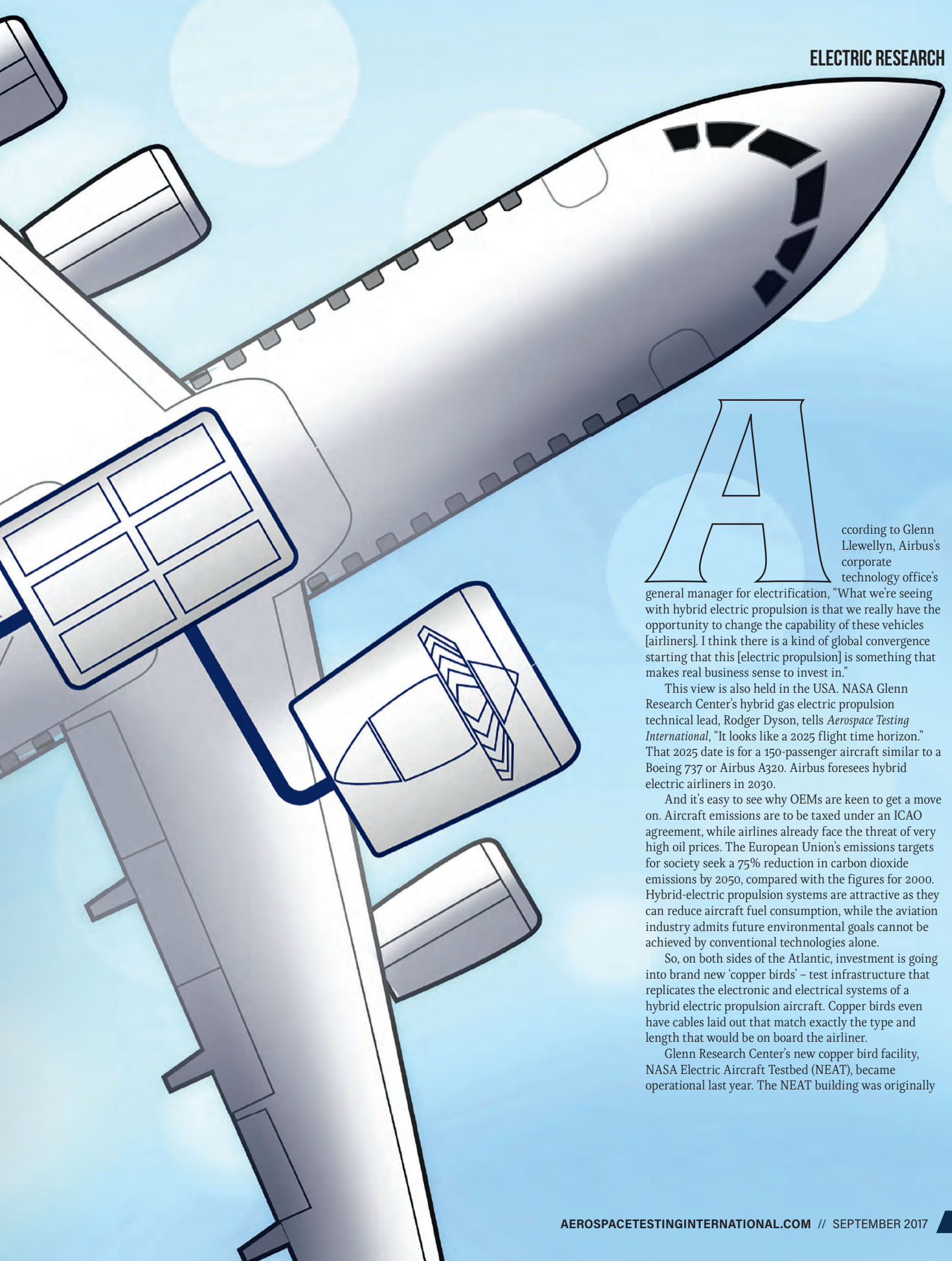
// ROB COPPINGER

Precious metal

On both sides of the Atlantic, considerable investment is going into new copper bird testing facilities designed for a new breed of hybrid electric aircraft

// An image of the E-Fan X concept aircraft, which is the basis for a 20MW electric aircraft design being developed in Airbus' E-House



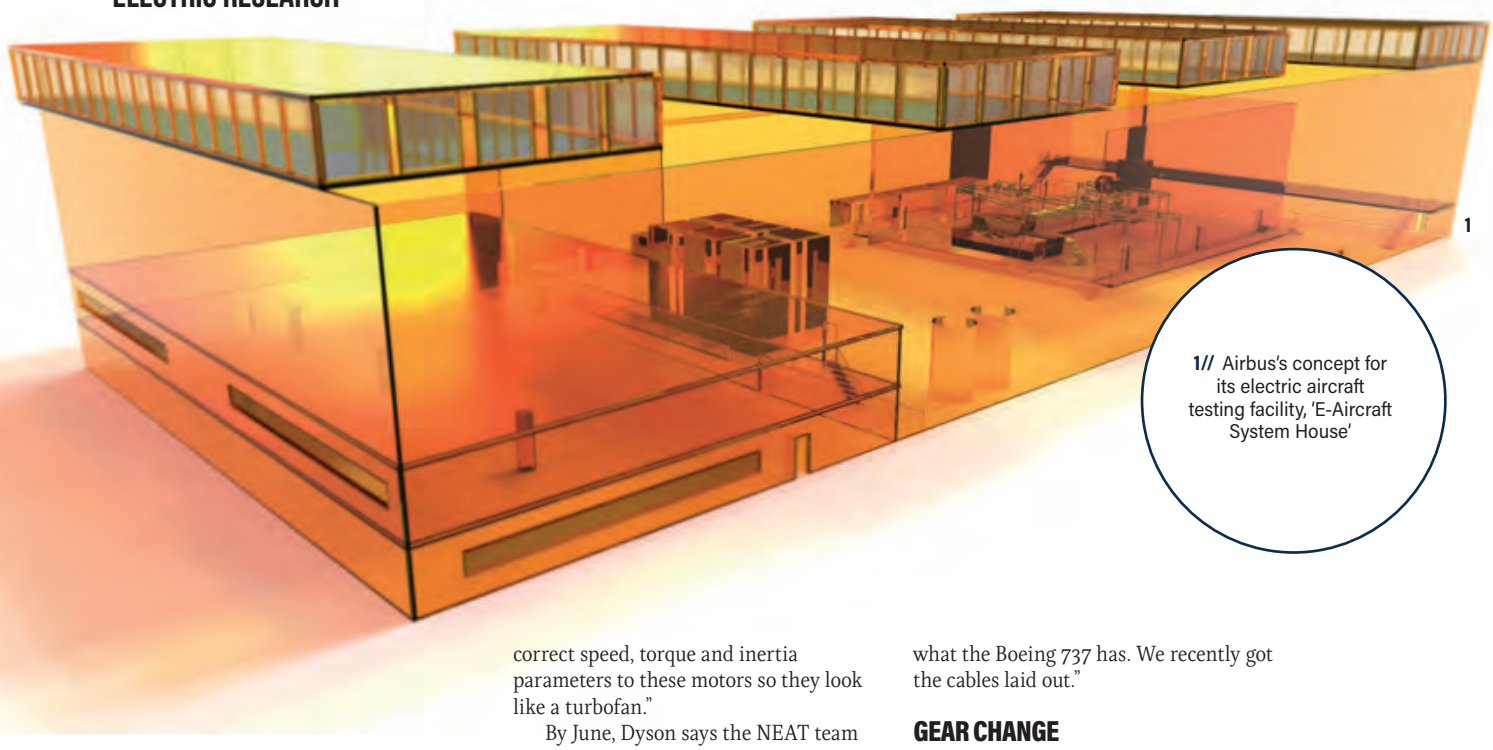
According to Glenn Llewellyn, Airbus's corporate technology office's general manager for electrification, "What we're seeing with hybrid electric propulsion is that we really have the opportunity to change the capability of these vehicles [airliners]. I think there is a kind of global convergence starting that this [electric propulsion] is something that makes real business sense to invest in."

This view is also held in the USA. NASA Glenn Research Center's hybrid gas electric propulsion technical lead, Rodger Dyson, tells *Aerospace Testing International*, "It looks like a 2025 flight time horizon." That 2025 date is for a 150-passenger aircraft similar to a Boeing 737 or Airbus A320. Airbus foresees hybrid electric airliners in 2030.

And it's easy to see why OEMs are keen to get a move on. Aircraft emissions are to be taxed under an ICAO agreement, while airlines already face the threat of very high oil prices. The European Union's emissions targets for society seek a 75% reduction in carbon dioxide emissions by 2050, compared with the figures for 2000. Hybrid-electric propulsion systems are attractive as they can reduce aircraft fuel consumption, while the aviation industry admits future environmental goals cannot be achieved by conventional technologies alone.

So, on both sides of the Atlantic, investment is going into brand new 'copper birds' – test infrastructure that replicates the electronic and electrical systems of a hybrid electric propulsion aircraft. Copper birds even have cables laid out that match exactly the type and length that would be on board the airliner.

Glenn Research Center's new copper bird facility, NASA Electric Aircraft Testbed (NEAT), became operational last year. The NEAT building was originally



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1// Airbus's concept for its electric aircraft testing facility, 'E-Aircraft System House'

constructed in 1968 for nuclear thermal rocket propulsion and later converted to a Mach 5-7 wind tunnel. Hence it already has an altitude chamber and can provide lots and lots of power, as well as cooling using a cryogenic fluid supply (liquid hydrogen, for example), plus facilities for jet fuel. There is also "a remote-control room about a quarter of a mile away", adds Dyson.

Meanwhile Airbus's facility is called the E-Aircraft Systems Test House – a 4,500m² (48,400ft²) building set for construction in Ottobrunn, Germany, which when completed will provide the ability to test electrical systems, power distribution, batteries, electricity generation and gas turbines; and to test the complete integrated system of an electric aircraft. "The E-Aircraft Systems [Test House] is definitely a hub for all of the hybrid electric activities we're doing at Airbus and, as a result, it is becoming a European hub for hybrid electric propulsion research," asserts Llewellyn.

"Full entry into service is scheduled for the first quarter of 2019," he continues. "The building itself is due to be operational at the end of 2018. Physical construction is planned to begin later this year."

NASA's NEAT facility conducted its first test in mid-2016, demonstrating that electric motors could act as analogs for conventional propulsion. "We used NPSS [Numerical Propulsion System Simulation] software control," explains Dyson. "NPSS is the software industry uses to design turbofan engines. The software sends the correct speed, torque and inertia parameters to these motors so they look like a turbofan."

By June, Dyson says the NEAT team had "tested all the major systems, and now we're confident the whole large [Single-aisle Turboelectric AiRCraft with Aft Boundary Layer propulsion (STARC-ABL)] aircraft is going to work right. We're testing that [STARC-ABL] powertrain at the facility this September".

"We're trying to get all the cables and the cooling lines exactly as they would be on the actual aircraft," says Dyson with regard to how the cabling is arranged. "The [electrical cable] layout is actually 69ft from wing root to the tail as that is what the Boeing 737 has. We recently got the cables laid out."

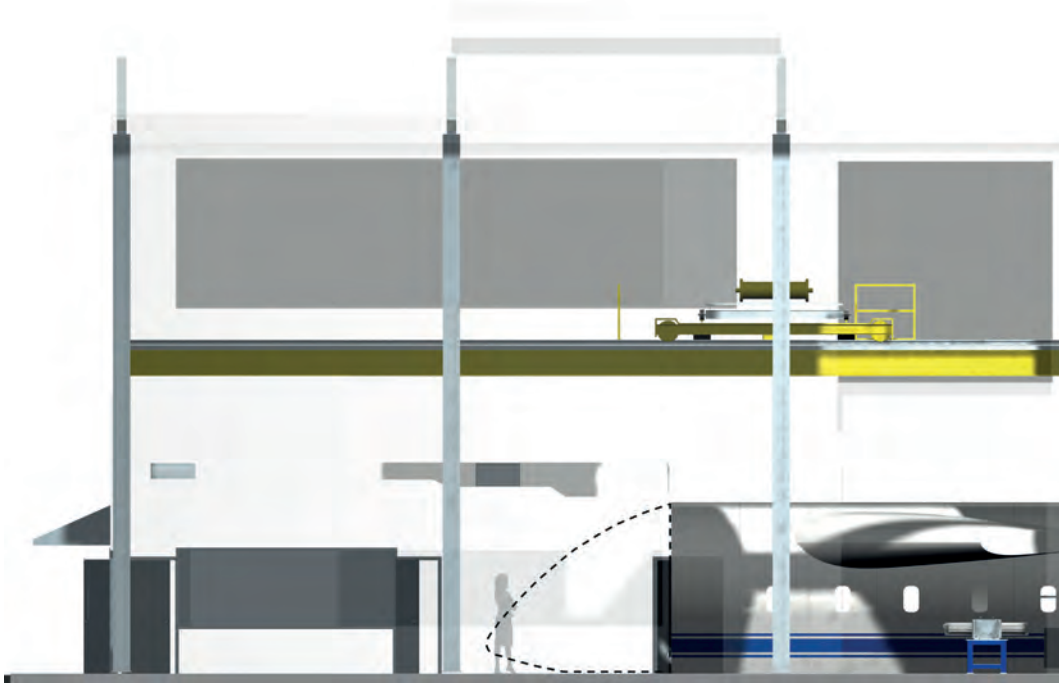
GEAR CHANGE

Despite all this electrification, a core mechanical technology still has a role – the gearbox. "With gearboxes, because they're mechanically coupled, you can have a wide range of voltages and powers on the powertrain," says Dyson. "We don't have to keep changing that part of the facility and we use the gearbox to match different powertrain systems."

That wide range of voltages is "several hundred to 1,000V, but then the powertrain can be any voltage the person who is testing wants to have". That wide

4,500M²
Size of the Airbus E-House (48,400ft²)

25FT
Diameter of NEAT's vacuum chamber (762cm)



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2// Zunum Aero, a Boeing and Jet Blue-backed startup, plans to develop a 10- to 50-seat hybrid electric regional aircraft by the early 2020s

range of voltages, powers and speeds means that NEAT can do research on other types of aircraft. Examples given by Dyson include aviation technology firm Empirical Systems Aerospace's (ESAero) ECO-150 airliner and the US government's Defense Advanced Research Agency's Aurora Flight Sciences Lighting Strike vertical take-off and landing (VTOL) distributed propulsion drone.

After September, Dyson's team are planning a jet fueled turbine generation test, demonstrating that a conventional jet engine can produce energy for the powertrain. Fault management and thermal management research will also take place later this year.

"If you look at the industry overall there is not a whole lot of flight weight, fault management technology for aircraft that has been developed because people have been focusing on motors and on other things, but that is going to be the next thing; system testing and fault management at these high voltages and high powers," says Dyson.

With the high voltages, electric aircraft systems will be hot, and one solution is a source of onboard cryogenic fluid to act as a heat sink. Because electric aircraft will be so fuel efficient, Dyson explains, they will not have enough fuel to act as an adequate heat sink. "In the past year, there has been a lot of development in non-cryogenic power electronics and motors and it's looking like for a 150-passenger type vehicle the answer is, 'No, you don't have to have the cryogenics'." Dyson's team expect to publish their new ideas for thermal management without cryogenics after September – if they can show that they work.

The NEAT building also has an altitude chamber, "25ft [762cm] across and two stories tall". The NEAT team can move an entire powertrain system into the chamber, coiling up the long cables, and can test the entire integrated system from ground level to an emulated 50,000ft altitude environment.

3// The NASA Electric Aircraft Testbed (NEAT) facility at its Plum Brook Station in Sandusky, Ohio, part of the NASA Glenn Research Center

SECOND OPINION

So what about Airbus? How serious is it about pure electric flight? "This is a big investment for us, it shows how serious we are in bringing this technology to reality. We have this ground test facility which is a very big part of our electrification strategy," says Llewellyn. "The capability is quite broad, so it suits a variety of product demonstrator options ranging from 1MW all the way up to 20MW, so it's a vast, very flexible capability that we are developing." Just as NASA will test powertrains for the DARPA Lightning Strike and ESAero ECO-150, Airbus is developing its urban mobility concept of the CityAirbus VTOL taxi.

3

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4// This hybrid electric concept plane is NASA's vision vehicle that is the basis for the research being carried out at its NEAT facility

4

5

5// Siemens' real-time simulation environment for an electric propulsion system, based on a Siemens LMS solution interfaced to a test bench

"We can test full electric vehicles such as those we're developing in the urban air mobility market segment, all the way up to probably more hybrid electric vehicles in the larger aircraft section. We have the capability to have gas turbine generators of 20MW scale inside the building, which can generate electricity as part of a hybrid electric propulsion system," explains Llewellyn.

Airbus is talking to potential partners for the gas turbine generation part of the hybrid propulsion system.

Like NASA, the voltage ranges Airbus is looking to are 1,500V, 3,000V and more. Llewellyn explains that part of the research will be determining what voltage is best for a commercial aircraft. And like NASA, software is being used to emulate aspects of aircraft subsystems.

"The mission simulation system is doing exactly that for the propeller or fan loads that the electric motor will see and we can see the behavior and the performance of the electric motor through the flight phase, from engine start or electric motor start, all the way through to the shutdown."

"We have the capability to have gas turbine generators of 20MW scale inside the building"

69FT/21M
Length of power cables in NASA's copper bird

1,500V
Likely voltage requirement for a B737 or A320-sized electric aircraft

There is one piece of equipment that Llewellyn views as new to an Airbus copper bird facility when compared to a more traditional test rig. "I guess one of the big pieces of test equipment that we'll have that would be different than what we've got in existing Airbus iron bird test facilities are the dynamometers," he says. The dynamometer is connected to the mission simulation system and "can simulate the loads on a fan or on a propeller that a vehicle would experience. It can simulate the loads on the electric motor from engine start through take-off climb cruise and descent, which is one of the quite unique features of this kind of test facility".

Airbus is also examining thermal management, but it is still "deciding what some of those key specifications are". In Llewellyn's view, the way to reduce the thermal management burden is to have more efficient motors, inverters and cabling. This is one aspect of Airbus's work with Siemens.

In April 2016, Airbus Group and Siemens signed a long-term collaboration agreement for hybrid electric propulsion. Siemens will be providing motor and

6

6// NASA personnel at work at NEAT, a reconfigurable hybrid gas-electric propulsion testbed with more than 20MW of power

SINGLE-AISLE CONCEPTS

Airbus and NASA have two different concepts they are developing with their electric aircraft test facilities. They are both for the narrow-body, twin-engine aircraft market and could replace the Boeing 737 or Airbus A320. NASA's concept, the Single-aisle Turboelectric AiRCraft with Aft Boundary Layer Propulsion (STARC-ABL), has a single electric engine – a propulsor – built into the tail cone and receives its electrical power, via a battery, from two conventional jet engines.

Meanwhile, Airbus says that its E-Fan X is representative of the research being done for the future electric airliner it is looking to develop. This concept drives two electric propulsors, which replace the conventional jet engines on the wing, using an onboard gas turbine that generates power that is supplied via a battery. Airbus has another concept that uses distributed propulsion with engines placed at the back of the aircraft, in a radical departure from existing airliner configurations.

7

7// Siemens' eAircraft test bench for high performance electric drive (260kW) is equipped with an SP260D electric motor with high power density (5.2kW/kg)

inverter related subsystems for the E-Aircraft Systems Test House. Siemens' head of systems test in its electric team, Marcus Bauer, tells *Aerospace Testing International*, "We are connecting this [physical test] environment to a simulator environment and then collecting this data for analysis and putting it back into our simulation models." Siemens is also using digital twins. This is where the physical prototype has a computer model twin. Data from the performance of the physical prototype is then fed into the computer model to make it more accurate.

Bauer sees certification of these hybrid electric propulsion airliners as a great challenge: "What is a big challenge is certification, as were going into a new domain and it is not clear what will be the certification. This is why we test systems against today's standards and sometimes it's a new area where nothing [in terms of standards] has been decided."

"We will need to collaborate quite openly with other partners"

Llewewllyn agrees that these are "extremely ambitious projects and in order to make them happen, we will need to collaborate quite openly with other partners, whether it's research institutes or industrial partners [such as Siemens]".

A team from Airbus visited the NEAT facility in June, and NASA's Dyson anticipates a lot of collaboration. "They were here to look at our test facility. One of the challenges has been trying to figure out where are the areas where we can do pre-competitive collaboration. It's something we're trying to figure out – how do we get everybody to work together for safety and certification. Other areas are more sensitive."

Llewellyn confirms that Airbus has visited NEAT and says, "As we develop this capability and as we bring these technologies to implementation, we're interested in expanding the partnerships that we've got, making them broader across both Europe and the USA." \\

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See full program on p.82

Volt future aircraft: ©NASA/BOEING/SCIENCE PHOTO LIBRARY

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With personnel embedded in key positions within the RAF's ongoing Typhoon development and test program, a UK company continues to carve an impressive niche in the delivery of high-end defense capabilities

Private

Lincoln, UK-based Inzpire received a Queen's Award for Enterprise: Innovation in 2014, for its Graphical Electronic Cockpit Organiser (GECO). Using purpose-designed apps accessed through a ruggedized tablet device, it's a powerful mission system with additional potential for delivering advanced training to experienced operators. As a cost-effective, proven system, GECO has gained considerable traction in its air and land forms, and although it remains Inzpire's only real 'product', it neatly encompasses all that's special about this unique company.

After little more than a decade in business, Inzpire has become a haven for ex-military personnel. With roles across the UK defense sector, Inzpire's primary involvement is in training at the individual, squadron and organizational level, but within its multiple other capabilities, a small cadre of personnel is deeply embedded in the Royal Air Force test and evaluation community.

A former RAF Tornado navigator and squadron commander with more than 2,000 hours, 70% of which were flown on operations, Jim Mulholland heads Inzpire's Integrated Sensors and Systems Division. The company's unique selling point is the quality and vast experience of its subject matter experts (SMEs), a careful recruitment policy enabling it to gain a core competence in systems integration, with particular expertise in radar, defensive aids, and information and weapons systems, extending from concept origination through to system test and analysis.

PERFECTLY PLACED

It's surely no coincidence that Inzpire's HQ is just a few miles from the RAF's intelligence, surveillance, targeting and reconnaissance (ISTAR) hub at RAF Waddington. The station is also home to the Air Warfare Centre and Air Battlespace Training Centre, where Inzpire personnel are integral to the teams developing, testing and training tactics with operators across all three armed services.

Royal Air Force Coningsby is also close by, housing two frontline Typhoon squadrons, the jet's operational conversion unit and 41 (Reserve) Test & Evaluation Squadron (TES), the latter responsible for service trials on new hardware and software for Typhoon and Tornado, as well as tactics and other test work.

1 // Inzpire personnel play key roles in RAF Typhoon weapons integration *(Photo: LAC Lloyd Horgan/ UK MoD)*

2 // Inzpire personnel work closely with BAE Systems at Warton, where Typhoon projects include the E-Scan radar *(Photo: BAE Systems)*

3 // The definition and, ultimately, the testing of E-Scan will inevitably involve Inzpire expertise *(Photo: BAE Systems)*

"We invariably find issues that industry has been unable to find"

The unit offers fertile ground for Mulholland's people and a core team is embedded in 41(R)'s building, along with other industry partners and 'blue suits' – serving RAF personnel. There are Inzpire personnel within the co-located Typhoon Mission Support Centre (MSC), where the mission data crucial to Typhoon operations is the lifeblood of day-to-day operations, but there is also considerable synergy with 41(R)'s trials work.

Mulholland explains, "The team sitting on 41(R) is contracted for Air Command capability delivery through DE&S [the Defence Equipment & Support organization]. While we also have a team in the MSC, ideally the setup at the MSC works hand-in-glove with the team on 41(R), testing new software on Coningsby's Typhoon Weapons Systems Software Rig – the WSSR [pronounced 'whizzer'] – ironing out problems before the squadron flies it.

"We invariably find issues that industry has been unable to find, because it designs and tests to a certain level toward a specific aim; it doesn't test with an operational military frame of mind since it has different drivers to us. So when we get something to the WSSR, our guys look at it in a different way and start identifying issues, which can flow back into the process for industry to begin looking at.

"Ideally, if the WSSR and MSC processes have enough people, equipment and time, we could probably iron out an awful lot of problems and avoid wasting valuable flying time on 41. Because when we give it to the aircrew, they stretch it to another level yet again. They look quite differently at a product that's been delivered against a contracted systems requirement document specifying certain capabilities within a certain envelope.

"They test the true envelope, as opposed to the spot points industry has had time to test to, and it's a natural part of the process that they'll find different problems. We play a role in reducing those problems through our teams at the MSC and on 41, because our people have seen the process many times, seen similar problems, and fed them back at an early stage or more quickly."

The nature of Inzpire's relationship with its military customer precludes discussion of individual product testing in detail, but considering a 'new sensor' for the purpose of illustration, Mulholland says its personnel would be involved in the test work at an early stage, ensuring that any observation is shared with the appropriate MoD stakeholders.

115
Employees as of early July, but Inzpire is growing steadily

8
Approximate number of Inzpire personnel with 41(R) TES and MSC at RAF Coningsby

16
Inzpire staff working in support of the Typhoon Project Team, 41(R) TES and the MSC

4 // Inzpire's Meteor subject matter expertise ensures program continuity between industry and the Ministry of Defence *(Photo: Bryan Walsh/BAE Systems)*

"They'll have a conversation with 41 Squadron, out of earshot of the supplier, if you will, and 41's team passes the message back through the appropriate RAF route," explains Mullholland. "But our guys are actually involved way before; some of my team are now working with industry, on the E-Scan radar for example, looking at the generation of that new capability at this early stage. They listen to what the companies have to say about their products and with their huge number of flying hours and significant experience in the military world, they recognize what some of the realities of those potential capabilities are."

COLLEAGUES REUNITED

The scenario works particularly well because the majority of Inzpire's personnel are working in a familiar environment, often with former colleagues – one recent Inzpire recruit said he was effectively doing the same job in different clothes, with the added security of knowing he would be able to spend plenty of quality time with his young family without potentially having to uproot them every couple of years to follow postings. The very quality that leaves the RAF's people so agile and capable, the system of posting them to new jobs every two or three years, is one that becomes less appealing for some as they get older.

It is one that ensures 41(R)'s personnel are never too far removed from the requirements of the frontline, while the unit's mix of test and evaluator aircrew also helps maintain the connection with the operational units.

Conversely, continuity of personnel brings considerable benefit to test programs that easily run through a posting and beyond. In this case, Inzpire's people offer that continuity; some will have worked the program as RAF personnel, taken their natural option to leave the service, then returned within days or weeks at most, to continue their test work.

As personnel approach the natural option points in their RAF careers, typically where they decide whether to continue on the promotion path, or leave the service, Inzpire is careful to make the opportunity it represents known to those it's keen to recruit. Mullholland emphasizes, however, that there's no formal approach or offer until an individual has informed RAF manning of a decision to leave.

In the instance of Typhoon capability, it means that smart, highly experienced operators with in-depth, perhaps even world-leading knowledge of a particular system and its test history are not lost to the program. Mullholland sees it as a means of continuing to contribute to a service and community about which he remains extremely passionate. But he also admits that the frontline knowledge Inzpire's personnel deliver on day one quickly erodes, since the operational tempo at the frontline easily outpaces the test community, and as civilians they no longer rotate back onto a combat squadron.

It's a catch-22 situation that the military system of posting solves by exactly the same means that leaves continuity in test programs so difficult to achieve. But since the Inzpire personnel embedded on 41(R) and in the Typhoon MSC are ex-RAF, they speak the language of the frontline, they're cleared to very high levels of security, and when new folk are posted into the test community from the frontline, their experience is shared and disseminated in a process that makes Inzpire's smart, highly experienced people even smarter.

CLOSE QUARTERS

The result of Inzpire's careful recruiting and the confidence its employees inspire is evident in 41(R)'s daily routine: "We work as closely as possible with our customer, the RAF, with no other agenda other than to help them get that which they require to look after people flying on the frontline, people we know because they used to be our colleagues," says Mullholland.

MULHOLLAND'S DRIVE

"I had my career all planned out," Jim Mullholland, head of Inzpire's Integrated Sensors and Systems Division, says. "I wanted a full career up to the age of 55. It was my mindset from the beginning, I wanted to be a qualified weapons instructor, squadron boss and then a station commander, and ultimately I had an eye on my ideal job at the Air Warfare Centre."

But instead of taking a promotion from wing commander to group captain and the plumb job at RAF Waddington, Mullholland moved across to Inzpire, for a simple transition into similar work at a similar level, with benefits to family life that for him were more important than continuing what had been a happy and successful military career.

Involved in every RAF Tornado operation from Kosovo, in 1999, to Afghanistan in 2014, he also brought with him extensive development and trials knowledge, having been involved in the processes that brought every current RAF Tornado weapon into service. He also wrote the user requirement document for the forthcoming SPEAR (Selective Precision Effect At Range) missile, with which he remains involved at Inzpire.

5 & 6 // Through Inzpire, the RAF and industry benefit from decades of accumulated Typhoon knowledge *(Photo: LAC Lloyd Horgan/UK MoD)*

"To do that, we work alongside QinetiQ, DSTL [Defence Science and Technology Laboratory] and others of course, but my guys also go to 41's morning and weekly briefings, and have input into those meetings, because they're all well-known to the squadron and the trust they had before in the military continues through to the work they do today.

"At the same time though, we are a commercial organization and we spend a lot of time ensuring we do the right thing in terms of the commercial relationship, making sure we don't overuse any personal contacts. As a small company, we make sure we're whiter than white in that regard."

The relationship is fundamental to Typhoon development and test: "One of my guys is the requirement manager for the Defensive Aids Subsystem [DASS], for example. It's a contract we won and have satisfied with a single individual for more than a decade, providing specialist continuity in the role. He has all the benefits of his previous EW [electronic warfare] experience, 10 years' experience gained in the program and the shared knowledge of RAF personnel rotating in from the operational squadrons.

"And because he's at 41, he's at the cutting edge of the DASS thought process. His role in requirement setting alongside Air Command is key in securing and keeping funding. His responsibilities include program managing the DASS trials, working with the squadron's trials management officers, ensuring trials are conducted to achieve the objectives needed to test against the requirement.

6

1,700
Total years of military experience notched up by the Inzpire team

200,000
Estimated cumulative flying hours of the whole Inzpire team

5

Ideally, he's involved in the process all the way through.

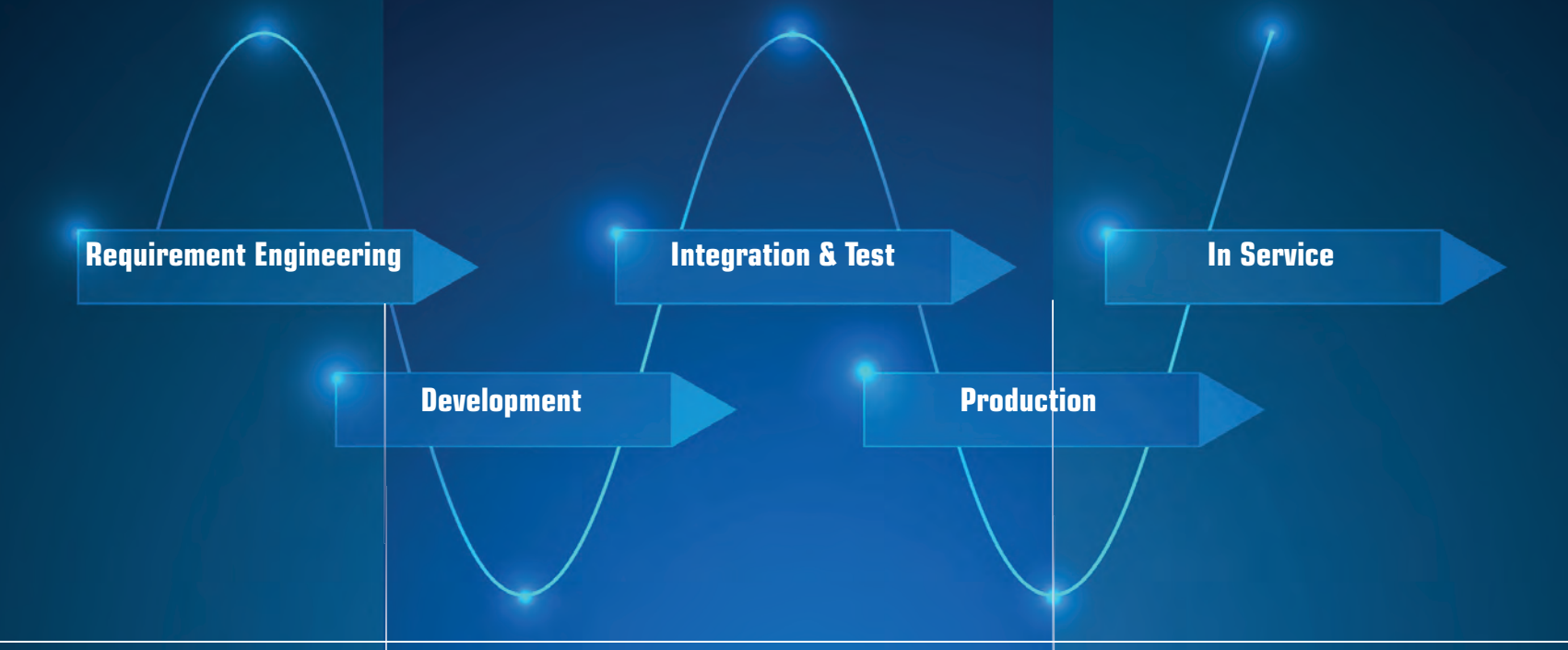
"We have someone else similarly embedded in the Meteor program and we've previously done it with ASRAAM and other weapons 41 Squadron has looked at. Could others do the same work? Yes, of course. But no one does, not in the same way. Meanwhile, we enjoy our relationship with DSTL and QinetiQ, each with their strengths and unique points, all of which makes 41 a great example of the RAF's 'Whole Force' concept.

"This group of people, who deploy around the world when required to test in particular environments, know what their aim is. It's to deliver the best capability they can and help with the tactics, techniques and procedures that their colleagues need on the frontline. And where something doesn't perform, they don't hold their punches in terms of reporting that failure.

"Having said that, I don't think it's until something undergoes that level of scrutiny and testing that some issues come to light. So 41 and ourselves work very, very closely with the Typhoon test team at BAE and the Typhoon Avionics Joint Team on software development, computers, displays, and so on. And based on our daily interaction with 41, we can help them understand what the guys would like to see and help the requirements process through the appropriate channels.

"Critically, our people provide continuity not only on 41, but also with our industry partners," concludes Mulholland. "They spend a lot of time at BAE's Warton facility, talking with the test team there and making relationships, ensuring that when a new RAF person is posted in, the knowledge and experience of their predecessor isn't lost to the program." \\

"41 and ourselves work very, very closely with the Typhoon test team"



MDVS Model-based Development & Verification System

VSIB Virtual System Integration Bench

SDIB Single Device Integration Bench

SIB System Integration Bench

FIB Functional Integration Bench

FAL Final Assembly Line Tester

PAT Production Acceptance Tester

IST In-Service Test Bench

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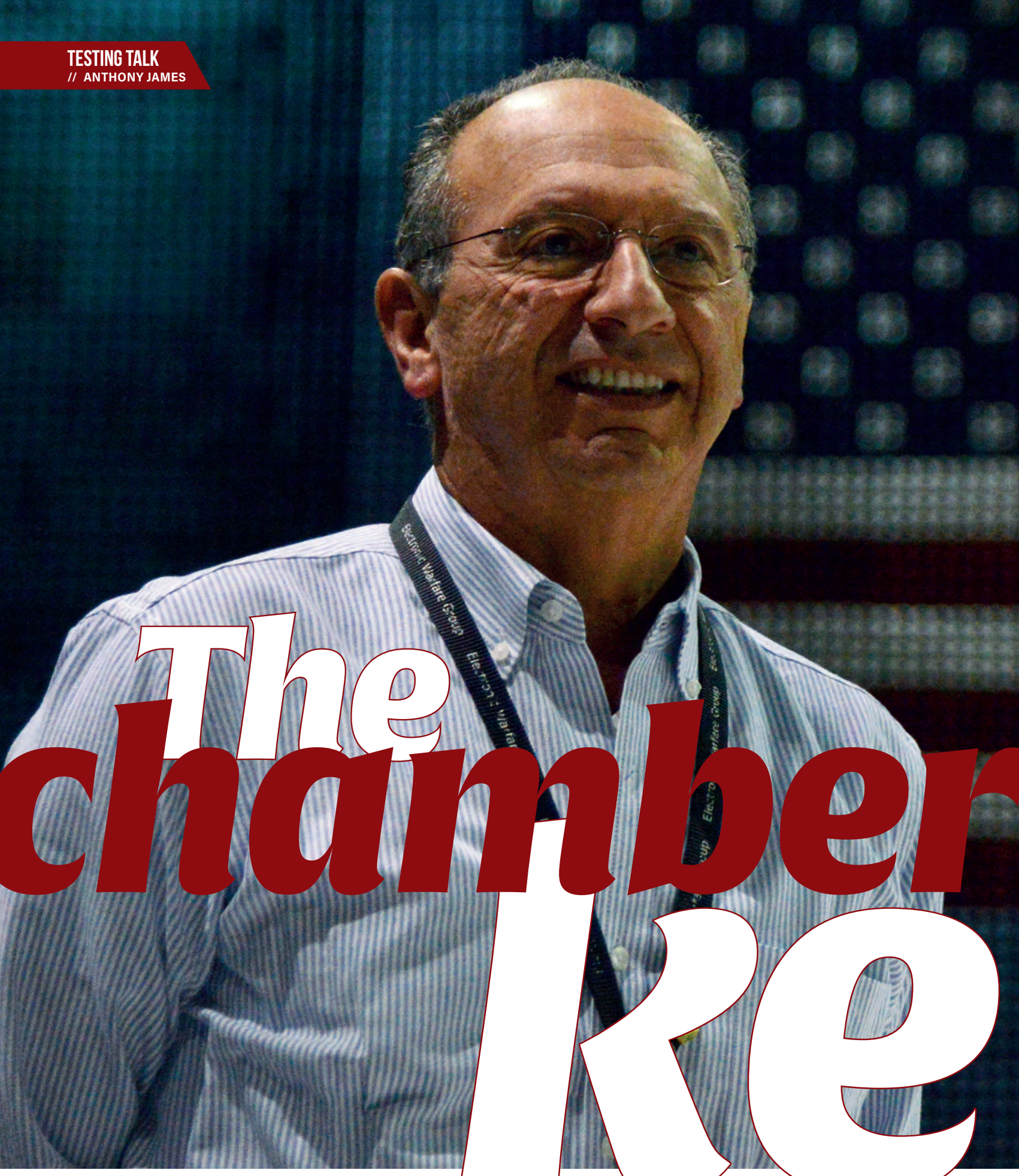


The chamber Re

MEET ED SABAT, PROJECT DEVELOPMENT LEAD AND CIVILIAN DIRECTOR OF OPERATIONS AT THE BENEFIELD ANECHOIC FACILITY, THE WORLD'S LARGEST ANECHOIC CHAMBER

epe

1 // The BAF, located at Edwards Air Force Base, California, is the world's largest anechoic test facility

1

// HOW DID YOU BECOME A TEST ENGINEER?

I was assigned as a test engineer on the B-1B programs back in the 1980s at Edwards Air Force Base (AFB) for the defensive avionics systems developer. Being around all of the various test programs of the 1980s and 1990s at Edwards and NASA Dryden [now Armstrong] was very interesting. Proving out new systems or discovering and correcting a problem, then seeing these new capabilities working in flight, is satisfying.

// WHAT WAS YOUR FIRST TESTING JOB?

Tasks involved testing the defensive avionics of the B-1B system at the integration lab at Edwards's Integrated Facility for Avionics Systems Test (IFAST) and then doing mission simulation. Additional testing and simulation was performed at the installed systems test level on the flight line. We designed test capabilities to enhance the test environment at the aircraft to perform installed systems level prior to committing to flight test at the ranges.

Eventually, at the latter part of the B-1B development program, the Air Force built what is now the Benefield Anechoic Facility (BAF) specifically for the B-1B and we tested the complex defensive avionics. The BAF has grown to a much more powerful comprehensive tool for the test of just about any system on any platform for many types of tests.

Back then, the test equipment available was not as easy to use or as capable as with today's technology. Simulating electronic threats or radars was very crude compared with the fidelity available today.

// WHAT WERE THE MOST VALUABLE 'EARLY LESSONS' FROM THOSE FIRST YEARS?

Often developers tend to take shortcuts when it comes to T&E. They often feel testing is too expensive and only causes delays to their schedule-driven programs. However, the lesson that has always proven true is that thorough testing at each development phase is necessary and less costly in many ways than finding shortfalls or failures in the latter phases or after deployment.

// WHAT IS YOUR CURRENT POSITION?

I presently do project development, which is the initial interface between customers and our senior subject matter experts, program managers and various experts for the diverse capabilities. It is sort of analogous to business development in industry. It also involves pursuing and tracking new candidate programs that would benefit from the BAF.

// DESCRIBE A TYPICAL DAY

Each day is different, each program is different, of course, but a 'typical' day would normally see our engineers, along with our program managers, gathering information about the system to better understand the test requirements for the system for which they are designing an anechoic chamber test. This involves close coordination with the customers' engineers throughout the test planning phases from the early stages through the execution phase. A BAF engineer then coordinates internally with the experts of our simulation, emulation and measurement test systems to design and set up the chamber and each test condition. The BAF is typically testing a different system on a different platform with different test requirements than the prior test. There is no routine, repetitive process from test to test. From utilities, hydraulics and cooling required to power up an aircraft, to the various RF considerations, threat environment, chamber setup, digital and RF data monitoring and collection, security, and safety, it is the job of the test engineer to orchestrate all the pieces for the chamber test.

They follow and document a test discipline that optimizes the production and collection of the data,

"Often developers tend to take shortcuts when it comes to T&E"

which is our primary product. This is what the customer is seeking at the BAF. This involves many technical meetings and other communications and then there is also technical and safety review/sign-off that must be accomplished by our engineers.

// WHAT MAJOR PROGRAM(S) ARE YOU CURRENTLY WORKING ON?

A lot of our efforts today are on BAF upgrades and modernization programs to meet the test requirements of the fifth-generation fighters and other advanced systems and, of course, the legacy systems and their ongoing upgrades. These BAF modernization programs are integrated into our schedule with several aircraft programs in the initial to various planning stages. Recently, that is within the last couple of years, though, we have had programs with the F-35, F-16, B-1B, B-52, KC-46A, an operational Navy HARM and NGJ.

// WHAT ARE SOME OF THE SPECIFIC EMC/ AVIONICS TESTING CHALLENGES INVOLVED?

The benefit of testing in an anechoic chamber is the ability to control the behavior of the RF and its interaction with the test facility. The idea is to create an RF environment within a secure and RF-controlled chamber that approaches being in flight where there is no RF reflection. It is always a challenge to provide that environment for each different weapons platform and its various RF subsystems across a wide frequency range. You then have to design and set up the desired electromagnetic environment consisting of the system under test (SUT) – usually an air vehicle – emulators, stimulators and monitoring systems, to create each test condition, which may be hundreds or thousands of conditions for a given test.

Each system and its test requirements presents a different challenge. Rarely, if ever, is the next test the same type as the previous one...

// WHAT MAKES THE BAF UNIQUE?

The BAF has, of course, in itself, a uniquely large anechoic chamber that is 264ft (80.5m) by 250ft (76m) by 70ft (21m). It supports an 80ft (25m) diameter, 175-ton capacity turntable and two 40-ton hoists.

The size of the chamber is an important feature, not only to accommodate large aircraft, but for its RF properties. Primarily the space of volume of the chamber provides much better isolation (free-space scatter loss or attenuation) between SUT and the facility. Also very importantly, it expands the frequency performance and allows far-field antenna measurements over a wider frequency and aperture range. Thirdly, we are able to handle higher power systems with less restrictions or the use of vented high-power radiation absorber material (RAM).

Then there is its RF simulation/stimulation/ emulation suite – comprising a robust free-space EW threat, a communication, navigation and identification (CNI) test system, data link interactive systems, radar target generators and a GPS scenario simulator. These are used to create a 'near-real world' RF picture for the SUT in a specific region.

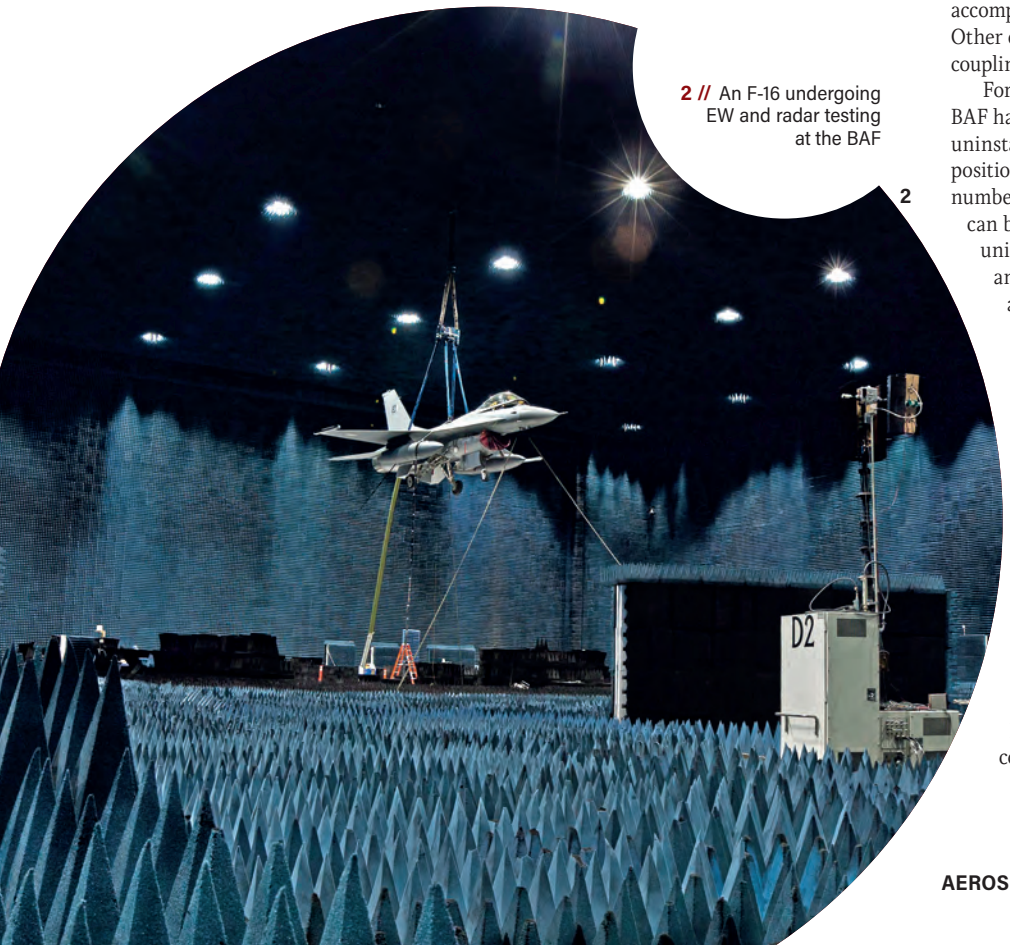
On the EMI/EMC side for the RF compatibility and susceptibility we have EMI receivers and measurement systems along with a high-power RF system for compatibility and susceptibility tests such as high-intensity radiated fields (HIRF). These are used to accomplish MIL-STD 461 and MIL-STD 464 type tests. Other equipment is maintained for antenna-to-antenna coupling or isolation tests.

For unique antenna measurement capabilities, the BAF has various equipment for installed (on-aircraft) and uninstalled antenna tests. These include high-accuracy positioners and high riser stacks to accommodate a large number of test configurations and geometries. These can be integrated with the turntable or the hoist for unique flexibility for different types of SUTs. The antenna measurement system is integrated with a comprehensive RF matrix that allows up to 16 antennas simultaneously if the need arises for efficiency.

The BAF also has the utilities to support a broad range of aircraft and their subsystems. These include the electrical power (AC and DC), air and liquid (various) cooling and hydraulics, for full-up aircraft operations without the engines running.

// YOU RECENTLY HAD THE KC-46A IN THE BAF – HOW WAS THAT?

The KC-46A involved a long-term planning phase that we teamed up with the Naval Surface Warfare Center – Dahlgren Division, Virginia E3 team, to satisfy Boeing, DoD and FAA requirements. These involved emissions control (EMCON), RF shielding and HIRF tests.



2 // An F-16 undergoing EW and radar testing at the BAF

3 // A Boeing KC-46 Pegasus is loaded on the rotating platform at the BAF for a series of avionics tests that took place this May

This was a high-visibility program with a tight schedule. The BAF was chosen for this test due to its ability to support such a large aircraft along with the large associated equipment to conduct these types of test. In the past, for other large platforms, these tests were done outdoors. The indoor test took approximately four weeks, versus months as it would outdoors. This is mainly a result of longer test hours available for the free-space RF radiation indoors where the weather was not a factor and there are no regulatory agency restrictions or clearances to radiate that result in short test windows overnight. The quiet indoor RF environment also facilitates more efficient and accurate RF measurements at the accuracy and margins needed for this aircraft's test requirements. Part of the HIRF test with the engines running [three nights] was conducted outdoors at Edwards supported by the same team.

The Navy, Boeing and BAF team members worked two shifts to accomplish this extensive electromagnetic environment effects (E^3) test efficiently and finish ahead of schedule in spite of delays due to aircraft maintenance requirements that were not foreseen.

Many deserved compliments are due to this team for their accomplishment to first have the insight to plan a highly more efficient indoor test never accomplished before, and then successfully execute it virtually flawlessly to support this high-visibility major developmental test program.

// HOW LONG IS A TYPICAL EMC/AVIONICS TEST AND HOW IS DATA CAPTURED AND STORED?

Typically tests take two to four weeks, but we have had customers take advantage of the unique capabilities to do a large amount of developmental testing and experimentation for as long as 12 weeks.

Depending on the test requirements, the BAF is instrumented to capture the digital, analog, video or RF data. This is done with our unique or commercial off-the-shelf instrumentation. There is a fiber-optic network that allows collection and distribution of the data from the SUT to where it is needed or recorded. Real-time display in the control room is also possible at any of the 26 test conductor stations or on the large displays on the wall.

Our engineers and technicians work with the customers to support the data collection, display and recording with each customer with our equipment, or by hosting the customers' test instrumentation. We support such data as MIL-STD 1553, Ethernet, video and analog or digital discrete parameters, but the facility is adaptable to what the test requires, or to match what the customer typically would have in their lab or system integration lab (SIL). We work to accommodate data instrumentation wherever it is technically feasible.

A customer may walk out of the BAF with terabytes of EW, antenna pattern, or other data. It really depends on the system and its requirement. But it is worth noting that due to the efficiencies in the indoor installed systems test, test execution and data collection is multiplied by orders of magnitude versus what is possible to test in flight.

// WHAT IS THE LARGEST AIRCRAFT TO VISIT THE BAF?

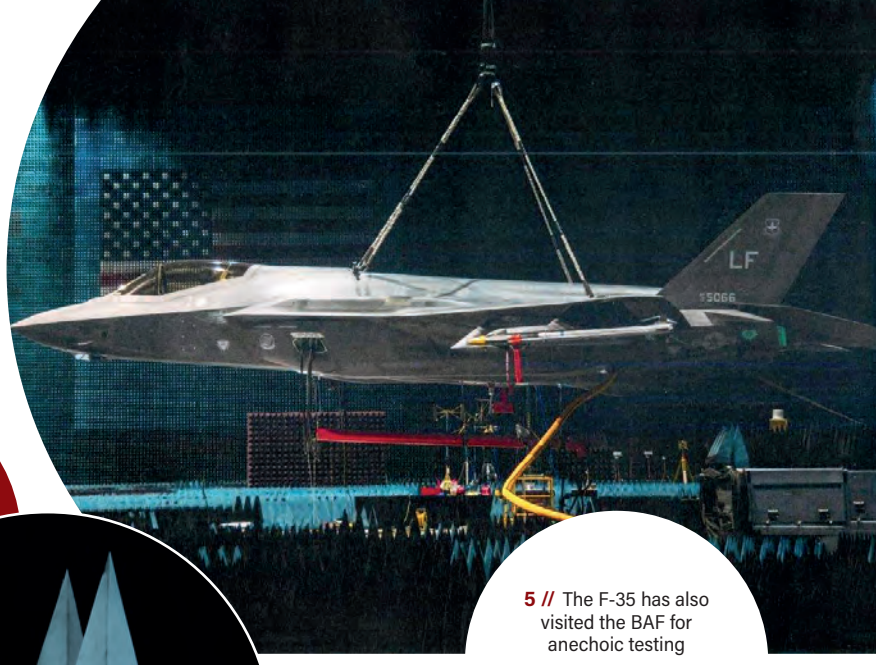
The largest aircraft, other than the KC-46A (767-200 based), that comes to mind is the C-17, B-52, E-3A. The chamber RF door is approximately 200ft wide by 64ft high, so we are presently limited by these dimensions from bringing in such aircraft as the C-5, for example. With respect to the turntable, it is 80ft in diameter [the landing gear footprint must fit within this diameter] offset from the center of the chamber, so that presents some limitation with respect to rotation of large aircraft that do fit in the chamber. For example, the KC-46A does fit in the chamber on the turntable, but we could only rotate it 290°. Nonetheless, this was an enormous capability that added to the efficiency of the test as it was possible to quickly rotate the SUT and not have to relocate large test systems for various geometry and aspect angle requirements.

"We have a hoist upgrade program to add to the present 40-ton capacity"

We have a hoist upgrade program to add considerably to the present 40-ton capacity. There are no plans to upgrade the turntable.

// HOW HAS EMC/AVIONICS TESTING CHANGED OVER THE YEARS?

Today's systems are more sophisticated and smarter. Demands on the simulation fidelity and quantity have increased, along with the improvements to the avionics systems. The BAF test capability suite has always been



5 // The F-35 has also visited the BAF for anechoic testing

developing with the evolution of the avionics systems and host platforms. Additionally, it has to evolve with the real-world threat environment we have to simulate. The BAF has been recently upgraded with newer threat-generation capabilities and in the next two to four years will add extra capabilities to its free-space simulation and radiation systems that take advantage of AESA technologies and the latest threat-simulation system technologies. This will improve our threat fidelity, density and flexibility for EW tests.

Other areas involve the capability to monitor and respond to the SUT RF system's more sophisticated emissions with higher accuracies and resolutions. The BAF has made improvements and has future plans in this area.

4 // Ed Sabat pictured next to some of the BAF's signature blue foam spikes

// WHAT NEW TECHNOLOGY HAS HAD THE GREATEST IMPACT ON YOUR WORK?

For me personally, having been in the T&E community for so long, it has been, as within all other industries, the evolution of the RF materials, equipment and electronic miniaturization. Field programmable gate arrays, for example, have continually transformed the test equipment, the systems this test equipment is testing, and the data collection and processing.

// HOW HAS TESTING EFFICIENCY IMPROVED?

The BAF team is constantly looking to improve efficiencies and throughput for the BAF. Automation of calibrations, data processing, and standardization of any processes that can support a cross-section of our diverse customer base, are areas that have been addressed by our leadership and team. Doing a lot, if not all, of the calibration, probing, setup and connectivity of the chamber and BAF systems prior to the arrival of the SUT is a major saving to the test program.

Also helping the customer understand chamber testing versus lab or flight testing is important. This is accomplished with good communication and documentation practiced prior to the SUT arrival at the facility.

See the BAF website at **www.edwards.af.mil/Units/772nd-Test-Squadron/** for more on 412 Test Wing 772d Test Squadron's unique capabilities

// WHAT DOES IT COST TO CONDUCT A TEST AND WHEN IS THE NEXT SLOT AVAILABLE?

The cost of a test depends on the number of test support systems required by the customer's test requirements and the number of test conditions driving the time in the chamber. Another factor is the level of new programming and customization required for the particular test, which will drive engineering hours and possibly material costs.

In terms of availability, our next slot isn't available until calendar year 2019. However, openings are constantly popping up as development program schedules change. The BAF has been used by the DoD, private defense industry, and others including the automotive industry, foreign military customers and partner nations.

// HOW WILL EMC/AVIONICS TESTING CHANGE IN THE FUTURE?

Modeling and simulation (M&S) has played a major part in improving testing and understanding what, how, and how much systems need to be tested. So we see M&S as a tool to improve and complement hardware testing, especially at installed systems test level. Installed systems testing, both ground and flight, can be expensive and time consuming if not planned properly or in the blind. M&S helps shape and define the requirements.

Conversely, the data from the installed systems tests is used for model validation and enhancement for both the developmental and operational communities. There are mutual benefits and we don't feel it will make 'physical' testing redundant – but complementary. Just as chamber testing will never replace flight testing, M&S will never replace installed systems testing. Together, they are effective in reducing program risk and cost, while also increasing the confidence level in the performance of our weapons systems.

Testing in the future will rely on smarter use of test resources and this involves the use of newer techniques and technologies to improve the M&S environment. M&S is also a helpful tool in the design and setup of our chamber test configurations. This can be helpful in RAM laydown plans, test equipment selection, and other RF predictions needed. Another is, for example, our Digital Integrated Air Defense, which is a mission-level M&S environment that can be used to generate the scenarios and threat laydowns for the BAF RF free-space simulation systems. \\

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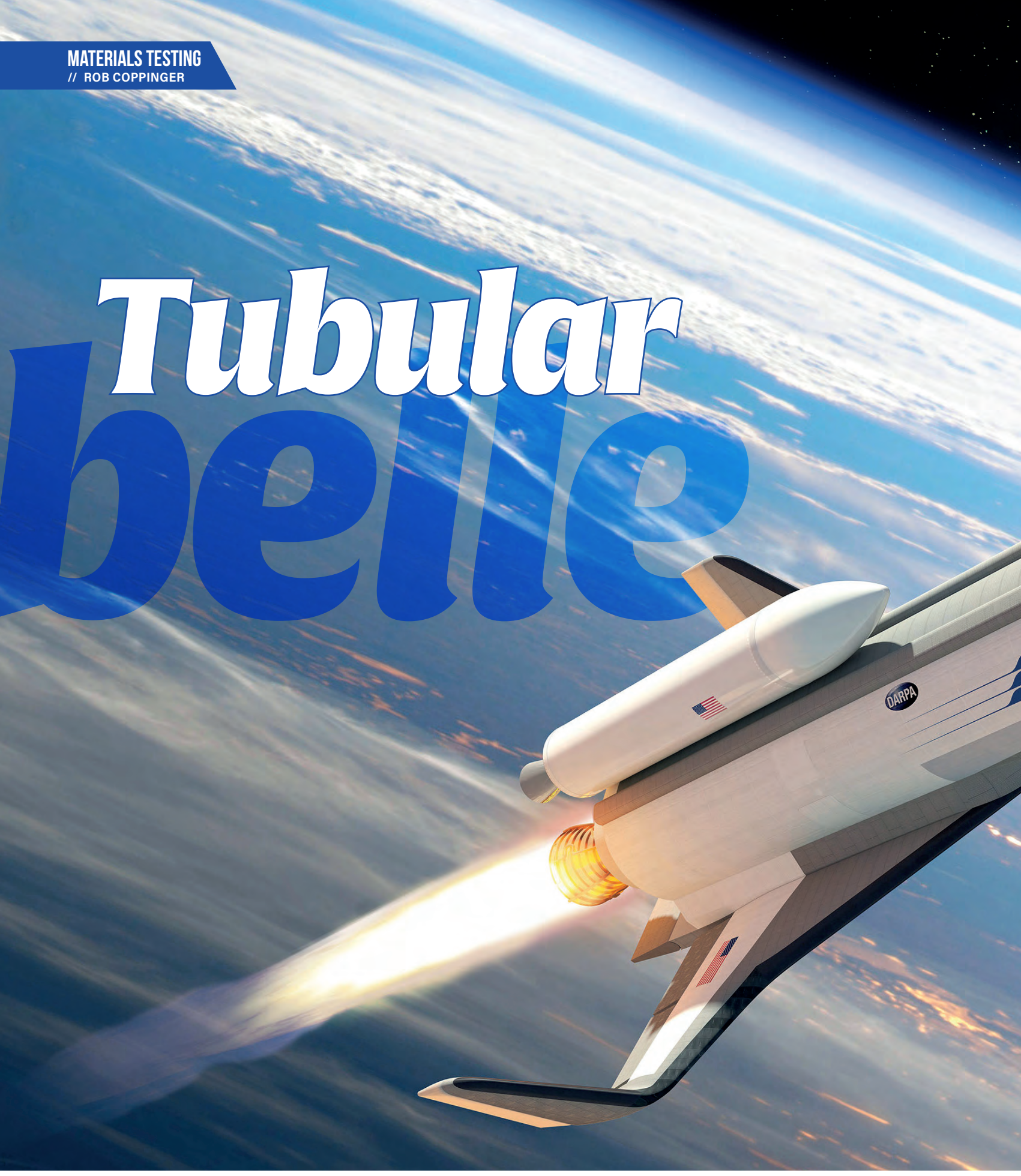


NASA has been getting to grips with a new nanotube fiber that could deliver radical weight improvements for structures used in space launch vehicles

1 // Future space launch vehicles such as Boeing's Phantom Express could benefit from the weight saving properties of nanotubes

Sending a nanotube composite structure on a suborbital flight for testing was the most exotic trial yet for this unique material and its success promises rockets that are much lighter than today's launchers.

"If you could come up with a composite that was twice as strong as normal [carbon fiber] epoxy, you could reduce the mass of the rocket by 30%; that is a killer app," NASA Glenn Research Center lightweight materials and manufacturing program manager, Michael Meador tells *Aerospace Testing International*. "We were able to get pretty close to that 2x [with nanotube fiber composites]."

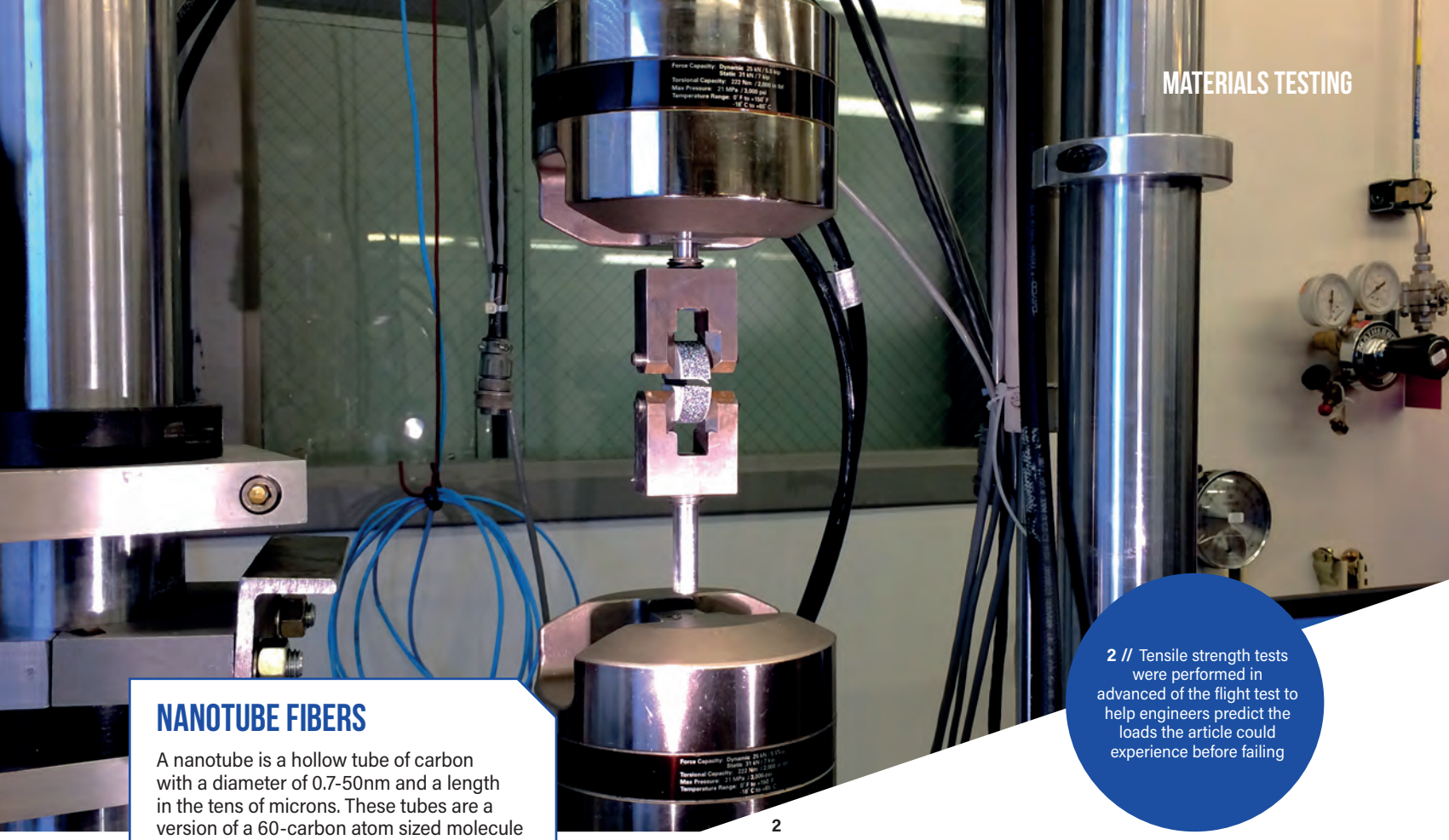
Meador's team was able to determine how close they got to that two-times strength improvement using standard strength, modulus and load-bearing testing, such as D-ring tests, as outlined in ASTM International's standards. ASTM International, formerly known as the American Society for Testing and Materials, provides testing standards information. Non-destructive and destructive testing was also carried out on the nanotube composite, including burst tests. However, there was one problem related to testing that had to be overcome – fixing test samples to the testing fixtures.

"The big challenge with the [nanotube] yarns was in gripping them. We were having issues with yarns pulling out of the cardboard tabs that we used to put them into the fixturing, so we did go back and change the [test] fixturing to deal with that," explains Meador. The nanotube yarns (see *Nanotube Fibers*, page 61) were the basis for the fibers that made up the composites.

CONSTRUCTION TECHNIQUES

Like conventional composites, the nanotube fibers are encased in a polymer resin – a matrix. "You use the carbon nanotube fiber as a drop-in replacement for more conventional fibers," Meador says. He added that the resin his team used was a typical type used for carbon fiber composites, but a different resin might be able to further enhance the composites' properties.

In NASA's May 15 announcement about its nanotube composite work, materials research engineer Emilie

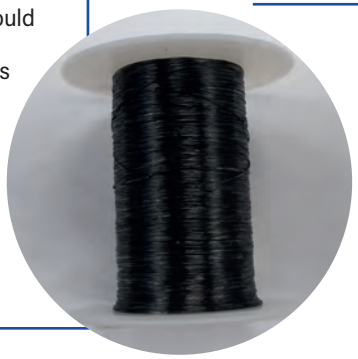


2 // Tensile strength tests were performed in advanced of the flight test to help engineers predict the loads the article could experience before failing

2

NANOTUBE FIBERS

A nanotube is a hollow tube of carbon with a diameter of 0.7-50nm and a length in the tens of microns. These tubes are a version of a 60-carbon atom sized molecule structure called a Buckminsterfullerene, or buckyball, which was discovered in 1985. In 1996, a Nobel prize was awarded for its discovery. As a material, nanotubes are 200 times stronger and five times more flexible than steel, and are very efficient conductors of heat and electricity; they have great potential for engineering applications. One of the Nobel prize winners, the late Richard Smalley, worked with NASA to solve a major problem with nanotubes – their production. In the 1990s, only a few hundred milligrams of tubes could be made at a time. Over time their production rate increased and by 2011 NASA had begun working with a New Hampshire based business called Nanocomp that produced the yarns and sheets of nanotubes used for the fibers for NASA's composites work. The space agency worked with the company to improve its processes to ensure the yarns provided the strength and elasticity promised by nanotubes. NASA then had to overcome production problems with the composites because the nanotubes would conglomerate and not have an even distribution through the composite. This meant the potential strength and other improved properties were lost. It is in the last five years that NASA and its partners have managed to overcome these many problems and create the fibers that can be used to make aerospace structures.



30%
Likely weight reduction of a rocket made using nanotube fiber composites

200X
Strength increase of nanotubes compared with steel

-45°F
(-42.7°C) Level of low-temperature testing for nanotube fiber samples

0.7NM
Diameter of a nanotube

Siochi said, "This represents the first large item that we've built by turning nanotube yarns into composites. We had to improve the properties, improve the quality and the quantity."

One of the reasons a 30% lighter rocket would be possible is because nanotube fiber composites do not obey the rule of mixtures that is known to typically govern conventional composites' strength. "Nanotubes lead to an unusual mechanism for load transfer that gives rise to properties in the composite that are better than carbon fiber. It was a pleasant surprise," Meador explains. That unusual mechanism operates at the nanoscale and the macroscale.

It is this nanoscale mechanism that the conventional composites made of epoxy resin and Kevlar, carbon, or glass fibers lack to the same degree. The nanoscale interface between the individual nanotubes in their fiber bundle and the usual epoxy matrix of a composite is what provides the better load-bearing properties. In addition, the interface between the nanotube fibers and the epoxy matrix at the macro level also contributes. While nanotubes are 200 times stronger than steel and five times more elastic, when they are included in the composite, that relative strength and elasticity falls considerably, which is why Meador's team have not quite achieved a 2x improvement in composite strength.

> ***"We tested at a low temperature and at higher temperatures"***

3 // Hoop strains superimposed over the composite overwrapped pressure vessel (COPV) during a burst test. These strains are measured using full-field strain mapping

3

TESTING TECHNOLOGY

As the goal for the project was to make a composite twice as strong as normal, testing for the material's tensile properties were employed and NASA chose a structure – a test article – whose design is driven by strength. The test article, a container, was a composite overwrapped pressure vessel (COPV). A COPV is a container that has a metal liner to separate the gas or fluid being contained from the composite structure that bears the load of the gas or fluid's pressure. The liner can be aluminum or titanium.

The destructive strength test that was carried out is described as 'burst testing'. This involved pumping an inert gas into the COPV until it failed, i.e. until it burst.

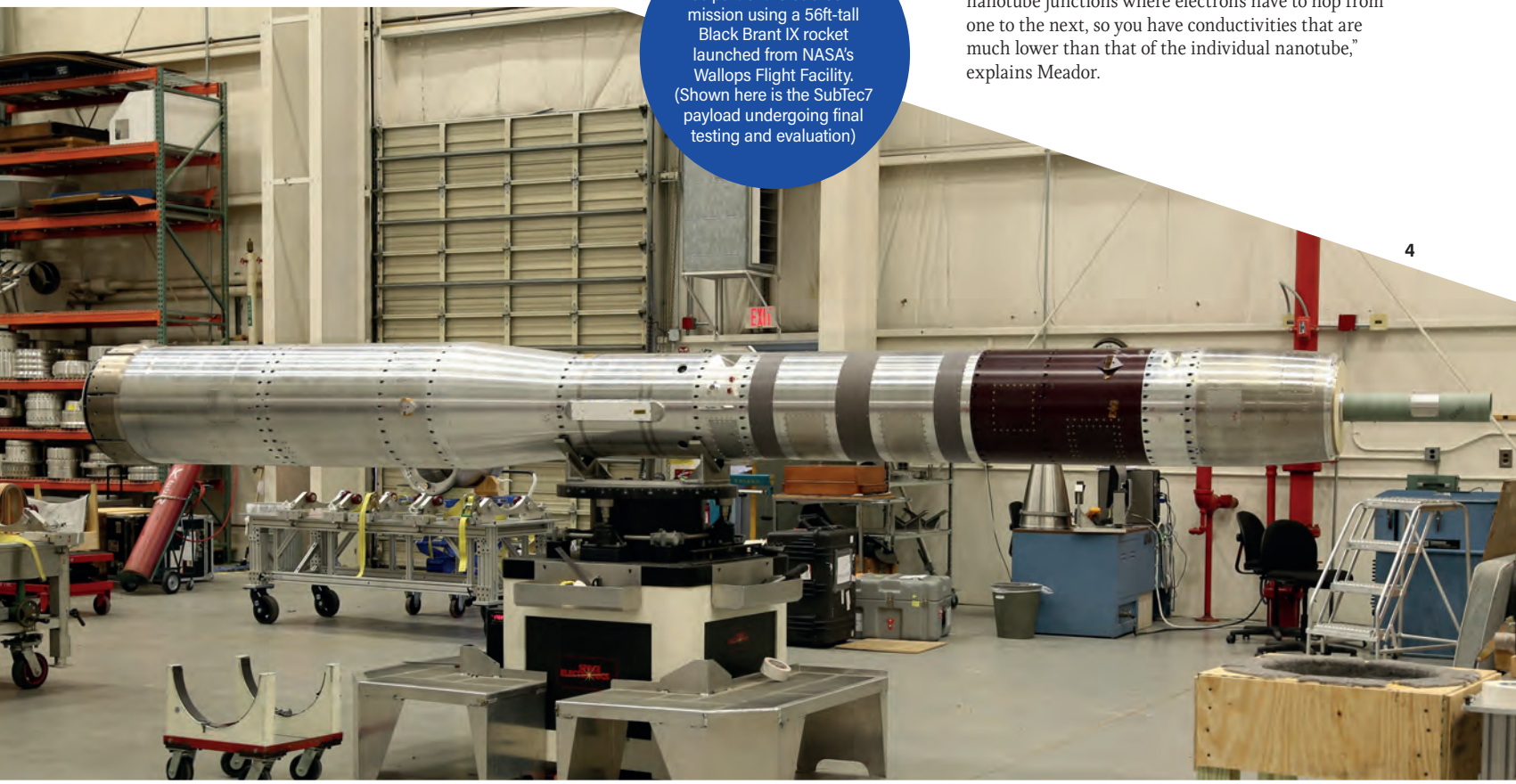
Meador's team also carried out a series of 25 assessments using different conditions for each of three different samples of nanotube fiber – a total of 75 individual D-ring tests. An ASTM International D-ring test can involve subjecting a ring of the fiber structure, a few millimeters in width, and with a diameter between 100mm and 200mm, to high loads.

"We did more than 25 of those tests, under different conditions that the tank would or could experience during manufacturing, during filling, during the flight test. In those tests, at least three samples were tested under each of those 25 conditions. We tested at a low temperature and at higher temperatures," explains Meador. The physical testing at Glenn Research Center included temperatures as high as 48.8°C (120°F) and as low as -42.7°C (-45°F).

CONDUCTIVITY

Nanotubes have good thermal and electrical conductivity properties. But, like strength, the conductivity properties of pure nanotubes are not replicated when they are incorporated into a composite structure with other materials. "The nanotube yarns are a mix of single and multiwall [nanotubes] and you have nanotube-to-nanotube junctions where electrons have to hop from one to the next, so you have conductivities that are much lower than that of the individual nanotube," explains Meador.

4 // A COPV recently flew as part of the SubTec-7 mission using a 56ft-tall Black Brant IX rocket launched from NASA's Wallops Flight Facility. (Shown here is the SubTec7 payload undergoing final testing and evaluation)



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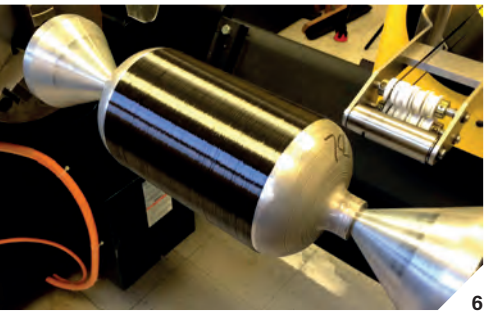
5 // COPV tank snug inside a sounding rocket



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6 // A demonstration flight article is wound with carbon nanotube composites

The nanotube conductivity tests involved passing electrical current through one or two points. Called two- or four-point tests, there are two or four attachment points for passing an electrical current into and out of the material. "And in these fibers, you have a mixture of metallic and semiconducting nanotubes and that also results in lower conductivity," he adds.

TEST FLIGHT

As the COPV was being launched into sub-orbit in a sounding rocket, shaker table testing was carried out at the NASA Wallops Flight Facility. Located on Virginia's eastern shore, Wallops is where NASA operates sounding rockets; the Orbital ATK Cygnus cargo spacecraft also launches from there. "At Wallops, they did shaker table testing to verify that it [COPV] was okay. I think there are shaker tables at any [NASA] center that is involved doing flight experiments," Meador says. Typically, strain gauges are used to measure the performance of structures on a shaker table.

The test during the May 16 sounding rocket flight involved firing a cold gas thruster system, with the cold gas in a COPV. It was the first time that a nanotube-based composite had been flight-tested in a structural component, according to Meador. "They gave us time at the end of the [sounding rocket] flight, just before the payload started to descend, and gave us control of the payload and we wiggled the payload back and forth and spun it up prior to descent [using the cold gas thruster]," he says. While strain gauges can be attached to COPVs in-flight to test their performance and the data transmitted back to the ground using the telemetry feed, Meador's team did not do this.

As well as the physical testing, computer modeling was also carried out. "We did do some computational analysis primarily to do modeling on the tensile properties of the fiber. This was more materials modeling kind of activities. I don't believe there was a whole lot of analysis done on the data from the D-ring tests."

NASA's work with nanotubes is ongoing, with research in the areas of radiation protection and mirrors for CubeSat telescopes. NASA has said telescope mirrors made from "nanotubes in a resin" have good thermal conductivity. Some cosmic observations use the infrared spectrum to analyze distant stars and galaxies. For radiation protection, the space agency is developing hydrogenated boron nitride nanotubes. These can be woven into spacesuits and can absorb some types of solar and cosmic radiation, thus providing protection for astronauts. More than 20 years after it first became such a hot topic, in the 1990s, the material is finally delivering test results that demonstrate nanotubes can make a meaningful contribution to the aerospace industry. \\

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// GEORGE COUPE

Tunnel vision

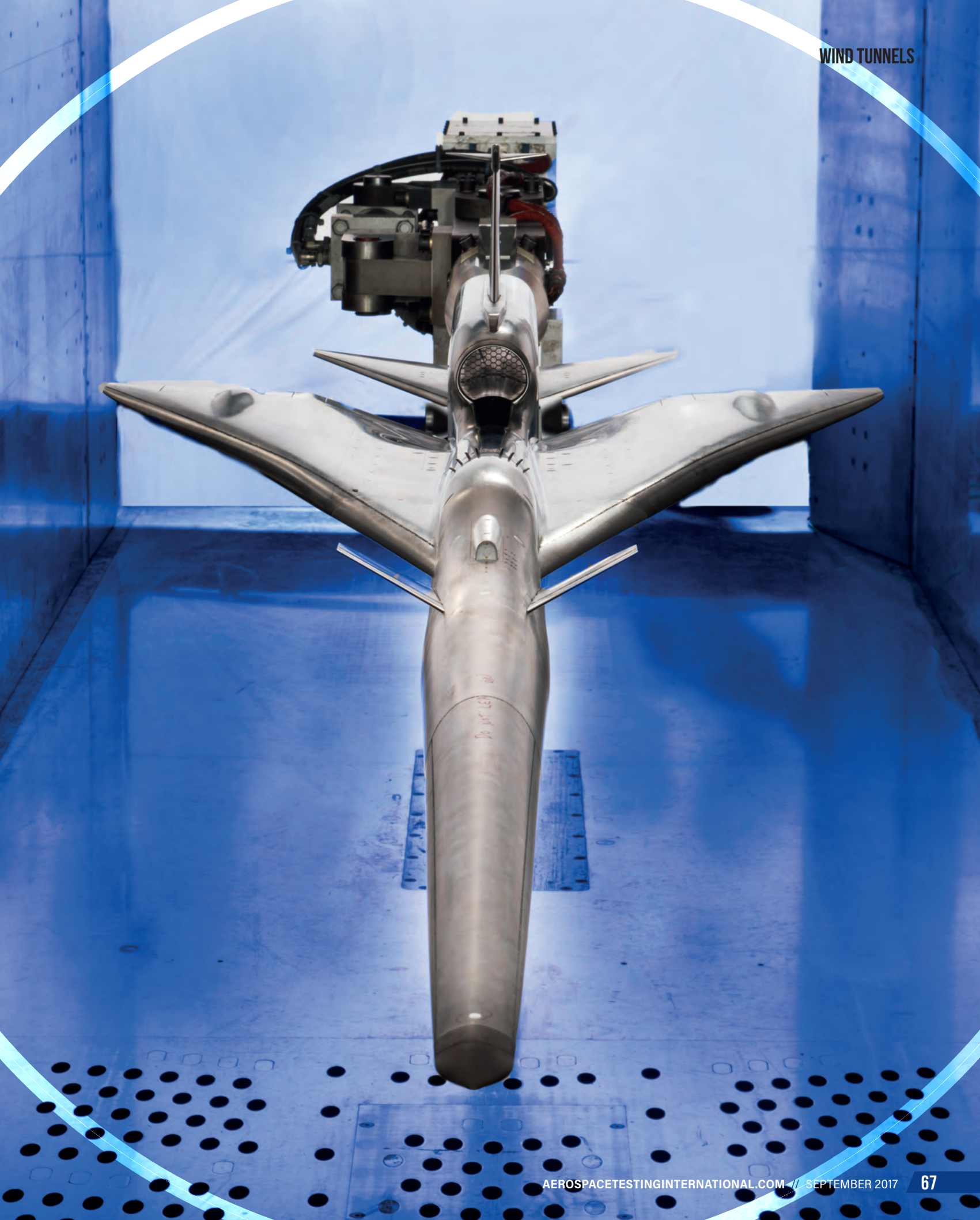
What role will wind tunnels play in the testing of future aircraft? NASA's latest supersonic testing program provides some clues

Far away and almost lost in the contrail of the aviation industry, a speck on the horizon suddenly became a little more distinct this year. A faster, cheaper and cleaner alternative to some forms of air travel appears to be gaining ground. It could be an illusion, of course, but in technical and cost estimations carried out by NASA, Elon Musk's Hyperloop concept, a system of magnetically levitated pods accelerated along a tube in a low-pressure atmosphere, could represent a viable competitor to short-haul flights at least. There are many differences of opinion on the viability of such a system, but perhaps the most important impulse behind technologies such as the Hyperloop is the desire to reduce the environmental impact of high-speed transportation – to shift away from noisy, fossil fuel-burning aircraft, to renewable energy options.

NASA is of course engaged in its own era-defining program (the New Aviation Horizon initiative) to develop the next generation of aircraft to fly faster, cleaner and quieter. But while the Hyperloop, and other 'vactrain' concepts as they are known, would achieve their target in part by removing or at least greatly reducing the density of the atmosphere around the vehicle, that option is not available to researchers working for NASA's Aeronautics Research Mission Directorate (ARMD).

To be faster, cleaner and in particular to reduce the boom of supersonic aircraft to enable overland flight, engineers must continue to work to unlock the secrets of how the aircraft interacts with its element, how it supports and impedes, in ever finer detail. Is testing a scale model in a wind tunnel the best way to expose the subtleties of that relationship, or will the wind tunnel ultimately be made redundant by advances in computational fluid dynamics?

1 // QueSST experimental aircraft in the 8 x 6ft wind tunnel at NASA's Glenn Research Center *(Photo: NASA)*



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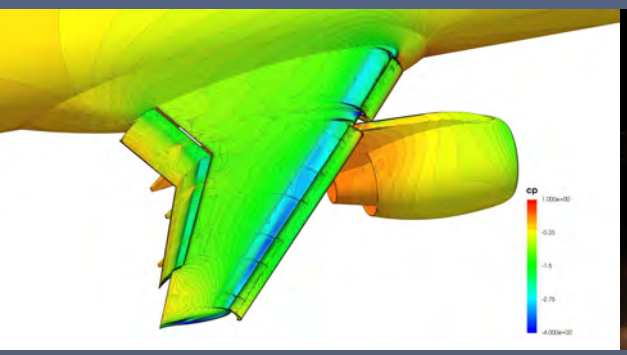


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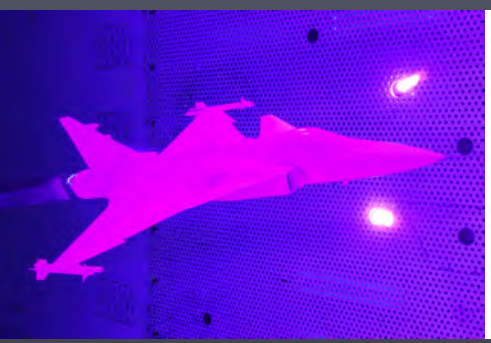

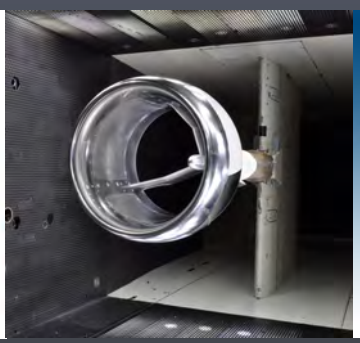


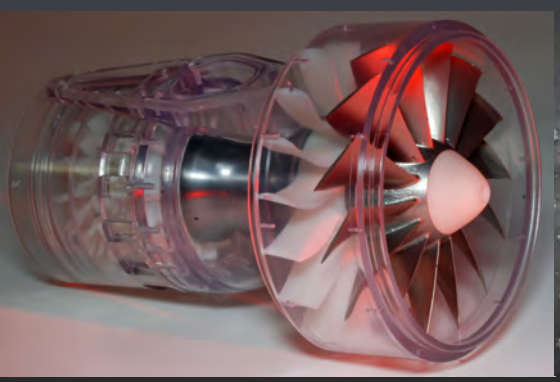
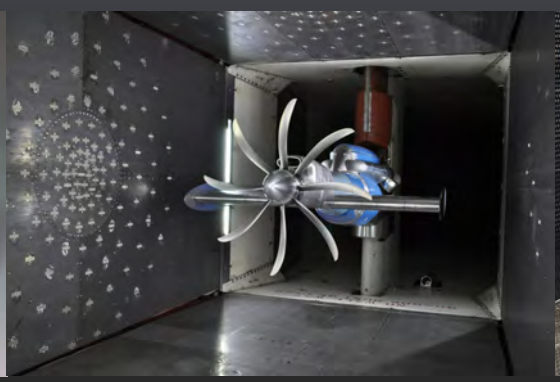
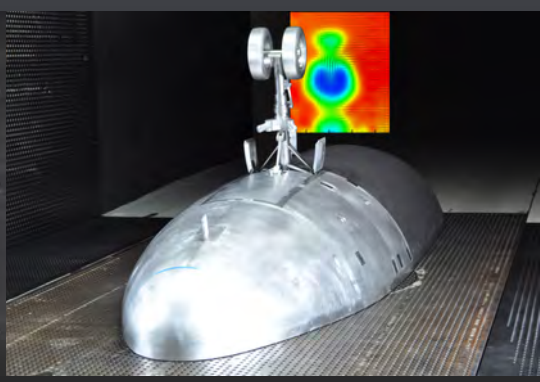

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2 // A NASA Glenn technician prepares the QueSST experimental aircraft for testing in the 8 x 6ft wind tunnel *(Photo: NASA)*

"The second test will use a 15%-scale model"

The question is relevant to engineers working on NASA's Commercial Supersonic Technology (CST) project, which is leading research on a number of key technical challenges: integrated low-boom aircraft design; sonic boom community response metrics and methodologies; and low-noise propulsion for low-boom aircraft. The CST project is also researching improvements in supersonic cruise efficiency, emission reduction, aeroservoelasticity and flight systems.

LOW BOOM FLIGHT DEMONSTRATOR

To accomplish its goals, NASA decided to commission a low boom flight demonstrator (LBFD) aircraft to validate the design tools and technologies applicable to low sonic-boom aircraft and to create a database of community response to support the development of a noise-based standard for supersonic overland flight. The objective is a research aircraft that creates a shaped sonic boom signature with a calculated perceived loudness level of 75dB or less during supersonic cruise flight at Mach 1.4. Although the aircraft will be smaller in size than future supersonic airliners, its sonic boom ground signature will be traceable to a larger aircraft. The LBFD aircraft will be capable of performing multiple supersonic overflights of a single community with passes nominally 50 miles (80km) in length and up to 20 minutes apart on a single flight.

86
Number of test configurations of the QueSST wind tunnel model in the stability and control drag test

75
Perceived decibel sound level created by the LBFD aircraft in supersonic cruise

15%
Proportional size of the QueSST scale model to be tested in NASA Langley's 14 x 22ft wind tunnel in the autumn

In March 2016 Lockheed Martin was selected to carry out the preliminary design of its LBFD concept, called the Quiet Supersonic Technology (QueSST) aircraft. It completed a preliminary design review in June 2017.

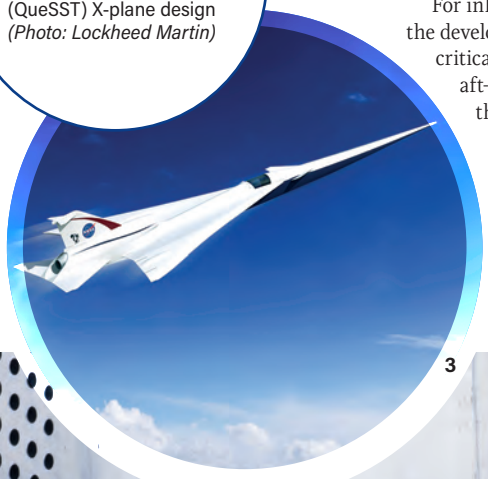
David Richwine, the QueSST preliminary design project manager at NASA Langley, says that prior to the initiation of the QueSST preliminary design, the team conducted several concept feasibility studies with Lockheed Martin and Boeing, a major component of which was the maturation and validation of low-boom design tools and technologies, including both computation and experimental assessments of the design concepts in high-speed wind tunnel facilities. This was followed by a series of wind tunnel tests of increasingly larger scale models.

"Early in the QueSST preliminary design, Lockheed Martin used a 4.5%-scale low-speed wind tunnel at its Palmdale, California facility to collect initial aerodynamic performance and handling quality assessment data for the configuration," explains Richwine.

Two further wind tunnel tests were planned as the core of the QueSST testing program.

"In spring 2017 a 9.5%-scale model of Lockheed Martin's QueSST configuration was tested at the NASA Glenn 8 x 6ft supersonic wind tunnel to obtain a high-fidelity set of high- and low-speed aerodynamic performance and propulsion/airframe integration data," continues Richwine. "The second test will use a 15%-scale model of Lockheed Martin's QueSST configuration to obtain high-fidelity low-speed aerodynamic performance data. Model fabrication is nearly complete, with testing planned in the NASA Langley 14 x 22ft wind tunnel in fall 2017."

Ray Castner, a NASA aerospace engineer at the Glenn Research Center, says that the wind tunnel tests focused on aerodynamic stability and control (S&C) and the performance of the propulsion inlet. The S&C aerodynamic lift and drag test completed a total of 86 test configurations and over 208 hours of wind-on



3 // Artist's concept of a possible low-boom flight demonstration Quiet Supersonic Transport (QueSST) X-plane design *(Photo: Lockheed Martin)*

testing, while the propulsion test completed a total of 12 configurations and underwent over 73 hours of wind-on testing. In both cases the results were compared with CFD simulations.

"CFD simulations were performed by both Lockheed Martin and NASA for the stability and control portion," says Castner. "The wind tunnel performance database was compared with the computational modeling database, with good agreement of modeling capabilities with respect to the test data.

"For inlet performance, computational tools are in the development phase, so the wind tunnel data was critical in the understanding of the top-mounted, aft-mounted inlet location. To NASA's knowledge, this is the first experimental database of a supersonic inlet in this location as tested on a full vehicle configuration. Wind tunnel test data showed the inlet to have adequate performance to fly the mission."

So while others might appear to be making progress in developing alternatives to high-speed air travel, those at the forefront of aviation research believe that the experimental data sets, combined with the computation output, will form the core of the performance data used for configuration assessment and control law design of the QueSST, and will also help to improve computational modeling for low-boom vehicle designs in the future.

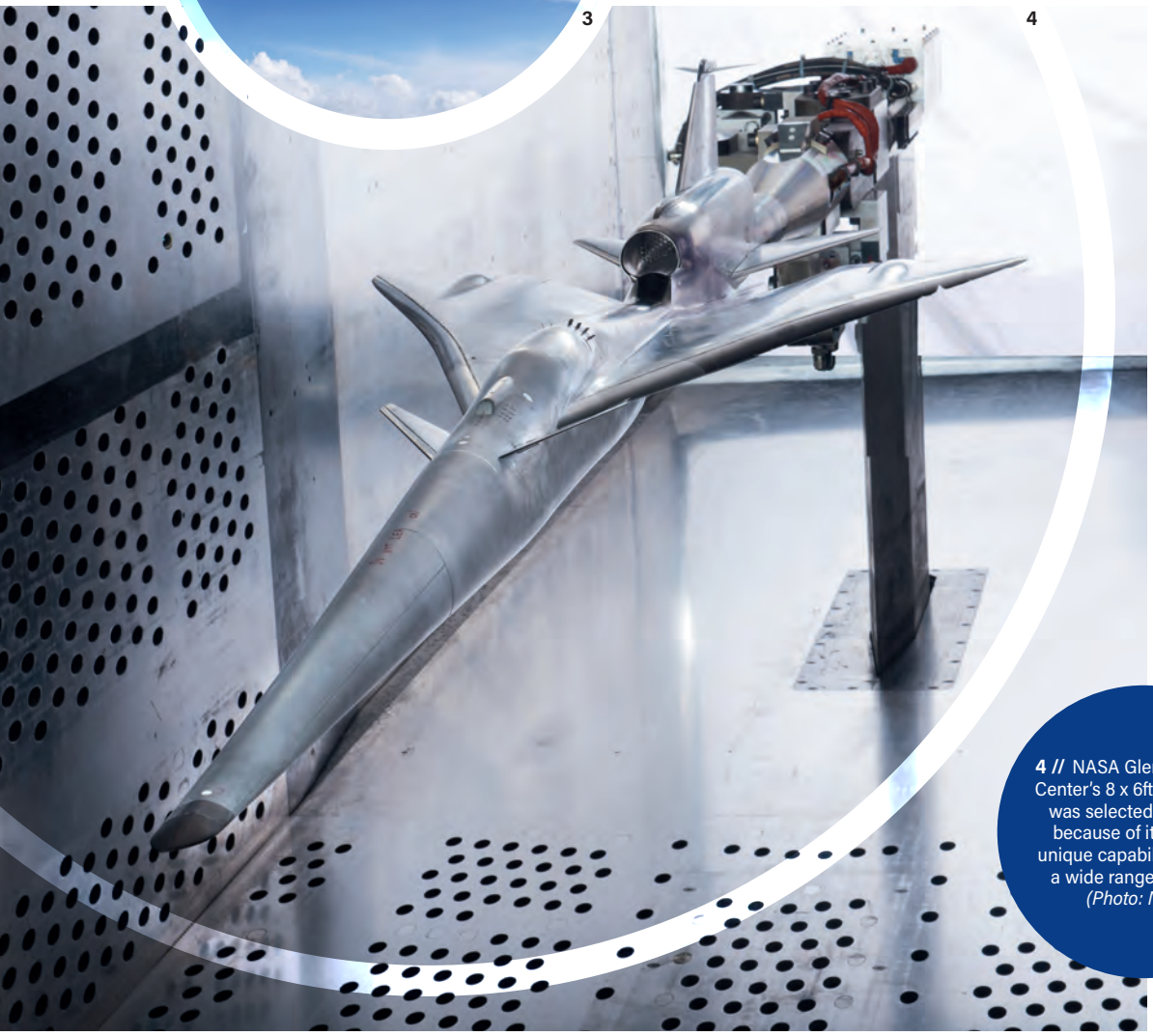
As Castner says, this is really how it has always been: "Validation data sets are important to make sure that modeling is correct over the range of expected flight conditions, as computer models are sometimes not accurate when used outside the range of validation. This modeling and wind tunnel test approach is typically used as risk reduction in aerospace vehicle development projects."

SECOND OPINION

Castner isn't alone in his view. Advances in CFD will never becalm the wind tunnel business, according to Peter Curtis, chief technical officer at the Aircraft Research Association (ARA), a UK-based independent research and development organization specializing in high-speed wind tunnel testing, CFD and high-precision wind tunnel model design and manufacture. However, Curtis believes that better computation will have an impact on the way tunnels are used. "There is a resurgence in new wind tunnels around the world at the moment, but the nature of tunnel testing is changing with the improvements in CFD capability," he says.

While CFD can reliably model flows "in the core of the envelope", says Curtis, wind tunnels still hold many advantages, particularly in terms of testing time when exploring less stable parts of the airflow, further from the surface of the aircraft.

"CFD is very good at predicting flows in the on-design area, where there are no separated flows or significant instabilities. To predict those correctly takes orders of magnitude more computing time," Curtis continues. "Wind tunnels have the advantage around the edges of the envelope in the off-design regime, where there are separations and instabilities. In such cases CFD can often tell you that something interesting is



4 // NASA Glenn Research Center's 8 x 6ft wind tunnel was selected for testing because of its size and unique capability to test at a wide range of speeds *(Photo: NASA)*

happening, but not confidently what that is. Once one has a model in the tunnel the number of cases that can be tested in a day is enormous."

But there is an important two-way relationship to be developed between experimental data and that produced by CFD.

"We believe it is essential that CFD and the wind tunnel are seen as complementary tools for the aerodynamicist," he says. "High-quality experimental data is needed to validate and calibrate computational tools, which can in turn be used to enhance data quality from the tunnel, for instance in improving blockage corrections or the scaling of Reynolds numbers. CFD data can also be used to help refine the test matrix for a tunnel campaign by highlighting areas where unusual phenomena are anticipated."

But in order to gather data for CFD validation, high-fidelity measurements must be taken at the surface of the test model and above. Traditional surface pressure ports can produce very high quality data, but they are limited by the number that can be integrated into a model. ARA, among others, has been developing the use of pressure-sensitive paint, which effectively increases the number of 'ports'.

"The current initiative with this technique," says Curtis "is to extend it into the time domain, by taking dynamic data with high-speed cameras, and making measurements in hard-to-access areas using miniaturized cameras. It is also necessary to know exactly what shape the wind tunnel model is when the measurements are being taken, so high-fidelity dynamic model deformation measurement systems are required. While such systems are relatively commonplace, their use in wind tunnels is fairly recent."

Curtis adds that until recently off-surface measurements systems, such as particle image velocimetry, have mostly been used in academic research. Now modern systems are being used in the industrial context, to help diagnose interesting phenomena and assist in CFD validation and calibration.

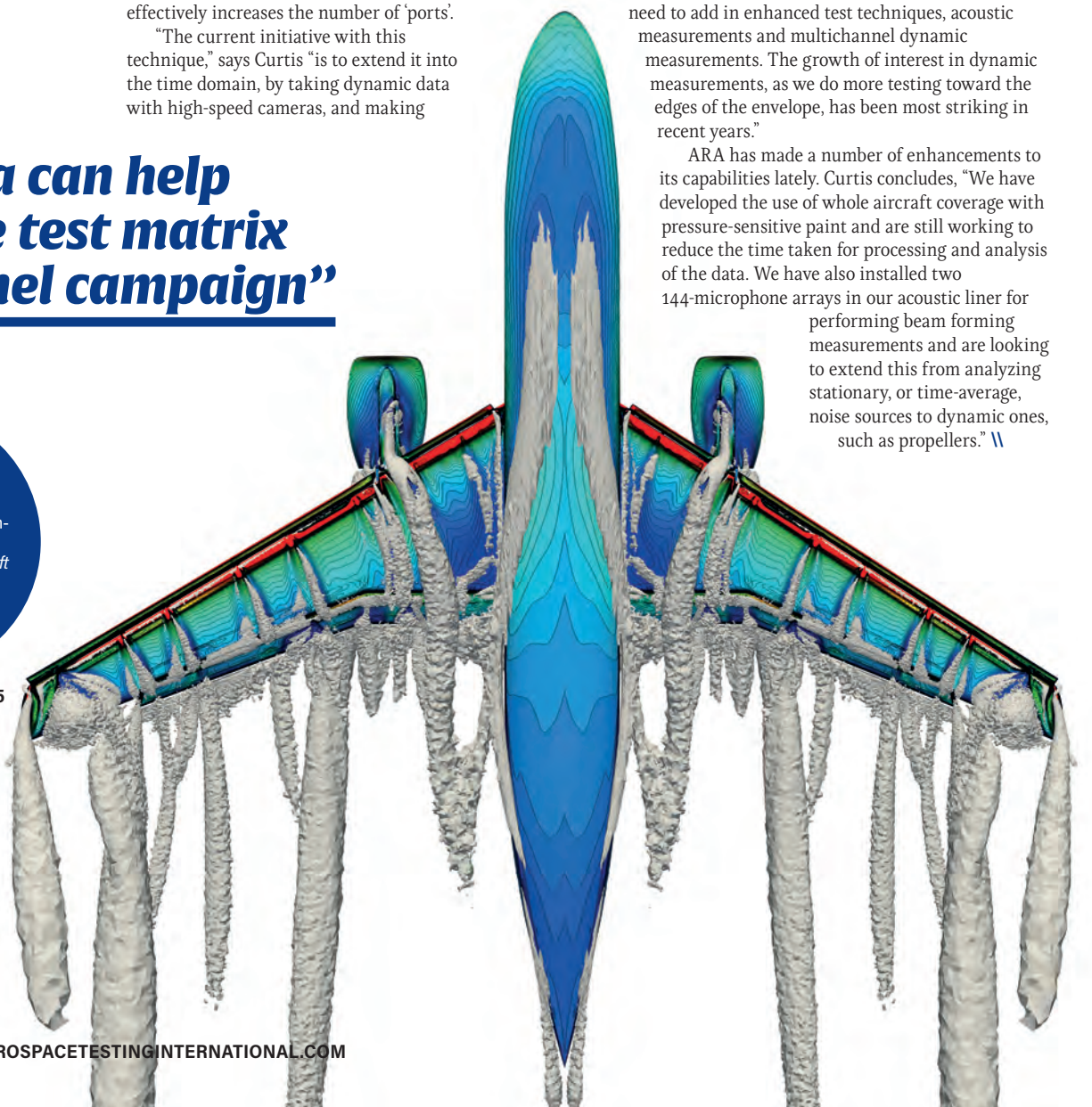
"Wind tunnels will always be necessary, says Curtis, "but there is also a need to make sure they can produce the best quality data and at reasonable cost.

"The constant drive from our customers is to maintain the highest quality while taking data faster and keeping a lid on costs. Therefore the upgrading of basic control systems, data acquisition systems and improvements in automation are all absolutely essential just to stay competitive in the commercial environment.

To improve their commercial offering, modern tunnels need to add in enhanced test techniques, acoustic measurements and multichannel dynamic measurements. The growth of interest in dynamic measurements, as we do more testing toward the edges of the envelope, has been most striking in recent years."

ARA has made a number of enhancements to its capabilities lately. Curtis concludes, "We have developed the use of whole aircraft coverage with pressure-sensitive paint and are still working to reduce the time taken for processing and analysis of the data. We have also installed two 144-microphone arrays in our acoustic liner for performing beam forming measurements and are looking to extend this from analyzing stationary, or time-average, noise sources to dynamic ones, such as propellers." \\

"CFD data can help refine the test matrix for a tunnel campaign"



5 // CFD image recently presented at the AIAA High-Lift Prediction Workshop, Denver, USA *(Photo: Aircraft Research Association Ltd)*

5

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How are ejector seats tested – and where do humans fit in?

1 // UTC Aerospace Systems performs a sled test for its ACES 5 ejection seat at the company's Hurricane Mesa Test Facility, Utah, USA

It has been 102 years since early parachute inventor Everard Calthrop patented the first ejection seat. The original incarnation used compressed air to propel the pilot clear of the aircraft. Since then air technology has been replaced by an explosive charge or rocket motor, along with a decidedly more rigorous and scientific testing process.

"Aircrew safety is our top priority," says John Hampton, UTC Aerospace Systems senior manager for ejection seat testing and engineering. "We are committed to helping aircrew return home safely and minimizing the injuries that may be sustained during an ejection so that they can successfully escape and evade in a combat situation and return to fly at the earliest opportunity."

UTC's ACES (Advanced Concept Ejection Seat) 5 provides some of the most advanced safety features available, and is an upgrade from ACES II, which was the industry standard for almost 40 years and brought uniformity to ejection seats in the A-10, F-15, F-16, F-22,

PROJECT WHOOSH

A pilot's decision to eject may be both instinctive and critical, but this act of self-preservation often solves one problem but leads to another. With the force of ejection close to 20*g*, compression fractures of the vertebrae are a common outcome. The most decisive factor with any ejection is the speed at which the aircraft is traveling at the point of expulsion.

It was initially believed that ejection at supersonic speeds would not be survivable. In the 1950s this was put to the test by Cherokee, an experimental rocket built for use by the US Air Force to test ejection seats under the umbrella term Project Whoosh. Launched from a B-29 at an altitude of 30,000ft, Cherokee fired a solid-fueled rocket that accelerated to supersonic speed. The rocket contained a sedated chimpanzee that ejected from the craft. Four tests were carried out and although none of the chimps survived, the project was considered a qualified success.

Since then there have been a small handful of cases where pilots have ejected at supersonic speed and lived. Most notable of these was Captain Brian Udell. During a night training mission off the coast of North Carolina in April 1995, Udell's aircraft experienced a sudden malfunction and plunged straight down at over 300m/s (670mph). He ejected. "The windblast when traveling at that speed stops becoming wind and starts becoming a freight train," he said. "My helmet was instantly ripped from my head. I broke all the blood vessels in my head and face. My head swelled to the size of a basketball and my lips were like cucumbers. My left arm blew out into the wind stream and instantly dislocated at the elbow, tearing the muscles across my chest. My right leg also went out into the windstream and started whipping around. Quickly the only thing holding this leg on at the knee joint was the right artery, the vein and the skin. My life preserver had never been tested at this speed and it was instantly shredded. It looked like rags." Miraculously Udell's life raft was preserved and he survived.

22
Number of test ejections required by the US DoD

60,000FT
Maximum altitude at which the F-22 ACES 5 ejector seat has been designed to operate

B-1 and B-2 jets. UTC operates the only privately owned sled test facility in the USA, at Hurricane Mesa, Utah. The Hurricane Mesa Test Facility (HMTF) includes a 12,000ft test track capable of propelling an aircraft fuselage or a representative mock-up on a purpose-built sled at supersonic velocities up to nearly 800mph.

"It's at HMTF that our ejection seats go through extensive subsystems tests, full system ejection tests and aircraft environmental tests," says Hampton. "We also use both government and commercial facilities for specialized testing. Altogether, individual tests for each ejection seat subsystem may number in the hundreds and major seat programs may have more than 1,000 tests completed. The subsystem tests include component checks such as parachute deployment, stabilization drogue chute deployment, windblast testing, ejection tower testing, cartridge actuated device testing, rocket testing, reliability cycling tests, seat/man separation, limb restraint deployment tests, and 40*g* crash testing, among many others."

In the USA, full system tests require a minimum of 22 ejections, as per requirements mandated by the US Department of Defense (DoD). In addition, just like any other system for a military aircraft, such as avionics, the DoD requires stringent aircraft environmental tests to ensure the system – an ejection seat in this case – will successfully function and perform in the various conditions it may be exposed to on board a military aircraft. These tests include exposure to extreme temperatures, water, salt, fog, humidity, vibration, rain, sand and dust.

CHALLENGES AND MANIKINS

"One of the unique challenges with regard to ejection seat testing is designing a seat that can accommodate the US Air Force's full aircrew size accommodation and weight range from 103-245 lb [47-111kg]," says Hampton. "We've addressed this through sitting platform adjustment, seat stabilization and load compensating technologies, and demonstrated in our testing that the ACES 5 seat meets all requirements for the entire aircrew accommodation range."

2

2 // Another sled test of the ACES 5 ejection seat undertaken at UTAS's Hurricane Mesa test facility

3

3 // Designed to enhance crew safety during an ejection, ACES 5 provides head and neck protection, as well as passive arm and leg restraint protection, free of lanyards, tethers and inflatables

UTC uses US Air Force-approved anthropometric test device manikins similar to those used in the automotive industry. These manikins are equipped with sensors to assess articulation of the human body during an ejection. In the past both bears and chimpanzees have been used in ejector seat testing to simulate the approximate size and response of humans.

"We never use humans in our ejection seat tests," says Hampton. "The manikins we use are approved by the US Air Force because they provide extensive information that we can use to understand probabilities of injury and assess margins of safety."

Data from the sensors is used to help predict the movement of a pilot, representative of various weight and height ranges, during an ejection. The recorded movements can be relative to factors including force, biomechanics, velocity and acceleration. Ultimately this data enables UTC to build better equipment so that the pilot can return home safely with no or minimal injury following an ejection.

"We have developed a proprietary simulation software program that models the entire ejection event," says Hampton. "The program captures six degrees of freedom – up, down and sideways, as well as rotation – and provides a video graphic output for visual representation that enables the user to see the entire ejection event. This simulation software is also used to analyze ejection test data to better understand the event."

43%
Percentage of ejection-related injuries that occur during the landing phase

1,500IN^3
ACES 5 survival kit volume

"In the past both bears and chimpanzees have been used in ejector seat testing"

HURRICANE MESA TEST FACILITY

After World War II the advent of jet propulsion meant more sophisticated ejection systems were required to catapult pilots safely from their aircraft. In 1953 Coleman Engineering Company won a US$2m contract from the US Air Force to build a research track on which supersonic ejection technology could be tested. Hurricane Mesa in southern Utah was deemed to be the perfection location. It's arid, mild climate enabled all-year testing; the flat bedrock was a secure anchor for the track; and the 1,500ft (457m) drop into the Virgin River valley meant test items could be ejected safely from the track. The track itself is made up of 4,000m (13,120ft) of continuously welded, hard-wearing hot-rolled steel that constitutes the longest rocket research track in the USA.

Since the 1950s, the 6,500-acre (2,630ha) Hurricane Mesa site has provided testing facilities for the US armed forces, as well as for domestic and international customers. Its secluded nature on a table-top mountain make it a secure and private location. Alarm systems, surveillance cameras and an 8ft (2.5m) fence create security for the facility, which is owned by the tire company B F Goodrich. Though it can meet numerous test requirements such as parachute validation drop tests, submunition delivery systems, aircraft canopy testing, rocket launching of UAVs, cruise missile launching and flight tests, and impact testing such as bird strikes, its primary use is still ejection testing.

4 // A dummy attached to a GR7000 parachute is recovered following a test drop at Edwards Air Force Base by the 418th Flight Test Squadron

4

NEW CHUTES

Testers from the 418th Flight Test Squadron at Edwards Air Force Base in California recently collected data on the GR7000 parachute, which is being been lined up to replace the C-9 canopy used in the ACES II ejection seat. The GR7000 parachute is designed to handle greater pilot weight and provide slower descents with less oscillation. "The overall test objective is to demonstrate the strength of the GR7000 parachute in worst-case ejection situations, high-altitude Mode 1 deployment, and evaluate its steady-state descent characteristics," says Alice White, 418th FLTS ACES II SSIP project manager.

Since ACES II debuted in 1978, the US Air Force has made two important changes affecting ejection seat safety. The first was expanding the aircrew weight range – originally 140-211 lb (63-96kg) – to 103-245 lb (47-111kg). The second, more recent, adjustment was to accommodate helmet-mounted devices. The introduction of sights and night-vision goggles, with their added mass, has increased the risk of head and neck injuries during ejection. Passive head and neck protection (PHNP) now acts like a catcher's mitt, cushioning and supporting the head and neck to avoid whiplash during ejection.

Using a Skyvan – nicknamed the flying shoebox and used mainly for skydiving – testing has been undertaken using 10 dummies, 20 live-person jumps and five drops using a crosswind deployment cylindrical test vehicle. Airspeed, altitude, rate of descent and canopy structural integrity were all tested during the exercises. Eighty percent of qualification testing has now been completed.

Hampton continues, "UTC Aerospace Systems supports its customers with post-ejection analysis, where data from the seat survivable data recorder is fed back into our simulator to reenact the ejection event."

Each ejection seat is equipped with a survivable recorder that captures data – including measurements including seat acceleration, aircraft velocity, aircraft altitude, aircraft attitude and ejection event timings – from ejection events. After an ejection event occurs, the data captured can be used in conjunction with the software program to simulate the event and analyze it with customers.

70%
Commonality of parts between the ACES II and newer ACES 5

630
Number of lives ACES II ejector seat has helped save since being introduced in 1978

THE FUTURE

With UAVs on the rise, the inclusion of cockpits, armor, flight controls and, of course, ejector seats, are all under threat as standard features in military aircraft. The popularity of combat drones is understandable, not least given a lack of pilot means instantly improved safety and lower costs. What are the implications for ejector seats?

"Although militaries around the world are making use of UAVs, as long as there are human aircrew members, we remain committed to ensuring they return home safely," says Hampton. \\

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Day 1: Thursday, November 16

09:00 - 12:30 — KEYNOTE PRESENTATIONS

ROOM A

AIRBUS GROUP

Presentation to be confirmed very soon. See website for details

Rolls-Royce

Presentation to be confirmed very soon. See website for details

SIEMENS

Presentation to be confirmed very soon. See website for details

NASA X-57 electric propulsion technology flight demonstrator development and progress

Sean Clarke, X-57 principal investigator, NASA, USA

NASA's X-57 is an experimental aircraft designed to demonstrate radically improved aircraft efficiency with a 3.5 times aero-propulsive efficiency gain at a 'high-speed cruise' flight condition over comparable general aviation aircraft. These gains are enabled by integrating the design of a new, optimized wing and electric propulsion system. Integrating new technologies into critical systems in experimental aircraft poses unique challenges that require careful design considerations across the entire vehicle system, such as qualification of new propulsors, compatibility of existing systems with a new electric power distribution bus, and instrumentation of newly qualified propulsion system devices.

Comprehensive modeling and experimental investigations of electric-VTOL aircraft

Prof. Anubhav Datta, associate professor, University of Maryland, USA

This paper will describe the research carried out at the Alfred Gessow Rotorcraft Center, University of Maryland, to understand, characterize and resolve some of the key barriers associated with practical, manned, all-electric and hybrid-electric rotary-wing VTOL aircraft. The paper will present the special requirements of VTOL flight (high torque, low RPM drives), the special barriers associated with electric VTOL (transmission, heat, power sharing), and the special technologies enabled by electric that might offset some of these barriers (variable Rpm, swashplateless, distributed electric architecture) at least for certain categories of special-purpose missions, including urban on-demand missions.

Progress on the Fokker 100 hybrid-electric centerline propulsor demonstrator

Simon Taylor, chief technologist, GKN Fokker, Netherlands

This presentation will serve as an introduction to the work performed and in progress within GKN on the Fokker 100 Hybrid-Electric (HE) Demonstrator program. The purpose of this program is to enable the development and demonstration of HE technologies at full scale on the Fokker 100 (100-seat) regional jet. The modified aircraft uses a centerline propulsor configuration that, in addition to the energy cycle benefits, ingests the boundary layer and junction effects related to the fuselage. Initial results of the program are presented and an insight into the ongoing work is provided.

13:30 - 18:00 — THE PATH TOWARD ELECTRIC FLIGHT

ROOM A

Robust TeDP electrical microgrid for vehicle thrust and yaw control

Stephen Long, system architect, systems design integration, Rolls-Royce, USA

This presentation will discuss the sensitivity of TeDP electrical microgrid size and its efficiency in air vehicle fault accommodation and flight control requirements. The efficacy of various configurations will be discussed and compared in terms of their ability to meet vehicle needs. Candidate alternative architectures will include AC and/or DC microgrid. The viability of TeDP is heavily influenced by the protection strategy and reconfigurabilty of the system.

Raising ambition: technologies for hybrid and electric aircraft

Mark Scully, head of technology – advanced systems and propulsion, Aerospace Technology Institute, UK

A number of key technologies are being developed in aerospace to enable a future hybrid and electric commercial aircraft. Key opportunities to demonstrate the technologies and their integration in a system of systems will be important to create the required maturity for consideration in future aircraft. To this end, the role of virtual integration will be increasingly important in providing clarity on the benefits and risks of these technologies.

Electric power systems for hybrid-electric distributed propulsion – a roadmap

Prof. Peter Malkin, strategic research advisor, Newcastle University, UK

Newcastle University was recently awarded funding by the EPSRC to support the UK ATI strategy in advanced systems. Pilot studies have been carried out in key areas to enable the development of hybrid-electric distributed-propulsion aircraft. The studies consisted of medium-voltage power systems for aircraft, high-temperature superconducting power network design and BLI motor studies including a feasibility study of adapting a tail-mounted BLI system for an existing large aircraft. The objective of each of these studies was to produce technology roadmaps and value propositions. These are linked to the timescales and requirements of the civil aerospace industry to facilitate the design and testing of HEDP aircraft from regional up to large long-haul designs.

Evolution of fundamental technologies for future electrified aircraft

Dr Ajay Misra, deputy director, research and engineering, NASA Glenn Research Center, USA

Gradual progression of electric and hybrid-electric aircraft from small planes to large planes will require technology advances in multiple areas, including energy storage, electric machines, power transmission, power electronics, control systems, materials, thermal management and multiscale modeling tools. Advances in fundamental research and applied interdisciplinary research will be required to realize the goals for future electric and hybrid-electric aircraft. The presentation will provide an overview of long-range research and technology needs for the next 30 years, and how the evolution of several early-stage technologies will influence the development of electrified aircraft in the future.

Summary of current electric flight activities within DLR

Dr Andreas Klöckner, engineer, DLR, Germany
Prof Josef Kallo, electrical engineer, DLR, Germany

DLR is currently engaged in a number of research and development activities supporting electric flight ambitions in Germany, Europe and worldwide. This ranges from fundamental research on technology such as fuel cells, through integrated aircraft design efforts up to applied technology demonstrators such as the HY4. This presentation will summarize recent achievements of ongoing projects and introduce the audience to planned programs.

Sensing and actuating capabilities of the electric propulsion system

Dr Akira Nishizawa, section leader, Japan Aerospace Exploration Agency, Japan

JAXA and the University of Tokyo have collaborated on a new control method utilizing the multifunctionality of the electric propulsion system. The electric fan itself functions as a sensor that estimates the air speed. It also functions as a sensor to detect propulsion system faults. Due to the interaction between the wake of the electric fan and the main wing, the electric fan also functions as an actuator for

adjusting the lift force. The presentation will Include ground and flight test results.

Electric engine certification

Régis Rossotto, PCM electric/hybrid propulsion, EASA, Germany

The safety requirements for aeronautical combustion engines were able to evolve gradually over decades as service experience pointed to where the most important risks lay. With the introduction of electric engines on aircraft, manufacturers and certifying authorities face new challenges. Due to the fact that their design and use are different from those of combustion engines, the certification requirements will have to be adapted to maintain a high level of safety for customers and passengers. How will the certifying authorities approach this challenge?

Electrification and hybridization – what aviation can learn from automotive

Sascha Kempf, project manager, electric and hybrid aviation team, P3 Aviation, Germany

In this presentation the P3 Group will give insights into applying prior experience of the automotive industry to current development in aviation, in terms of challenges, mistakes and best practices regarding e-mobility. To successfully electrify and hybridize aviation from a technical as well as an economic perspective, aviation has to learn from related fields such as batteries, electronics, charging, infrastructure and implementation. Special emphasis will be put on the transfer to VTOLs, on-demand mobility and thin-haul commuter aircraft concepts.

Day 1: Thursday, November 16

13:30 - 18:00 — POWER GENERATION, ENERGY STORAGE & ELECTRICAL SYSTEM ARCHITECTURE

ROOM B

Development of a solar-powered stratosphere UAV in Korea

Dr Seokmin Ahn, principal researcher, Korea Aerospace Research Institute, Korea

Korea Aerospace Research Institute has developed solar-powered UAVs since 2010. Elementary technologies were developed and tested individually for the first three years. Developed technologies have been integrated into aircraft. A total of six versions of UAV have been tested, the smallest one with a wing span of 1.8m and the largest and the latest with 19.5m. The latest version, named EAV-3, remained at a height of 18.5km for 1.5 hours. The presentation will outline what has been accomplished and how it has been executed, including flight test results.

Systems readiness level maturation of hybrid aircraft

Dr Patrick Norman, lecturer, University of Strathclyde, UK

This presentation will provide an overview of recent activities at the University of Strathclyde, where new end-to-end simulation-based design and experimental testing capabilities have been developed for hybrid-electric aircraft electrical power systems. It will show how these developments recognize the importance of technology and systems readiness level maturation in realizing the full benefits of the hybrid aircraft concept, and facilitate collaborative efforts through the provision of remote connection with other design tools and labs.

Optimizing battery power, energy and weight for aerospace

Gregory Albright, vice president of business development, AllCell Technologies, USA

Many aerospace applications require high energy and high power from batteries. Battery cells that provide enough power sacrifice energy density to achieve high power. More energy-dense batteries will overheat if used for high power, reducing performance and causing safety issues. Specialized phase change materials can help bridge the gap by allowing high-energy cells to be used in high-power applications without overheating. This presentation will show testing and simulation results to illustrate how thermal management can improve net performance.

Hybrid turbine solid-oxide fuel cells for more-electric aircraft

Prof. Christopher Cadou, associate professor, University of Maryland, USA

This paper describes the design and construction of a prototype engine-integrated solid-oxide fuel cell (SOFC) system for more-electric and all-electric aircraft. The baseline engine is a small (50 lbf/222N thrust) COTS turbojet and the baseline electrical prime mover is a 200W integrated reformer/SOFC cannibalized from an Adaptive Materials APU. The performance of the engine and SOFC is measured and the data used to develop validated models for each. These validated models are combined to create a model of the integrated system that is used to design the prototype.

Designing electrical power systems for aircraft: an architectural challenge

Dr Jonathan Menu, research engineer, Siemens Industry Software NV, Belgium

Increased aircraft hybridization and electrification represent a next step toward more efficient, greener and safer aviation, but the design questions systems engineers are faced with are only partially addressed by current software tools. We present a methodology and tool that unifies different steps in the design process of electrical power systems. These steps include the automatic generation of system architectures, reliability analysis, controller generation and formal verification by simulation. The solution is generic and can be applied to failsafe design for other systems, among them hydraulics, hybrid powertrains and environmental control systems.

Status of process technology for type 2G high-temperature superconductors

Manuel La Rosa Betancourt, founder and director, PI Integral Solutions Limited, Germany

After 30 years of development, high-temperature superconductors (HTS) have achieved a degree of maturity that makes them suitable to become game changers in the race for developing all-electric airplanes. The superconductor industry has entered a phase of growth and economies of scale. Manufacturing technologies enable serial and continuous production of large quantities of wire, coils and magnets. Theva has succeeded in achieving substantial improvements in the performance of gadolinium-based HTS wire, using proprietary developed technology. The maturity level achieved allows commercial supply of products supported by robust processes, high quality consistency and competitive costs.

Can we fly jets and still save the planet?

Alex Major, founder and chairman, Green Flight Foundation, USA

In an attempt to reduce carbon emissions and reverse global warming and climate change, the entire transportation industry is transitioning to electric and hybrid-electric drive. In this presentation, we unpack the concept of using renewable aviation fuels in the range extender engines proposed for hybrid-electric aircraft propulsion systems, which do not turn propellers, but turn generators that charge battery packs that power electric drive motors that turn propellers. These next-generation renewable aviation fuels will reduce carbon emissions by 85-95%.

Liquid hydrogen storage technology for airborne applications

Emmanuel Bensadoun, aerospace innovation projects manager, Air Liquide Advanced Technologies, France

Hydrogen fuel cells have been extensively investigated in the past five to 10 years for aerospace applications such as drones and aircraft, as power supply sources for auxiliary power or propulsion purposes. Most of these projects rely on high-pressure hydrogen storage devices that display a high maturity level but low gravimetric index. The latter can be dramatically increased by liquid hydrogen storage technology inherited from space technology. This presentation focuses on liquid hydrogen storage for applications such as fuel cells on board aircraft.

Day 2: Friday, November 17

Day 2 Friday, November 17

09:00 - 17:00 — FUTURE GENERAL AVIATION TECHNOLOGY & CONCEPTS

ROOM A

Preparing the regulations for hybrid and electric aircraft

Gregory Bowles, VP – global innovation and policy, General Aviation Manufacturers Association, USA

From the regulations governing the design of aircraft to operations and licensing, the existing regulatory landscape in each country needs to be addressed to ensure key technologies can be fielded in the near term.

Aviation goes electric – does this fit into current regulations?

Manfred Reichel, section manager CT.2.2, European Aviation Safety Agency (EASA), Germany

Due to the nature of aviation, the high level of public attention aviation gets, and the complexity of the worldwide network, aviation is internationally well regulated and defined, and organized with only limited flexibility. The future possibilities with the upcoming new technology of electric propulsion, hybrid propulsion or more-electric aircraft go far beyond the current regulations and boundaries. This presentation will give information on how the European Aviation Safety Agency (EASA) will support the introduction of electric and hybrid propulsion in aviation, and what companies need to take into account when going for electrification.

Eviation Aircraft Alice – a new electric horizon for regional transport

Omer Bar-Yohay, CEO, Eviation Aircraft Ltd, Israel

Eviation Aircraft is leading a consortium of companies that is building the Eviation Alice commuter. Alice is an all-electric, 9+2-seat aircraft, capable of cruising at 240kts at 10,000ft with a range of 600 miles plus IFR reserves. The plane has been designed with high efficiency and passenger experience in mind, in close collaboration with several regional operators in the USA and the EU. Alice is expected to start flight tests for its FAR 23/CS23 certification by late 2018. In the presentation, Eviation's co-founder and CEO will describe the design and near-term use cases.

Conceptual design and flight testing of a subscale eVTOL aircraft

Francesco Giannini, aircraft designer, Aurora Flight Sciences, USA

Aurora Flight Sciences is developing an electric vertical take-off and landing (eVTOL) aircraft to satisfy the nascent aerial urban mobility market. This presentation covers the conceptual design phase. Safety, low acoustic signature for community acceptance, and robust handling qualities were deemed essential. A subscale model was designed and flown to retire perceived risk, particularly in the transition phase. Valuable feedback was obtained that led to the optimization of the relative arrangement of the center of gravity, lift rotors and lifting surfaces. The design of subscale models, as well as initial flight test results, will be discussed.

Testing results of 1MW high-efficiency generator for hybrid-electric propulsion

Cristian Anghel, technology fellow, Honeywell Aerospace, USA

This presentation describes the testing results of an efficient, high-power-density generator rated at 1MW of power, which is used in hybrid-electric propulsion and other applications requiring large power and compact installations. This generator is one of the key technologies supporting the goals of hybrid-electric propulsion. Honeywell has an extensive generator range, including fixed- and variable-frequency AC and DC generators, both air- and oil-cooled, based on 100 years of innovation and product development. Building on this experience, a 1MW generator was developed and tested.

The rise of electric aviation, sub-regional airlines and airports

Darrell Swanson, principal consultant, AviaSolutions, UK

In this presentation we will review the Uber Elevate paper and propose an alternative history of the rise of sub-regional airlines and the eventual fulfillment of Uber's vision. We will discuss the economics of such sub-regional airlines, outline their likely operating characteristics and identify factors that will be their enablers. Additionally we will review how sub-regional airlines could reinvigorate beleaguered regional airports and give rise to sub-regional airports and eventually sub-regional hub airports. We will also discuss the challenging economic and operating characteristics of airports looking to serve sub-regional airlines.

Applying autonomy to on-demand mobility

Steven Jacobson, CEO, Autonodyne LLC, USA

The presentation will focus on simplified vehicle operations (SVO) and technologies that enable on-demand mobility (ODM) using distributed electric propulsion (DEP) vehicles.

Day 2: Friday, November 17

09:00 - 17:00 — PROPULSION CONCEPTS & ELECTRIC MOTOR TECHNOLOGY

ROOM B

Integrated hybrid-BLI propulsion development

Dr Michael Armstrong, vision systems lead, Rolls-Royce North American Technologies, USA

This presentation will provide an update on the concept development of an integrated hybrid-electric and/or boundary-layer ingestion (BLI) propulsion system for a range of aircraft. It will discuss the latest incorporation road map for this technology and describe some of the progress made in overcoming the critical integration challenges for delivering this kind of propulsion system.

Hybrid and turbo-electric propulsion architectures for different aircraft configurations and mission requirements

Dr Panagiotis Laskaridis, head hybrid electric propulsion group, Cranfield University, UK

Hybrid-electric propulsion is a novel concept that can revolutionize the design and performance of future aircraft. The concept offers increased design and operational flexibility and enhanced synergies with other novel technologies, such as boundary-layer ingestion, turbo-electric propulsion and all-electric systems. The exact benefits of the concept depend heavily on the application and integration of the system. In this context, the presentation considers the application of hybrid and turbo-electric propulsion systems to different aircraft. Emphasis is given to the different architectures and the integration of various technologies at component, system and aircraft levels as a function of aircraft design and operational requirements.

Toward hybrid-electric propulsion – Safran's view

Dr Pierre-Alain Lambert, head, energy & propulsion, Safran Tech, France

The talk will address an update of Safran Group research on architectural and technological challenges associated with hybrid-electric propulsion, as viewed from the perspectives of a Tier 1 equipment supplier and a propulsive system integrator. Highlights covering several research programs currently underway at Safran will be shown, ranging from multisource non-propulsive energy generation for SMRs, up to longer-term disruptive propulsive architectures, through intermediate concepts based on the parallel hybridization of gas turbines.

Electric contra-rotating propulsion system for light aircraft

Nicholas Sills, founder, ContraElectric Propulsion Ltd, UK

Contra-rotating propeller systems have proven and significant benefits over single-propeller systems with the same horsepower, particularly by eliminating yaw. However, piston- and gas turbine-powered systems are mechanically complex and extremely expensive.

New electric motor architecture offers the opportunity to design simple, gearless and affordable coaxial contra-rotating systems for light aircraft. ContraElectric Propulsion has designed and built a 225kW twin-motor system and, in collaboration with Hercules Propellers, developed the special propeller sets necessary to match motor performance characteristics. Ground testing is complete and flight testing will commence in a specially built FURIO aircraft.

Fault-tolerant motor design for a helicopter electric tail rotor

Prof Philip Mellor, professor of Electrical Engineering, University of Bristol, UK

Dr Mircea Popescu, chief design engineer, Motor Design Ltd, UK

The JTI CleanSky ELETAD project investigated the feasibility of powering the tail rotor of a helicopter with an electric drive, replacing the current mechanical system comprising high-speed shafts and gearboxes. The program has led to successful ground testing of a high-integrity electric tail rotor drive for a medium twin-engine helicopter. An electro-thermal design tool for such machines has been established, which can accurately model temperatures over representative mission cycles and predict the thermoelectric degradation of the winding insulation system. The presentation offers an overview of the design drivers and modeling tool development, and will be accompanied by test results taken from the full-scale electric tail rotor drive.

Analysis of electric technologies application in airplane propulsion systems

Dr Anton Varyukhin, head of department, Central Institute of Aviation Motors, Russia

The results of analysis related to the application of electric technology for different classes of airplane are presented in this report. The analysis is based on the complex airplane preliminary design mathematical model. Requirements for the specific weight of electrical devices were defined. The main purpose of the calculations was to estimate the minimum achievable mass. This makes it possible to determine when the use of an electrical propulsion system is efficient.

Multidisciplinary design of hybrid-electric aircraft

Alexander Schneegans, managing partner, PACE Aerospace Engineering and Information Technology GmbH, Germany

The works presented during the 2016 symposium have been industrialized and made available in an industrially used software product for multidisciplinary design of aircraft. To this end, battery models and electric motors allow simulation in active and passive mode to account for energy recovery during descent phases. The propulsion model is embedded in a fully fledged environment for multidisciplinary aircraft design. Its application is demonstrated on the example of a three-engine commuter aircraft whose conventional turboprop engines are sized for cruise condition, with the electric engine providing the additional thrust for take-off and climb under one-engine inoperative conditions.

Technology path to megawatt electrical machines for commercial aircraft

Dr Mike Benzakein, AVP, aerospace research, The Ohio State University, USA

This presentation addresses the design and validation of high-reliability, high-power-density electrical machines and power electronics for commercial aircraft. The thermal management of these high-energy systems is discussed as well as their regulation in commercial aircraft. The system optimization to maximize the fuel and emission benefits for twin-aisle applications is outlined. This presentation summarizes this initiative led by The Ohio State University in cooperation with five other universities, NASA and industry in a multidisciplinary effort to address commercial aircraft of the future.

How high-performance hybrid supercars can drive aeronautical EV technology development

Justin Almeleh, program manager, Motivo Engineering, USA

Ever since the NACA duct was introduced to the automotive world, technology has typically transferred from the aeronautic to the automotive industry. With the advent of hybrid powertrains being used by supercars to increase performance rather than efficiency, recent electric vehicle powertrain development has focused on increasing power-to-weight ratios. Given that the high-level system architectures of an electric aircraft and those of an electric supercar are markedly similar, there exists a unique opportunity for the aviation industry to leverage much of the cutting-edge technology currently being developed in the automotive industry.

Electric contra-rotating boundary layer propulsion in fuselage mounted tailplane

Nelson Cámara Aguiar, R&D advanced consultant, Aeronautics, Space and Defence Division, Altran, Spain

In the present study developed by Altran ASD I + D Spain, we focused on the energization of the boundary layer of the conventional single-aisle transport aircraft rear fuselage by the integration of electrical counter-rotating propeller in the tail end zone in one configuration. With a horizontal stabilizer located at the height of the fuselage, impact studies have been developed on the aircraft's electrical system, structure and flow irregularities induced by the fuselage and the stabilizers in the efficiency of the propeller in conditions of flight from cruising to Mach 0.78, and measures have been developed to counteract it, and to increase the obtainable propulsive efficiency and its reflection in the reduction of fuel consumption and the improvement of performance.

Problems of electrical aircraft design – efficiency versus safety

Sergey Khalyutin, CEO, Experimental Laboratory NaukaSoft, Russia

The ability to create electric or hybrid aircraft depends on the efficiency of the electrical power sources and the energy intensity of energy storage. Increasing the energy intensity and energy efficiency leads to a decrease in aircraft safety. The solution is to use a control system that is capable of providing the desired level of safety. Examples of control actions are presented.

Hybrid-electric propulsion systems for UAVs

Feriel Samouda, aeronautical engineer, Star Engineering, France

One challenge in the unmanned aircraft vehicles industry will be achieving a sufficiently high power-to-weight ratio for the drive of the system. One critical aspect in UAV design is the provision of high power with light mass. In addition, research programs on new transportation mean that the target today is for unmanned aircraft vehicles to be alternatives to conventional transportation solutions, especially regarding their operating cost and environmental impact. This paper discusses some case studies on existing hybrid research programs in the field of UAVs, regarding technical and certification aspects.

*This program may be subject to change.

BRAND-NEW PAPERS!

Topics under discussion:

- The possibilities created by aircraft hybridization
- More-electric aircraft systems
- Commercial aircraft application possibilities and research
- Battery technologies
- Electric motor technologies
- Environmental impact
- Real-world fuel-saving possibilities
- Energy-storage systems
- Solar possibilities
- Efficiency and durability
- Safety and legislative considerations
- Increasing flight range through hybridization
- The possibilities of pure electric-only commercial and military flight
- Case studies of existing global electric and hybrid research programs
- Overcoming engineering challenges
- Best design practices
- Investment possibilities
- Additional advantages of increased electrification
- Range-extender technologies

**This program may be subject to change.*

SPACE TECH EXPO EUROPE

24 – 26 October 2017
Bremen, Germany

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Europe's Largest Dedicated Space Technology Trade Fair and Conference

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- **Europe's only senior executive and technical-level two track free-to-attend industry forums** featuring sessions on Global Cooperation and how to do business with Agencies, Primes and Tier 1s
- **B2B Matchmaking –** a complimentary B2B Matchmaking service to connect with other businesses on a one-to-one basis

2017 exhibiting companies include:

esa European Space Agency · DLR · OHB · ThalesAlenia Space · ArianeGroup · TESAT SPACECOM PIONEERING WITH PASSION · Fraunhofer SPACE · IABG · Orbital ATK · TESTIA · BEST OF SPACE SME: The Backbone of Business · Luxembourg Space Cluster · ROHDE&SCHWARZ · ZARM · BAE SYSTEMS INSPIRED WORK · SGS · Rosenberger · Air Liquide creative oxygen

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European Space Agency (ESA)

Prof. Dr. Pascale Ehrenfreund,
Chair of the Executive Board,
DLR

Jean-Yves Le Gall,
President,
CNES

Sylvain Laporte,
President,
Canadian Space Agency (CSA)

Timothy Tawney,
NASA Europe Representative,
NASA

Dr. Oliver Juckenhöfel,
Head of Site Bremen and Vice President On-Orbit Services and Exploration,
Airbus Defence & Space

John Roth,
Vice President of Strategy & Business Development, Space Systems,
Sierra Nevada Corporation

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// ANTHONY JAMES

THE PLACE FOR SPACE TECH

Thousands will gather in Germany for the space sector's pre-eminent free industry event on October 24-26, 2017

VENUE DETAILS

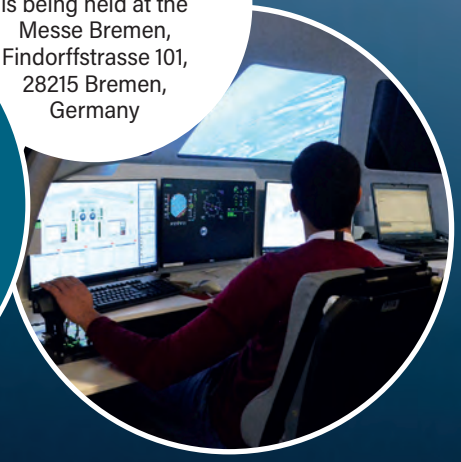
Space Tech Expo Europe is being held at the Messe Bremen, Findorffstrasse 101, 28215 Bremen, Germany

OPENING HOURS

Tuesday, October 24
9:00am–*6:00pm*
(Drinks reception in the exhibition hall, 4:30pm–6:00pm)

Wednesday, October 25
9:00am–5:00pm

Thursday, October 26
9:00am–3:00pm

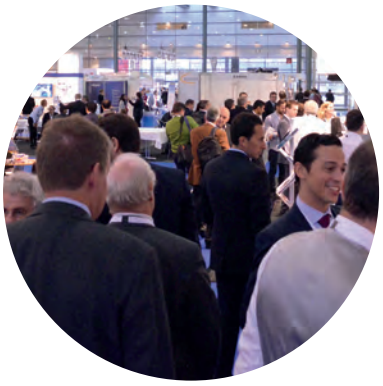


This autumn, thousands of industry players from the space and aerospace technology sector will flock to Bremen, Germany, as Space Tech Expo Europe returns to its host city.

From October 24-26, 2017, expo attendees will have access to almost 300 exhibiting suppliers, as well as high-level speaking forums and B2B matchmaking sessions. The free-to-attend trade fair is Europe's largest event for the space sector and offers unparalleled opportunities for industry engagement. Held at Messe Bremen, Space Tech Expo is dedicated to space technology engineering and manufacturing, products, services and testing solutions.

Bremen has a long history of space and technological innovation, and today the city is a hub for aeronautics and aerospace innovation, making it the perfect location for space industry representatives to gather and discover the latest developments in the sector. Space Tech Expo Europe draws thousands of technical visitors who represent all areas of the space sector – from space agencies, satellite manufacturers, launch providers to technology suppliers and testing service providers. Some of the industry's biggest names will be exhibiting at the event, including ESA, DLR, OHB, Thales Alenia Space, ArianeGroup, Tesat-Spacecom, MBDA, Fraunhofer Space, Orbital ATK, BAE Systems, iABG, Testia, Rohde & Schwarz, AIM GmbH, SGS, HBM Test & Measurement, ZARM, BReTeCe and Sonatest, with key sponsorship from Airbus Defence & Space.

"We are very much looking forward to Space Tech Expo Europe's return to Bremen, the hub of space and aerospace innovation," says Andreas Gerber, director of international affairs at Bremen Invest. "We've calculated that Bremen has the highest aeronautics and aerospace employment density in Germany, with approximately 12,000 employees working in the local aeronautics and space industries sector, turning over more than €4bn annually, so this show is very well placed. The 2015 expo was highly regarded by all who attended and we're sure the success of the show will grow in 2017."



B2B MATCHMAKING RETURNS TO BREMEN

Space Tech Expo Europe offers a focused marketplace for the European space industry to bring representatives from across the supply chain under one roof for three days of discovery, business and innovation. It also serves to connect individuals and businesses from across the industry spectrum, and this is where the B2B Matchmaking service comes in.

Incredibly popular in its first year, the service – organized in cooperation with Enterprise Europe Network Bremen – connects attendees with other businesses on a one-to-one basis. An online profile allows users to share information, detail their business requirements and schedule meetings with like-minded companies. The 2015 service enjoyed phenomenal success, resulting in more than 1,000 meetings over three days. Participating companies included OHB System, Airbus Defence and Space, Thales Alenia Space, Airbus D&S, QinetiQ, SITAEL, Excelitas, Nexeya, Intespace, Printech Circuit Laboratories, Marshall Aerospace & Defense Group, SYSGO, DSI GmbH, Arrow Electronics, Kongsberg Satellite Services, Saft, Netherlands Aerospace Centre and many more.

The B2B Matchmaking service enables users to network ahead of the event, maximizing opportunities for meeting prospective clients and partners. The platform encourages participating companies to present and discuss new projects and engage with other users outside their business field, as well as find clients for products and services. Meeting industry peers, pinpointing investment opportunities and meeting multiple potential business partners in one place are all major advantages.

One 2015 participant said, "It was really good talking to people and having that really quick but worthwhile interaction." Many others echoed this, and Bremen Invest's innovation manager, Ellen Horstmann, was thrilled, saying: "Usually when you go to a show you have to do desk research to find relevant companies. Now this is being done by the online platform, so it's really time-saving. Participants can discuss the project before meeting in person."

A PLATFORM FOR DISCUSSION

The Industry and Technology Forum is a platform for space industry professionals from around the globe to exchange ideas, discover groundbreaking new technologies, and discuss market trends, developments and challenges.

Free to attend, these senior-led forums are designed for engineers, manufacturers and decision makers at commercial space, aerospace and defense organizations, startups and space agencies.

This year the forum will tackle topics, from how to do business with space agencies to investing in space. Speakers will discuss global cooperation and investment in the sector, and discussions will cover some of the hottest topics in the industry (and in the media). For example, on the agenda is a panel examining how advanced space transportation systems are changing human exploration.

Speakers from industry-leading companies will take the floor, with ESA's director-general, Prof. Johann-Dietrich Wörner; DLR's chairwoman of the executive board, Prof. Dr Pascale Ehrenfreund; and Jean-Yves Le Gall, president of CNES listed on a long line-up of high-level speakers who will be sharing their insights and encouraging well-informed debate. There is a comprehensive agenda planned, with contributing companies presenting the latest on additive manufacturing, propulsion, electrical components, robotics, and testing and measurement, to name a few.

With its complementary learning sessions, high speaker quality and huge subject scope, the Industry and Technology Forum stands out as a compelling event for industry players from all segments of the space and aerospace sector. Access to the forum is included with the free expo pass, so to be involved simply register for your free pass at www.spacetechexpo.eu.

Get on the 1553 bus with AIM

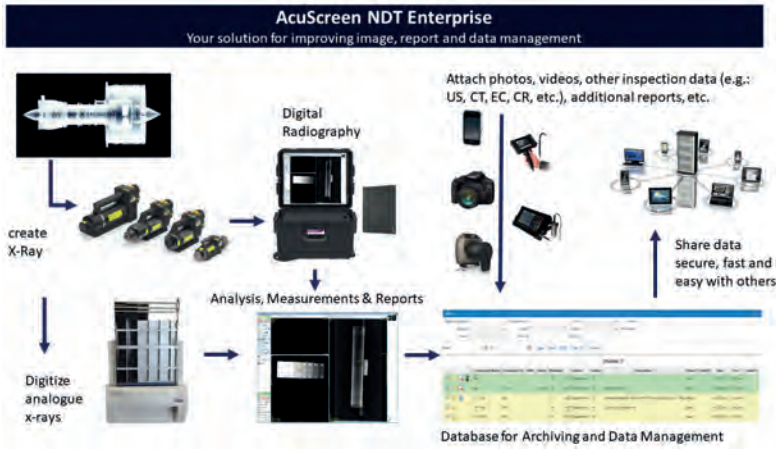
AIM GmbH on Stand G77

AIM GmBH, a leading designer and manufacturer of high-quality avionics test simulation products, will be bringing SmartCable to the exhibition floor. Portable USB-based interfaces for MIL-STD-1553 testing have been on the market for a few years, but never before in the form of a SmartCable, which boasts lightweight, portable and low-power design with a full-function, dual-redundant MIL-STD-1553 interface. Avionics test engineers can debug, monitor, record and play back MIL-STD-1553 bus traffic for troubleshooting and bus analysis purposes. Meanwhile, users can write their own dedicated application software or use AIM's powerful, off-the-shelf PBA.pro databus test and analysis software.

Head to stand G77 to discover other exciting new products from AIM for the avionics test and simulation market. Its focus at the event will be on MIL-STD-1553 and ARINC825 for space applications.

Unique solutions for the aerospace sector

Pacsess NDT develops, delivers and integrates solutions for NDT imaging, archiving and communications. The company's goal is to optimize daily workflow and improve productivity and the quality-management process, and it has the digital acquisition process covered. At the Space Tech Expo, Pacsess NDT will be showcasing its dedicated NDT software AcuScreen modules, for the acquisition, analyzing and dedicated archiving of x-ray images and inspection reports. The company's latest development is AcuScreen Enterprise – a specific software tool to collect x-rays, ultrasonic images, CT scans, photos and other test images alongside various report formats. It is possible to use just one application to connect many testing images and reports in an easy-to-use, secure workflow. AcuScreen Enterprise is the first to integrate planning and order-management processes for all testing with relevant measures and inspection reports, and has been specifically designed to fulfill the needs of the aerospace industry. To find out more, visit Pacsess NDT on stand H74.



Pacsess NDT on stand H74

Just Vacuum on Stand H50

Capable partner in vacuum and deposition technology

Since 1993, Just Vacuum has been producing a range of vacuum and deposition technologies, from standard flange parts over vacuum chambers, deposition components and systems, to complete vacuum systems including pumping and measuring equipment and complete system control and automation technology.

At Space Tech Expo Europe 2017, Just Vacuum will be demonstrating its space simulation chambers, which are used to simulate changes in pressure and temperature as they occur in space. A system includes a dynamically controllable temperature range from -180°C to +180°C in high and ultra-high vacuum conditions, integrated measuring technology and customer-specific feedthroughs. They can also be fully automated.

Visit Just Vacuum at stand H50 to watch the demo of this state-of-the-art measuring technology for the space industry.

m+p International on Stand G92

Technical leader in vibration control and analysis

m+p International supplies advanced software that supports high-performance instrumentation for both shaker testing and noise and vibration measurement and analysis. Applications include vibration control, shock testing, multishaker testing, overtest protection, structural dynamics, modal testing, ground vibration testing, acoustics and rotating machinery. The company also provides solutions for multichannel data acquisition, temperature measurements, strain measurements and experimental stress analysis to the aerospace testing community.

m+p International upholds its belief that continuous research and development rest at the heart of global success, and the company will be exhibiting some of its newest hardware innovations for multichannel mobile and laboratory use at Space Tech Expo Europe. Stop by stand G92 to learn more about m+p International's latest innovations in product development.

NPL on Stand E90

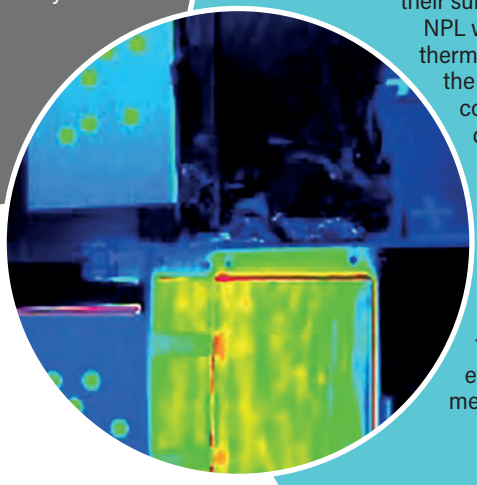
Precision solutions for tomorrow's spacecraft testing

NPL – the UK's National Measurement Institute – works to meet the precision-measurement needs of the space industry, and at this year's Space Tech Expo Europe the company will be exhibiting new-to-market technologies that have the potential to greatly improve the verification of satellites and their subsystems.

NPL will be showcasing its 3D thermography testing technique, the only method enabling non-contact true temperature qualification of whole satellites and subsystems, and demonstrating a new system designed to increase customer confidence in the adoption of cutting-edge propulsion technologies. The new micro-Newton electric propulsion thrust measurement system is the first of its kind to provide independently accredited performance.

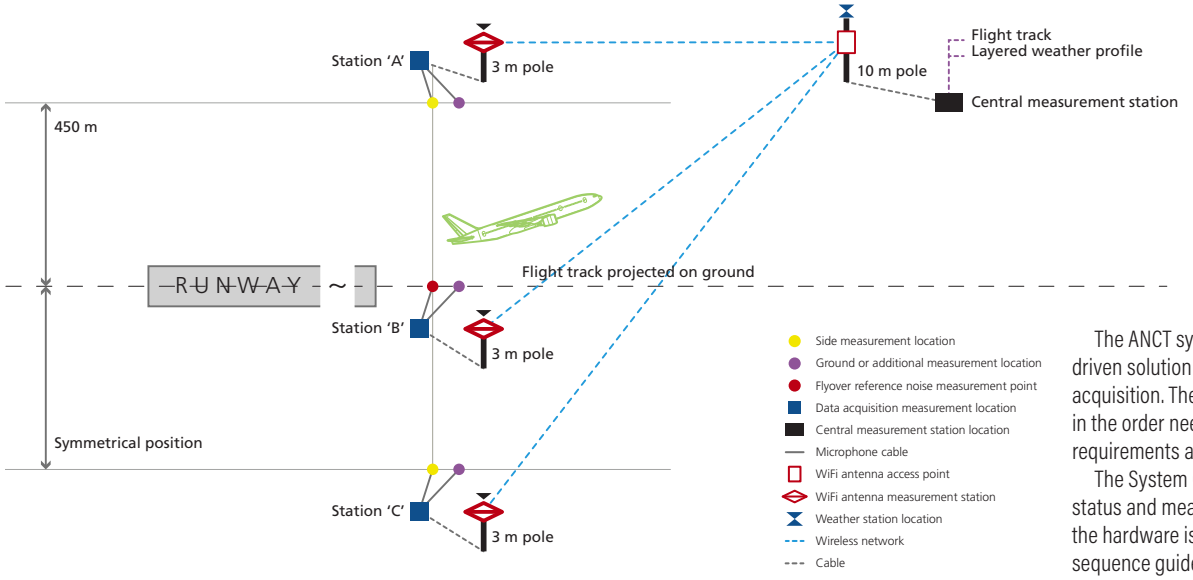
Driven by the challenges faced by the industry, NPL pioneers commercial testing instruments and techniques to improve satellite performance and the end-to-end value chain, and meet the demands of tomorrow's spacecraft testing and manufacturing. The company works with space agencies and companies to improve their quality-control systems, reduce the cost of testing and increase the credibility of their services through digital innovations, advanced manufacturing techniques, as well as measurement products and services such as precision instruments, calibration services, consultancy and accredited training.

NPL's customers and partners include the European Space Agency, Airbus Defence & Space, Telespazio VEGA UK and Orbital Sciences. To discover more, visit stand E90.



A STREAMLINED SOLUTION FOR COMPLEX NOISE CERTIFICATIONS

Aircraft noise certification tests require establishing certified effective perceived noise levels (EPNL) in accordance with aircraft noise certification standards. Without these, the new bird won't fly...



1 // Schematic overview of an ANCT. Distributed measurement locations are remotely controlled from, and transmit data by wi-fi to, the central measurement station

The Aircraft Noise Certification Test (ANCT) system is a dedicated solution integrating and optimizing the inherent features of Brüel & Kjær's commercial off-the-shelf products. The ANCT system provides the corrected noise measurement data for post-calculations and then approval by the certification authority. In addition, Brüel & Kjær engineering experts provide assistance with the process of obtaining measurement system certification.

Because this process is very costly to organize and implement, the ANCT procedure is designed to be completed in a day, from setup to providing the corrected data. The entire measurement chain has been codified into one dedicated and streamlined workflow that ensures all required tasks and operations are performed with maximum reliability and efficiency. The system supports intercept and break-off flight track test procedures, as outlined in *Environmental Technical Manual on the use of Procedures in the Noise Certification of Aircraft*. This procedure is widely accepted by the aircraft noise certification community as the most efficient, as it eliminates the need for actual take-offs and landings, thereby providing operational advantages and substantially reducing flight testing time and costs.

The ANCT system is compliant with the requirements and procedures governing use by aircraft manufacturers for aircraft noise certification and employs Brüel & Kjær's PULSE data acquisition and analysis (overall and one-third octave) system, based on the LAN-XI data acquisition modules and PULSE real-time/post-processing application. Workflow is managed by the data acquisition and handling framework, which provides an optimized user interface to control PULSE software for all setup, calibration, measurement, analysis, calculations and data management. The system provides full integration of the measurement chain to optimize test preparation, improving efficiency and reducing overall cost.

The system architecture has been streamlined to enable a minimal preparation and measurement time with a distributed, scalable and synchronized data acquisition setup. Because of its distributed and scalable design, the system can be used for acquiring the certification data or expanded for research and development and tests leading up to the final certification test flights.

The ANCT system is a complete workflow-driven solution supporting all phases of data acquisition. The tabs are set sequentially, in the order needed, to ensure standard requirements are met.

The System Overview tab provides overall status and measurement controls and once the hardware is set up, the software's tab sequence guides engineers through the process, starting with Configuration (configuring each measurement station) and Calibration (which sets up the correct calibrating actions to occur at the right time).

The tabs are for setting up monitoring/validating and/or recording include Acoustic, Weather, Flight Track, Events View (viewing all the flight runs available and the synthesis plot), Validation (EPNL post-calculations, test validation purposes only) and Data Handling.

This Brüel & Kjær ANCT system is designed to meet the requirements of the applicable standards by reducing the complexity and expense of the certification process. The configuration of the system is organized in a logical and intuitive way to support integrated flight test workflows.

The measurement stations are designed to minimize setup time to benefit engineering personnel and these benefits all combine to provide a streamlined and cost-effective solution to a requirement that all aircraft manufacturers must meet. \\

CT AND DIGITAL X-RAY INSPECTION

Are third-party computed tomography and digital x-ray inspection services right for your business?

Non-destructive testing has seemingly limitless applications. From miniscule integrated circuit parts to large airplane engine turbines, 2D x-ray and 3D computed tomography (CT) imaging technologies provide stunning high-resolution pictures for defect and structural testing and analysis. However, the infrastructure, labor capital and certification required to carry out such tests on-site can be a considerable investment. It is not only the cost of a state-of-the-art inspection system, but the personnel training, installation and legal regulations that require time and money, too.

Third-party inspection services offer an economically efficient and reliable alternative. Whether a company needs to temporarily increase its existing testing capacity or does not have the business case or capital to invest, these services aim to make the capabilities and benefits of NDT by x-ray and CT accessible to everyone. By taking the brunt of the investment, inspection service partners can help with project planning, technology support and data analysis, prototyping, and the inspection of over-sized components. Support in these areas saves companies time and money. Beyond standard assembly control, inspection services help companies of all sizes with a myriad of testing needs.

Some common test examples include:

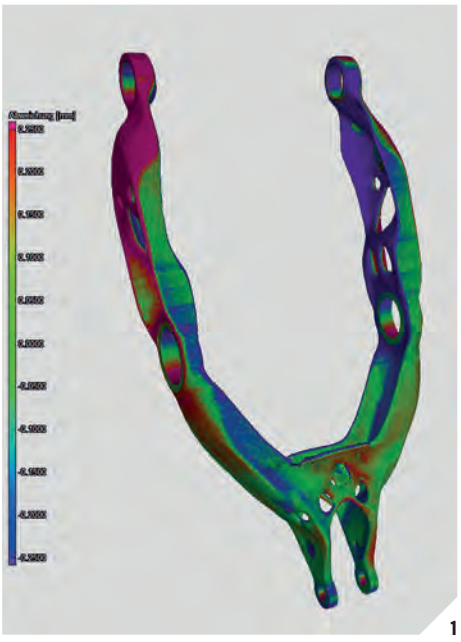
Defect and porosity analysis: These tests, including the P201/202 test, the German Foundry Association (VDG) standard regulatory analysis, provide the location and size of cracks and pores, which allows users to make informed decisions about production variables such as injection pressure, temperature, and the location of injection points.

Fiber analysis: This technique can help visualize and characterize the fibers in fiber-reinforced materials and determine metrics such as fiber volume, orientation, length and diameter in order to determine the optimal fiber ratio.

Actual versus nominal: This comparison is used to detect deviations between the actual part and the CAD or STL information, and procure exact metrological dimensions not attainable through tactile or visual means, to help you find quick and cost-effective solutions to problems in specific production patterns.

Metrology: Now that CT has been accepted as a metrology tool for many applications, companies can render 3D images of any component and retain data sets that allow you to measure the smallest distances orthogonally to develop extremely precise models that aid in efficient production.

Reverse engineering: This approach digitizes components' attributes and dimensions using highly precise measurements to enable reproduction of 'new old stock' or parts whose CAD models and drawings either do not exist or were not systematically archived.



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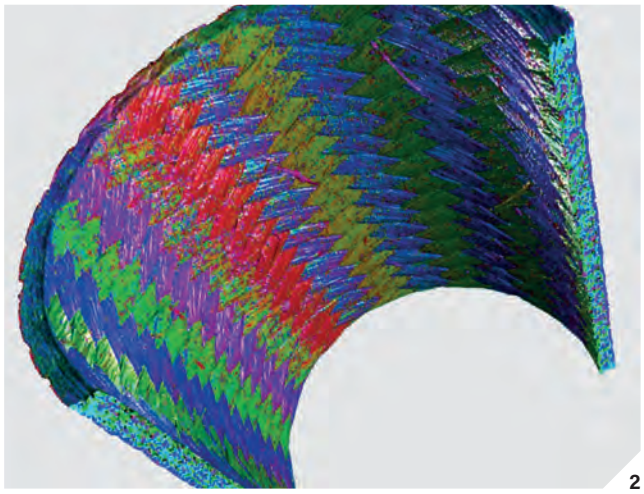


2

1 // Actual versus nominal CT-generated comparison of bell crank

2 // Color-coded composite fiber analysis using CT

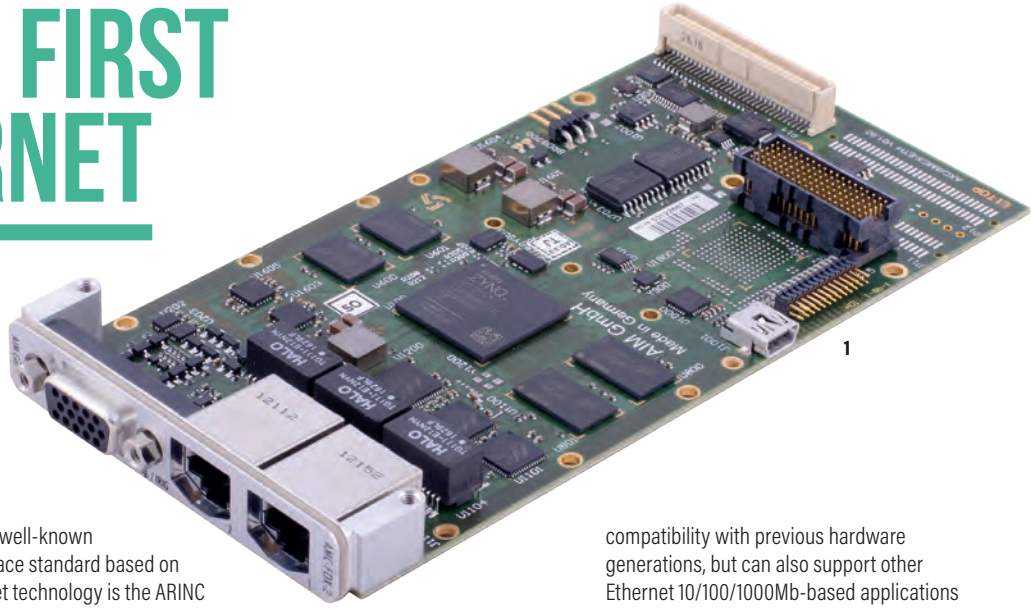
All of these procedures are carried out with very specific goals in mind – to reduce processing times, help develop the highest-quality products and, ultimately, save companies money. That's why Yxlon (which has pioneered x-ray inspection for the past 120 years) supplies its customers with the latest in 2D and 3D imaging technology.

The company is now striving to make inspection services available to everyone, everywhere. With its 12 inspection service locations worldwide, it sees every conceivable sample. From animal fossils to Formula 1 race car components, to sophisticated aerospace engine parts, to printed circuit boards, Yxlon's huge array of x-ray and CT inspection systems accommodates an unlimited range of applications.

On October 4, 2017, it will continue this strategy of bringing technology closer to its customers by adding yet another service location to the list. Yxlon's parent company, Comet Group, will open Lab One in San Jose, California, which will be an inspirational and collaborative hub for all Comet technologies. As Comet's largest technology laboratory to date, it will make RF power, ebeam, as well as a wide variety of Yxlon's inspection systems, available to the public, under one, innovative roof. \\

FLEXIBILITY FIRST WITH ETHERNET

Testing solutions using Ethernet-based data communications are simple in concept, but variations in upper layers add complications, and enabling special features requires flexibility



1

There are several well-established dedicated communication standards in the aerospace and defense market, but Ethernet is the most prevalent communications method in avionics architectures. Despite dating back to the 1970s, Ethernet technology remains in demand. There are several reasons for the popularity of its new programs.

First, it offers high data rates of 10/100/1000Mb based on proven implementations and COTS components. Second, the development of higher data rates up to 10Gb is already implemented, offering transparency for upper layer standard protocols and enabling the efficient migration of existing Ethernet-based applications to the latest technology.

Statements like 'using Ethernet' do not really make the situation clear, since they can refer simply to the lower layers of the ISO/OSI model, specifically the physical layer. An important step when envisioning the use of Ethernet for an operational data communication system is to look at the application or system requirements, since dedicated data communication standards such as MIL-STD-1553 offer redundancy and a robust, deterministic behavior that is missing in the standard Ethernet world.

Today, there are many extensions of standard Ethernet, derived from applications tailored for industrial automation, automotive, railway, aerospace and defense. These derivatives have their own specialities with respect to addressing specific application needs. Potential users, such as system designers, adopters of Ethernet technology and test equipment suppliers, need to understand that talking about 'using Ethernet' is not enough to identify the best testing protocol solution.

One well-known aerospace standard based on Ethernet technology is the ARINC 664P7 standard, or the Avionics Full-Duplex Switched Ethernet. First adopted more than 15 years ago, it uses reduced IP and UDP upper layer protocols over 10/100Mb, but with extensions on the MAC Layer (ISO/OSI Layer 2) for deterministic behavior and redundancy support.

The nature of these extensions means that, although standard Ethernet equipment may be fit for some testing purposes, dedicated test equipment is needed.

More complex testing scenarios, such as interface/device verification or the simulation of multiple devices of an aircraft system, demand powerful hardware and software testing products to support the corresponding testing solutions.

AIM has more than 16 years' experience with Ethernet-based systems. As a test equipment supplier for avionics databuses and networks, AIM has addressed almost all aspects of AFDX/ARINC664P7 testing.

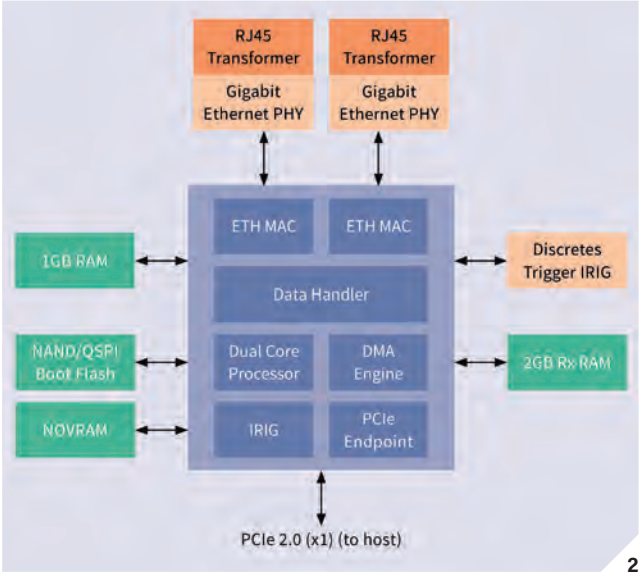
The products and systems from the company range, from protocol analyzers, interface modules for system integration benches, and switch and end systems compliance testing solutions, to Boeing ARINC664P7 variants, ARINC 615A data loading and dedicated technical seminars.

AIM has now developed a family of modules which not only handle all of the AFDX/ARINC 664P7 features, but can also be easily adapted to other types of applications and Ethernet variants. The hardware platforms for testing the Ethernet-based AFDX/ARINC 664P7 have been updated with the new APE-FDX-2 PCI Express board design, utilizing the latest SoC (system on chip) technology (Figure 2). This offers compatibility with previous hardware generations, but can also support other Ethernet 10/100/1000Mb-based applications due to a flexible hardware and software design with a customized FPGA MAC (media access controller), external time sync and hardware trigger I/O capability, and an embedded LINUX-based onboard dual core CPU.

A major goal for this new interface – also available as XMC and PMC (Figure 1) – was 'flexibility first'; in addition to AFDX/ARINC 664P7, it handles other Ethernet-based data communication standards up to 1Gb. \\

1 // AXC-FDX-2: XMC-based ARINC664P7/ Ethernet module

2 // Block diagram for PCIe-based ARINC664P7/ Ethernet module



2

ENERGY-SAVING 350KN SHAKER

A new water-cooled shaker offers 350kN of force, which should meet aerospace testing needs for higher test specifications

Development in the space industry is shifting, with more companies and university-based groups exploring the building of smaller, low-cost satellites. The trend is pushing OEMs and suppliers to come up with ever more reliable methods of testing and validating the products. Vibration testing is used to simulate launch-induced shaking. Sensitive equipment mounted on satellite systems is exposed to a tough launch environment.

IMV has launched a K-series water-cooled vibration simulating test system with a rated force of 350kN – the K350. This unit meets the requirement for high excitation force and high-level shock testing in the aerospace industry.

The new shaker has 3in (76.2mm) peak-to-peak stroke and a high-frequency range of 2,000Hz (up to 3,000Hz with no load) without a lowering of its resonance frequency. This is a specification that can enlarge the scope of testing and responds to the market's demand for increasingly high test specifications.

Additionally, the K350 shaker can provide a maximum 3.5m/s shock velocity for testing, which was impossible to do before on a conventional shaker. There is no limit for the number of times this can be achieved and it is possible to perform a sine sweep test at 100% excitation force.

So how is the K350 shaker capable of achieving this level of performance? The main challenge in the development of the K350 was the armature, which has been designed from scratch for optimal configuration for frequency response analysis. The armature is made of highly rigid aluminum alloy. It has 30% higher stiffness than the armature in a conventional shaker and this choice of material is one of the factors that increases the resonance frequency.

The Parallel Slope Guide (PSG) is used on the K350; it is an IMV-patented system designed to achieve a highly durable armature. Its design offers excellent performance as well as sufficient stiffness and durability to resist cross-axis forces. It also produces low distortion at all levels of vibration.

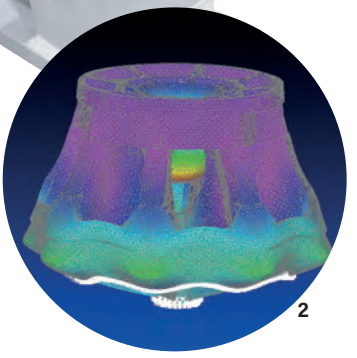
High vibration levels also place extreme stress on the main parts of the vibration generator and the solid construction of the K350 is designed to resist these.

In addition, the K350 incorporates a high-voltage power amplifier equipped with a 'New Power Module' rated up to 200V rms, so it can produce remarkably high acceleration and velocity output without needing a matching transformer and extra amplifiers.

The K350 is available with IMV's award winning eco-technology. The unique eco-technology with automatic energy-saving operation has the capability of full field control to deliver high-level system specification for accurate vibration testing.

With traditional shakers, tests needing high shock velocities use a matching transformer to achieve higher armature voltages. This increases system costs and means that modern armature positioning systems (DC controlled) will no longer work.

Since IMV's eco-shaker has complete control over the field level values, these can be adjusted to increase the maximum shock velocity capability of the system. \\



1 // IMV's new K350 shaker offers 350kN of force for high excitation force and high-level shock testing

2 // K350 armature frequency response analysis diagram

BREAKTHROUGH PERFORMANCE

Frequency range
DC ~2,000Hz (no load ~3,000Hz)
Resonance frequency
1,320Hz
Max force
Sine: 350kN,
Random: 315kN rms,
Shock: 700kN peak
Max acceleration
Sine: 1,000m/s² (for durability testing)
Random: 700m/s² rms,
Shock: 2,000m/s² peak
Max velocity
Sine 2m/s, shock 3.5m/s peak (field currency at 560A)
Max displacement
Sine 76.2mm p-p
Max load
3,000kg
Power requirement
420kVA

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TEST PILOT SCHOOL ORDERS DATA ACQUISITION SYSTEM

The National Test Pilot School in Mojave, California, has recently turned to a small British company to answer its data recorder needs

1 // Nginuity DAQ9000 data acquisition system

Relatively new company Nginuity, based in Dorset, UK, continues to win some impressive customers for its DAQ9000 data acquisition system, having recently captured an order from the National Test Pilots School (NTPS) in Mojave, California.

The DAQ9000 is a highly configurable multifunction, multiprotocol, data acquisition/recorder system and data concentrator for use as a flight data acquisition unit (FDAU) or instrumentation data acquisition system. It allows a wide range of characterization modules to be installed to provide the functionality desired, for digital and analog input or output. Inputs and outputs are highly configurable by customers to allow the use of common hardware across a range of applications.

The DAQ9000 primarily consists of a chassis and power input/system controller module with recording, GPS and a real-time clock to provide time stamping of data. Additional modules may be selected to provide a range of functions to suit the intended application and/or installation.

DAQ9000 modules from the DAQ family provide functionality such as ARINC-429, ARINC-573/717, RS232, RS422, MIL-STD-1553B, CAN, IRIG-106-13, analog I/O, frequency I/O, engine tacho, potentiometer input, strain gauge input, synchro and discrete I/O. The unit also provides dual Ethernet and USB interfaces for programming, data download and real-time display, while also allowing multiple DAQ9000 chassis to be interconnected as part of a larger, distributed, data acquisition system.

Supported by the DAQManager software suite, each card in the DAQ9000 chassis can be configured, calibrated and mapped to the target sensor or databus parameter while providing a real-time display of the calibrated parameter, ensuring a versatile and rapid method of sensor installation and calibration. DAQManager also provides a sensor calibration wizard to simplify the calibration process. For a simple linear voltage output sensor, this process can take only a few seconds. For serial output cards, such as IRIG-106-13, MIL-STD-1553B, ARINC-429 and ARINC-717, a frame builder utility is provided to provide control of parameter output order, repetition rates, etc.

A graphical presentation uses a flight instrument display format to enable labels such as altitude, airspeed, rate of climb, heading, attitude, etc, to be displayed.

In addition to DAQManager, the DAQ9000 is also supported by Nginuity's DAQ-RT real-time parameter display software. The standard Ethernet interface in the DAQ9000 unit is provided for maintenance and setup purposes. A second Ethernet interface may be included for real-time data output via UDP. The DAQ9000 can output the full parameter list live to a laptop/PC for display as tabular/graphical data or as virtual instruments using Nginuity's DAQ-RT real-time display software.

Finally, the DAQ9000 is also supported by DAQReplay, a post-flight data visualization and analysis tool. DAQReplay provides a data download and decode facility, allowing data to be plotted and analyzed post-flight. DAQReplay also provides an export facility, such that data can be converted and exported in CSV format for porting.

Asked to summarize the DAQ9000's key advantages, Nick Kidd, Nginuity's director, emphasizes its novel approach to meeting data acquisition objectives. "The DAQ9000 may not be the smallest product or have the highest data rate available, but it does provide the 'best value' package, for a large proportion of applications," he says. "It provides a wide range of data acquisition functionality and industry standard telemetry interfaces, including C band IRIG 106 telemetry and Ethernet. Direct real-time data monitoring and display can allow inflight data analysis, including real-time connection to the industry-standard Symvionics IADS software. DAQ9000 is flexible and easily reconfigurable by the customer if required, to allow the same hardware platform to be used across a range of aircraft types. The DAQ9000 uses robust and reliable MIL-C-38999 connectors for easy maintenance and repair of wiring harnesses and equipment reuse. The latest DAQ9000 variant also includes independent air data and inertial measurement."

Regarding the recent NTPS order, Kidd says that the company has been working with the test school over a number of years to add functionality to allow the same DAQ9000 hardware platform to work across a range of six fixed-wing (jet and propeller) and rotary-wing aircraft, aided by the unit's built-in flexibility and reconfigurability. "As each additional requirement was presented by NTPS, the DAQ9000 was enhanced to meet it."

Nginuity also provides an extensive range of supporting test equipment, both airborne and ground-based, for common avionics interfaces, and production fit equipment for data acquisition, data conversion and flight data acquisition units. \\

SILENCING AIR TRAFFIC NOISE WITH ELECTRIC PROPULSION

Electrically powered aircraft are quieter than conventional aircraft and fly-over testing results show that the noise they make is more agreeable to the human ear

An electrically propelled Extra 330LE aerobatic airplane set a new speed record on March 23, 2017 when it reached a top speed of around 340km/h (211mph), over a distance of 3km (1.9miles). The record attempt took place at the Dinslaken Schwarze Heide airfield in Germany, and the next day, the aircraft became the world's first electric aircraft to tow a glider into the sky.

It takes power to deliver such performances. The Extra 330LE is a prototype, powered by a next-generation electric motor design developed by Siemens. Boasting a weight of just 50kg (110 lb), the Siemens SP260D electrical motor delivers a continuous output of about 260kW (349bhp). This is five times more than comparable electric drive systems. The aircraft's motor is almost silent and fly-over tests revealed it to be about 14dB quieter than an internal combustion engine.

Electric propulsion is not solely about energy efficiency and instant power. It will also shape the future of aviation by reducing air traffic noise. Air traffic is expected to continue its unstoppable growth, and with it come potentially damaging consequences for the environment. In addition to CO_2 emissions and greenhouse effects, aircraft noise pollution, especially near airports, is a source of concern. Its negative impact on health has been proven.

With electric propulsion systems, aircraft noise pollution can be considerably reduced. Lowered engine noise that improves in-cabin sound levels will make flying more enjoyable. More importantly, the health and well-being of those on the ground would not degrade due to acoustic disruptions.

How much could electric or hybrid-electric aircraft contribute to reducing air traffic noise? To find out, a fly-over test was performed, using Simcenter noise and vibration engineering solutions, to compare the acoustic levels of the standard Extra 330LT combustion engine with the electric motor version of the Extra 330LE aircraft.

Three different flight conditions were tested: take-off; fly-over at 50ft (15m); and fly-over at 1,000ft (304m). The results are astounding: during the fly-over test at 1,000ft, the electrically powered aircraft produces 14.5dB(A) less than the combustion engine aircraft. When measured according to the prescribed standard ICAO Annex 16, the LASmax (maximum level of the A-weighted sound pressure, in decibels) only reaches 69.2dB(A) for the electric aircraft, compared with 83.7dB(A) for the conventional-engine model. To record fly-over noise measurements, engineers used an LMS SCADAS Mobile system designed to acquire and condition data simultaneously from the ground array microphone kit deployed on the tarmac, and from the adjacent weather station. The data was analyzed using LMS Test.Lab data analysis software.

The analysis revealed propeller noise remains a major contributor to the fly-over noise for both aircraft; engine noise is nearly non-existent with the electric aircraft. In objective terms, the quality of the sounds emanating from the electric aircraft is also improved. Beyond being softer, the sound of an electric aircraft flying by is commonly perceived as more pleasant than usual.

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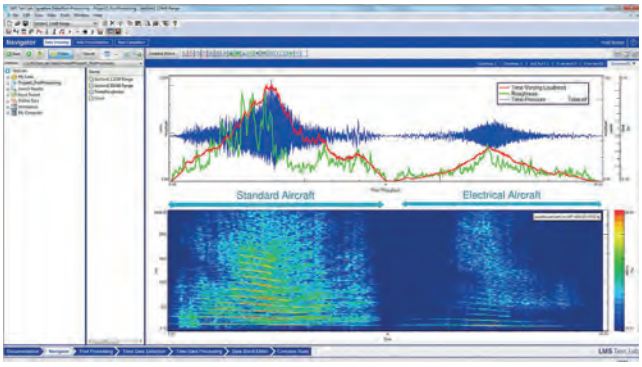

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1 // The Extra 330LE in a fly-over test with engineers using an LMS SCADAS Mobile system

2 // LMS.TestLab test results comparing sound signature data from a conventionally powered Extra 330LT and much lower levels emitted from the electric Extra 330LE

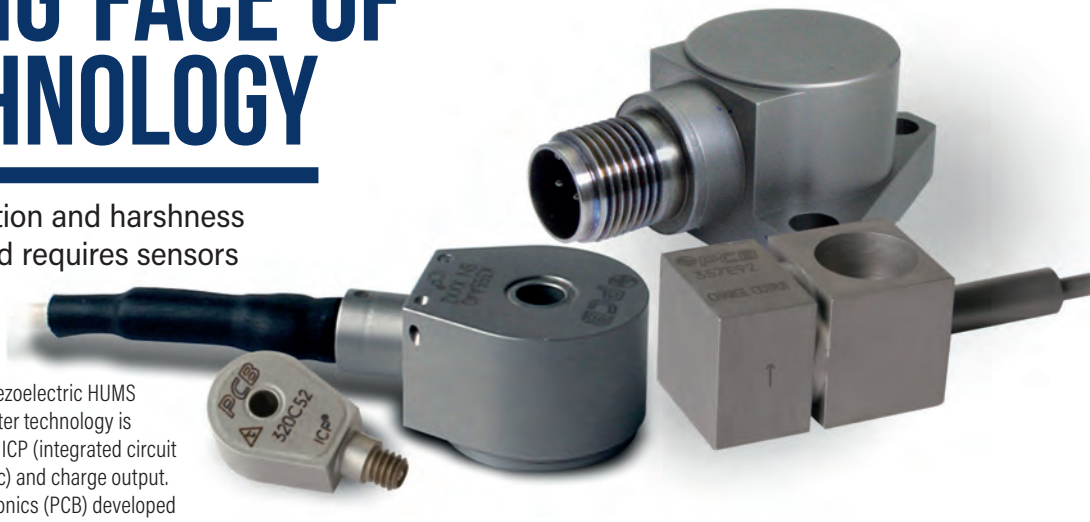
The time-varying loudness depicts the intensity actually experienced for a tone of given frequency and sound pressure level when compared with a reference pitch (1kHz-tones are the references). Loudness levels are expressed in sones. The time-varying loudness is calculated every 2ms and accounts for spectral and temporal pre- and post-masking effects.

Perceived loudness is clearly lower when an electric aircraft flies. Another sound quality metric – roughness – quantifies the subjective perception of rapid (15-300Hz) modulation of a sound. The unit of measurement for roughness is the asper, and a rough tone is often perceived as unpleasant. At 1.9 asper, compared with 0.3 asper for the e-aircraft, the combustion engine aircraft sounds rougher, thus more disagreeable to the human ear. The metrics prove flying electric is quieter and it also sounds better.

Reducing fly-over noise is vital. With its Simcenter portfolio of solutions for predictive engineering analytics and its leading SP260D electrical motor, Siemens is taking off toward a future where even cars will fly. \\

THE CHANGING FACE OF SENSOR TECHNOLOGY

Research and testing into noise, vibration and harshness monitoring on-flight and on the ground requires sensors tailored for aerospace applications



// Easy to mount HUMS accelerometers have through-hole mounting and sensors which are available with cables in removable or integrated configurations

Health and usage monitoring systems (HUMS) are gaining wider acceptance as an effective predictive maintenance strategy in helicopters and fixed wing aircraft. Similar applications have evolved, such as active vibration control (AVC), to reduce airframe stress, increase passenger comfort and extend mean time between overhaul.

The large number of critical flight safety systems on aircraft, particularly rotating ones on helicopters, make vibration monitoring effective in the detection and prevention of catastrophic mechanical failures.

Use of HUMS started years ago as a safety system and evolved into a front-line strategy for reducing maintenance costs. Two key benefits are safety – alerting maintenance personnel to drive-trains operating outside approved parameters, and financial savings – eliminating precautionary landings, minimizing unscheduled down time, and reducing inspections, which can lead to potential insurance savings.

Recording of flight conditions exceeding approved parameters is enabled by HUMS, and provides a check on aircraft health status during and after each flight. Typical helicopter applications include rotor track and balance, shaft balance, monitoring of transmission and engine vibration, gearbox monitoring and bearing diagnostics.

HUMS include a basic data acquisition device and processor, piezoelectric accelerometers and signal conditioners. The accelerometers and signal conditioning, instrumentation performance criteria and specifications continue to be optimized to meet the stringent operational requirements of the aerospace and defense industry.

Piezoelectric accelerometer technology is a widely accepted standard used in HUMS. It is applicable to standards such as MIL and DO-160, and is readily optimized for the special performance, reliability and packaging requirements of the aircraft platform. Piezoelectric HUMS accelerometer technology is divided into ICP (integrated circuit piezoelectric) and charge output. PCB Piezotronics (PCB) developed ICP technology in the mid-1960s. It is now an industry standard, known as IEPE (integrated electronic piezoelectric).

ICP accelerometers have a microelectronic amplifier converting high-impedance charge output from the piezoelectric sensing element into a low-impedance voltage signal. In hermetic packages, the high-impedance circuitry is sealed and electrically shielded. Sensors operate from a low-cost, constant-current power source over a two-wire circuit, with one carrying the signal/power and the other serving as the ground.

The main advantage of ICP accelerometers is that they can operate continuously in adverse conditions without an increase in noise or loss of signal quality, even when long cables are required. Per-channel cost is less than with charge output sensors, since low-noise cable and expensive charge amplifiers are not required. Previously the only limitation for ICP technology was its operating temperature range, but PCB's recent designs can withstand up to 325°F (163°C), well above the normal levels of many measurement points on a helicopter.

HUMS accelerometers are typically electrically case-isolated, so they are unaffected by electromagnetic interference and pass various environmental and lightning category tests (DO-160).

Depending on the particular airframe and mounting location, HUMS accelerometer specifications can provide high resonant frequencies for rotating parts and accurate low-frequency phase data for rotor track and balance. They also feature an internal shear mode element designed to limit base strain influences, reliable hermetic connectors and cable systems that are oil resistant and some have low smoke characteristics. For helicopters, single-bolt mounting is ideal for transmissions and hard-to-access locations.

Charge output accelerometers are useful for HUMS as they operate in temperatures above 325°F (163°C). They generate a high-impedance charge output in response to mechanical stress applied to the crystal sensing element. These accelerometers send a signal through low-noise cable to a charge amplifier that converts the signal into a usable low-impedance voltage for data acquisition. The charge amplifier has signal amplification, sensitivity normalization, gain adjustment and filtering. Charge output accelerometers are often used in high temperatures, such as for gas turbine vibration measurements.

PCB's UHT-12 is a new crystal element with more accurate, lower noise measurements during large temperature variations, and has improved data quality compared with ceramic crystal designs.

The main technical advantages of this new crystal for HUMS and gas turbines include elimination of pyroelectric noise spikes at elevated temperatures up to 1,200°F (649°C), a sensitivity that remains more consistent over a wide temperature change, and shear mode crystal design for isolation from unwanted base strain and transverse measurement errors. The proprietary technology comes in a hermetic package and has proven reliability in hundreds of gas turbine installations used for research and monitoring. \\

DIGITAL RADIOGRAPHY FOR NDT

Inspectors in the aerospace industry are switching from traditional radiography to digital inspections

1

Globally, an average of 150,000 airplanes take off and land at around 50,000 airports each day. With aircraft achieving thousands of take-off and landing cycles each year, rigorous periodic inspections are paramount. Every time an aircraft is pressurized, its wings and fuselage are stressed. The rivets, fasteners and plates of the aircraft fatigue over time to give birth to incipient cracks around the fastener holes that might lead to bigger cracks and serious safety issues if not attended to.

To ensure an aircraft's reliability, non-destructive testing (NDT) is done both during production and throughout its life. During maintenance and servicing, various parts of the craft are meticulously examined using an array of techniques, including visual (VT), ultrasound (UT) and radiographic testing (RT). The most accurate methods can detect cracks and defects as small as 0.04in (1mm).

In industrial radiography, silver compound-based films have been the norm for close to a century. In recent years, innovative companies such as Teledyne DALSA and Teledyne ICM have been introducing new digital systems that are revolutionizing the industry. The aerospace world is no exception as we see an increasing number of commercial airlines and military bodies embracing digital radiography (DR).

These organizations undertake the switch from film to digital radiography based on factors such as exposure time, image quality, ease-of use and costs.

The time component has always been a crucial factor in the aerospace industry. With Go-Scan, the 49µ, 4 x 6in (102 x 152mm) portable digital system developed jointly by Teledyne DALSA and Teledyne ICM, the exposure time required to get an image of a 20mm (0.8in) aluminum plate with a constant potential generator such as the CP160B (Teledyne ICM) is less than a second, while it can take up to a minute with regular silver films. The digital process also eliminates the time it takes an operator to retrieve, treat, develop and finally interpret the film. This new technology speeds up not only the exposure time, but also the entire radiographic operation.

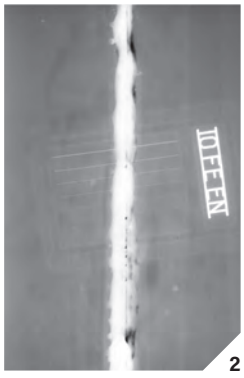
When it comes to image quality, digital detector arrays (DDA) are reaching greater capabilities. With modes of digital radiographic image quality metrics such as the contrast-to-noise ratio (CNR) and signal-to-noise ratio (SNR) entering the industry, the quality of images obtained with digital systems are unmistakably becoming the new benchmark.

To obtain an image quality matching specific American and international standards (ASTM–ISO), the Go-Scan system, for instance, takes and averages as many pictures as needed to match CNR and SNR levels dictated by those standards.

Radiographers around the world, and particularly those in the aerospace industry, are well aware of the costs linked to disposables such as films and chemicals.

1 // Go-Scan is coupled with the CP160B X-Ray generator and tablet operation is supported

2 // A weld inspected by the Go-Scan System



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Even though the initial investment might represent a barrier to the acquisition of such equipment, the ROI observed over a couple of months in terms of operating time, disposables costs and storage is manifest.

While DR might seem a daunting technology at first, it quickly becomes clear to the operator that the learning curve is anything but steep. With user-friendly software like that implemented in the Go-Scan, radiologists are able to interpret, analyze and edit images right next to the aircraft without having to go back to a lab for development and analysis.

With those image-editing software platforms, aerospace technicians are now easily able to detect defects such as porosity, water entrapment, crushed core, cracks, corrosion, inclusions and loose fittings in a matter of seconds and quickly archive and store those images and analyses in the inspection system.

As the commercial and military aerospace industry is moving forward and adopting new technologies to improve performance, the manufacturers of non-destructive evaluation solutions have to adapt to this rapidly changing industry and offer solutions tailored to those increasing requirements. \\

AIRFRAME NOISE EVALUATIONS

The wind tunnel testing capabilities at INCAS have been used for a wide range of investigations including EU projects into greener regional aircraft designs

1

The National Institute for Aerospace Research 'Elie Carafoli' (INCAS) in Bucharest, Romania, operates state-of-the-art infrastructure for aviation research including wind tunnel testing capabilities from low subsonic regimes up to Mach 3.5 supersonic velocities.

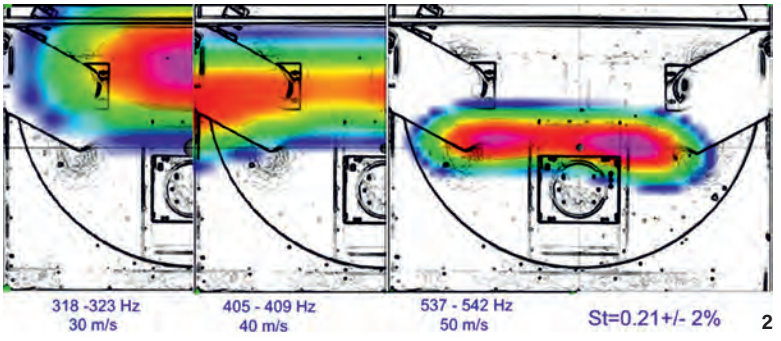
Airframe noise investigation is part of the work successfully performed by INCAS for projects such as the European Union's JTI Clean Sky Program Joint Technology Initiative and the Green Regional Aircraft (GRA) Integrated Technology Demonstrator, the largest EU public-private partnerships engaged in programs of aviation research.

The INCAS subsonic wind tunnel is a classic atmospheric closed-circuit facility with a 2.5 x 2m (8.2 x 6.6ft) octagonal test section. This facility is driven by a 1.2MW (1,609hp) motor producing speeds up to 110m/s (246mph) in the test section with a 10:1 contraction ratio and 0.1% turbulence level. The basic model setup uses a six-component external balance of pyramidal type (T E M design) with a maximum lift capability of 1,000Kg (2,240lb) and 0.02% accuracy. Typical Reynolds numbers range from 1 to 4 million/m, depending on the model size and special setup requirements.

Aeroacoustics investigations in this tunnel have been implemented using a circular antenna of 72 microphones within the test section, located on the upper wall above the center of the test section. The microphones have been embedded in solid foam and the capsule of each microphone is 2.5mm (0.098in) below the wetted surface. The resulting cylindrical cavity is enclosed with flush-mounted soft foam. To match the requirements for a low background noise level (for example, 60-65dB) several modifications have been applied: profiling of the ramp to prevent flow separation; cleaning of the rigid foam surface by removing gaps, orifices and any obstacles; and closing of any windows in the test section. This led to a reduction of the background noise level by 10-12dB at 50–60m/s (111-134mph) tunnel air flow velocities.

A dedicated test campaign was performed in order to assess the capability of the beamforming technology to assess airframe noise for a reference case. This was based on measurements of the noise generated by a 2cm (0.78in) diameter rod, 1m (39.4in) span, at three velocities (ranging from 30m/s to 50m/s (67-112mph)), and for the noise generated by two rods in tandem, separated by a distance of 5cm (1.97in) (upstream rod: 2cm diameter, downstream rod: 1cm diameter, both 1m span) at the same velocities.

The results show that noise generated by a single rod rises by about 10-15dB from the background noise at Strouhal 0.21 (±2%), which is in very good agreement with the literature. More importantly, for the noise generated by the tandem configuration, the system had the capability to discriminate between the two sources, showing a reversed '8' source map (two main spots).



2

1 // The INCAS subsonic wind tunnel

2 // Calibration for beamforming technology

A direct investigation for wing movables configurations was performed for the new generation of high-lift devices in Clean Sky GRA. The research interest ranged from leading-edge devices (Krueger flaps) to flaps for the trailing edges (single and double slotted) as well as for side edge architectures. This included a series of new concepts, from more classical fences to Helmholtz resonators and micro-perforations.

For these types of low-noise evaluation tests, the struts of the balance were removed and the model was inverted, using the external mounting system, allowing the array of microphones to measure noise from the pressure side, while still enabling use of the traditional Kulite transducers for pressure correlation purposes.

Airframe noise source characterization for the high-lift configuration was very successful using beamforming technologies, as well as direct identification of benefits for a specific concept. This methodology is now further developed for high angle of attack unsteady flows with massive separation areas, in close correlation with active flow control systems. \\

DATA LOADING SIMPLE AND SECURE

Software data loading is becoming a more and more important issue to the aerospace industry. Data has grown in complexity and new security requirements have to be met

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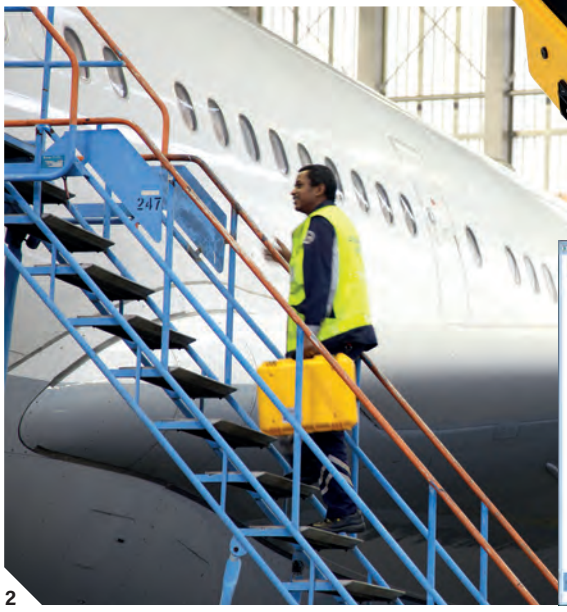

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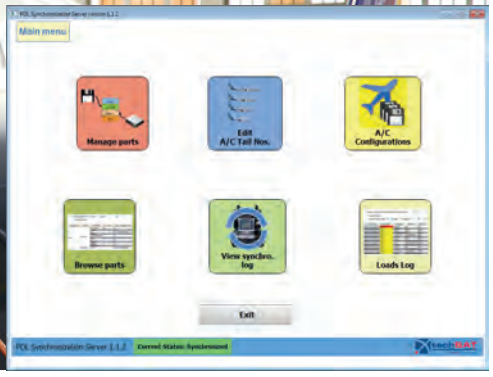

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Portable data loaders, Secure PDLs and the Gardt Technology from TechSAT are certified to comply with the software security requirements defined by Airbus. They give operators the guarantee that field-loadable software can be loaded on aircraft equipment (either in the shop or aboard the aircraft) with no security risk for the integrity of the data being loaded or the A/C domains.

Besides this, TechSAT supplies a complete family of innovative ground-support equipment (GSE) data loaders for all avionic maintenance requirements. Solutions are available supporting all avionic industry data loading protocols, ARINC 615, 615A, 826 and 844. TechSAT has a solution for every data loading need for next-generation aircraft as well, including 615A over AFDX/A664, A825 over A615A, and A615 over AFDX/A664.

TechSAT's solutions suit all aircraft maintenance environments: flightline, hangar, avionics repair shop, as well as specialized data loaders specifically adapted for supporting avionics and aircraft in a manufacturing environment and the development environment. A complete family of advanced portable data loading solutions are available. The simplest is the 'Bring your own PC host' PDL Mk.III, which allows any Windows PC to be turned into a full-featured 615/615A portable data loader.

In the middle of the range is the Flightline Wrangler, designed for airlines that are transitioning from physical media to electronic distribution, but still require floppy disk support. Next is the PDL Mk.II, which offers a fully ruggedized solution for modern fleets supporting full electronic distribution. TechSAT data loaders are Airbus-approved, Boeing-recommended solutions. They are designed for the day-to-day maintenance needs of large and small fleets.

Each TechSAT data loader is supplied with a full software management system that allows software to be imported and managed at a device or fleet level. The solution allows all fleet software to be carried on the data loader itself, and for the data loader to be updated electronically. A full fleet of data loaders can be managed this way.

TechSAT data loaders provide a scalable series of software part management solutions, valid for service fleets with 500 aircraft or five. There are a variety of service and support packages to make sure that data loader fleets never go out of date. These support packages keep equipment updated with the latest software versions so that line maintenance staff can get the data load completed the first time, every time.

Data loaders from TechSAT are also ideal for laboratory and development work for developers adding or updating avionics to a new data loading protocol. Implementation of ARINC 615, 615A and 826 are reference standards, used on many next-gen aircraft programs. And for those developers who need a drop-in solution, TechSAT supplies drop-in code and certification packages for ARINC 615, 615A, 826 and 844. Next-generation aircraft built since the millennium fly with avionics that use a TechSAT-supplied Target Data Loading Engine – that is, more than 6,000 LRUs flying with a TechSAT data loading solution, supporting commercial transport every day.

For next-generation aircraft, TechSAT data loaders now bring portability to data loading over the new generation of avionic bus and network types: AFDX/A664, Avionic & Deterministic Ethernet, TTP and 825/CAN. \\

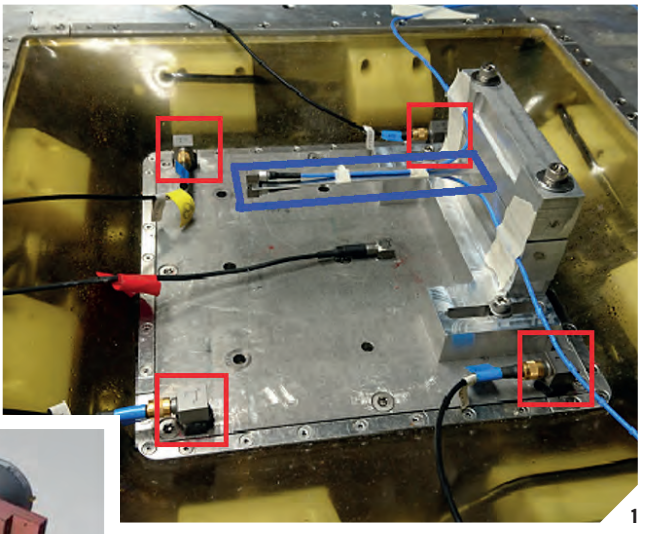
1 // The PDL Mk.II is the cornerstone of TechSAT's robust family of modular portable data loaders, designed to respond to the challenges of the line-maintenance environment

2 // Modular components make up the Mk.II and are all mounted into a robust chassis mated to its tough carrying case

3 // The PDL Synchronization Server software is a front-end to manage the PDL central repository

MULTI-AXIS VIBRATION TESTING

Non-linear structural qualification testing can be performed using a 6DOF shaker table and a specialized vibration controller



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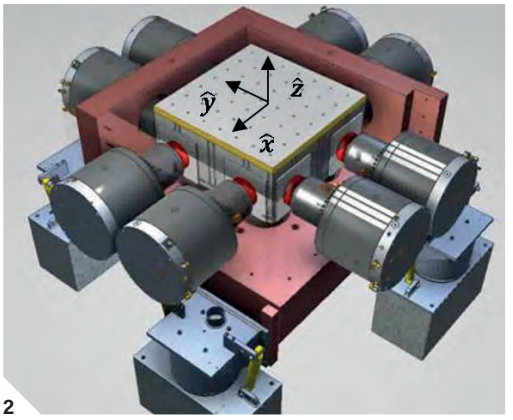

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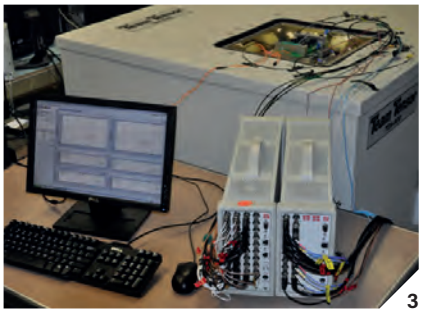


3

A Data Physics customer and partner – the Center for Advanced Life Cycle Engineering (CALCE) at the University of Maryland – has recently used the Data Physics Multi-Axis Controller and the Team Tensor 12 actuator shaker system to simulate multi-axis non-linear vibrations, showing accelerated failure times. Testing involves the reliability of electronic circuits that have large electronic components mounted on them. When a circuit card was subjected to simultaneous two-axis random vibration versus sequential single-axis vibration, the multi-axis testing showed a reduced time to failure.

The next quest was to identify and validate the non-linear interactions that led to these faster failure times, and to validate their findings on a multi-axis shaker table. Finite element studies and additional research pointed CALCE toward a geometric nonlinearity caused by the large deflection of the components. This large deflection occurred at the component's first bending frequency. The component was attached to the circuit card in a typical fashion; with the component's leads perpendicular to the plane of the circuit card. Thus, the component's first bending mode (and large displacement) is excited by vibrations in the plane of the card. The large deformations coupled with vibrations out of the plane of the circuit card (at a specific frequency of twice the component's first bending frequency) was suspected of causing the accelerated failures. Testing required development of a method to experimentally validate these simulation results.

The controller used was a Data Physics Matrix Multi-Axis vibration controller, which can control up to 16 actuators simultaneously to replicate a random, sine, shock/transient, mixed mode, or time history profile in all six (or more, if non-rigid body motions are considered) degrees of freedom using all actuators simultaneously. The controller was tied to a Team Tensor shaker table; a table capable of full 6DOF motion driven by 12 independent actuators: four actuators in each orthogonal axis. Four tri-axis control accelerometers were used, one at each corner of the table.

Real-world simulation demanded a test requirement that had never been performed before. Using the Team Tensor, they wished to excite a component at its natural frequency in one axis; then simultaneously excite the component in another orthogonal axis at twice the natural frequency. The idea was to excite the component's first bending mode using one axis's actuators, allow steady state to be reached, then add the orthogonal vibration to the mix and allow a new steady state to be reached. Each of the Tensor's axes is driven by four independent shakers; and thus they required simultaneous multi-axis multi-frequency sine control. This was a test that no previous commercial vibration controller had the ability to run.

Data Physics was successful in advancing current control technology to meet the challenges this test posed. The DP Matrix controller enhancements allowed the researchers to decouple the single multi-axis control loop into two separate multi-axis control loops which ran simultaneously. The first DP Matrix controller loop controlled the four shakers exciting the component's natural frequency. The second control loop controlled the perpendicular axis's four actuators. The two independent control loops were timed using programmatic control, which the DP Matrix allows. Phase control was of particular importance to this test, as any phase mismatch between the axes' four control accelerometers implied rotation being imparted into the test structure. The desired precision would not be obtainable by teeing the same drive signal to all four shakers, as non-symmetric fixturing and mismatched amplifiers would not produce the pure translation that was desired.

The Data Physics Matrix proved a robust solution for this first-of-its-kind vibration test, and CALCE successfully reproduced the results predicted from the finite element simulations on the shaker table. The results point in the direction of further multi-axis testing to provide more realistic simulations of real-world vibration phenomenon. \\

1 // Close-up of the moving 6DOF table on the Team Tensor, with the four control accelerometers outlined in red and the test specimen in blue. Designed to exaggerate the modal properties of a large electronic component, the test specimen was a beam with a tip mass

2 // Exploded view of a Team Tensor shaker table, with four actuators in each axis. z^ actuators are mounted below the table, not shown

3 // Matrix controlling two-axis simultaneous random vibration on a Team Tensor, with a circuit card mounted on the Tensor's table

IMPROVING TESTING SUSTAINABILITY

Continuous data access paves the way for multiple applications operating in parallel

Not long ago, testing in environmental simulation applications was a bold venture involving preparing and conducting a test and the subsequent evaluation, reporting of the results, and data archiving. It needed to be thoroughly thought-out to avoid compromising data integrity, especially in the case of a singular, non-repeatable test scenario. The productivity and reliability aspects of testing can be improved through refining the testing process or its automation.

Efficiency is increased by using standardized networking components for the whole process. Starting with a permanent access to the data stream, tests can be prepared and executed instantaneously. The recorded data can be processed and archived in a subsequent seamless process. The pivotal element in this context is a powerful platform enabling a trouble-free execution of the complete testing workflow.

Müller-BBM VibroAkustik Systeme's next-generation of solutions offers increasing efficiency in environmental testing at an unprecedented level. The PAK family portfolio of COTS products ranges from a flexible data acquisition hardware platform to powerful analysis and reporting applications, along with sustainable workflow management tools. Integration into large environments as well as small-scale, standalone operations is equally possible. Most standardized testing scenarios are easily addressed, while offering customization options at all levels. Each test setting is covered by an optimal set of independent components used throughout the entire test cycle.

Such a cycle is split into four distinctive, independent subsets of tasks: test preparation (assignment and definition); test execution (recording and monitoring); data analysis (reduction and reporting); and data storage (access and archiving).

In preparation, a test procedure is defined with respect to the item under test and a chosen measurement method. All essential online analyses are configurable through a test assignment method.

The PAK assignment system integrates the preparatory step into an existing context, for example a spreadsheet-based configuration and test definition. Emerging standards in workflow and data management such as openMDM and ASAM ODS are fully supported by the PAK platform to ensure sustainable openness for data exchange among different providers. Measurement and recording hardware is not required during test preparation.

// The PAK family data acquisition, analysis and management platform is adaptable across a wide range of testing tasks

PAK MKII, Müller-BBM's data acquisition hardware platform, allows measurement front-ends to independently start collecting data at each system's power-on and to continue until power is switched off. The data stream delivers fully calibrated sensor information in real physical quantities. This permits an execution of all preliminary operations in the measurement chain such as sensor calibration or in-situ signal validation monitoring. Procedures can be performed near the test item with a smart device, or remotely through PC software. All devices are fully synchronized using optical sync methods or standardized network-based (IEEE1588 v2) protocols. Virtual devices can be used for –but are not limited to– direct compensation of transducer sensitivities, which either show non-linear behavior or depend on other physical properties such as temperature or pressure.

During testing, preconfigured applications can be used to directly observe test execution, monitor test item health, or even transmit a selectable subset of data to peripheral systems through bidirectional communication. The chance of data loss is minimized by utilization of multiple instances of the PAK recorder service in parallel to capture and store individually configurable subsets of available channels in a separate record file. Tests can be monitored through applications, giving direct feedback to the operator regarding the test item's behavior. Each application can run on a single PC or multiple networked computers to account for various testing scenarios.

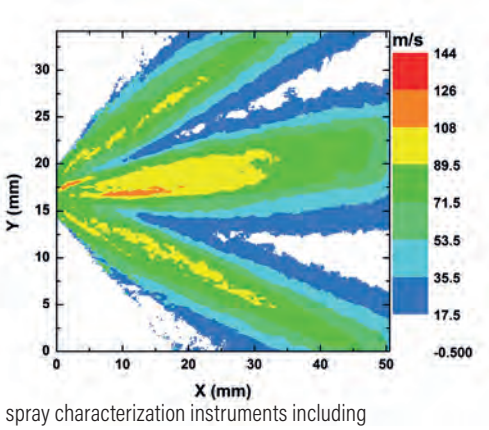
Post-test data processing and analysis is done with the PAK analysis suite or third-party analysis tools. Common engineering tasks such as data reduction, complex or embeddable proprietary analyses, data reporting, data export and visualization are performed and automated for subsequent execution or used for immediate, interactive data evaluation.

Retrieval of previously recorded data and further off-line processing can be done through the PAK cloud service platform, Müller-BBM's solution for data management. From smaller setups, to an enhanced solution covering the needs for distributed computing over different locations and different sets of data repositories, PAK cloud services comfortably scale with the customer's environment while easily adapting to individual requirements. \\

PATTERN IMAGING VELOCIMETER

En'Urga is announcing the release of its SPIvel velocimeter (Statistical Pattern Imaging velocimeter). The near injector region of most modern high-pressure aerospace fuel nozzles is optically dense. Obtaining accurate velocity measurements near the nozzles is almost impossible using conventional tools such as phase Doppler interferometers and particle image velocimeters. For this reason En'Urga has developed a statistical pattern imaging velocimeter that provides planar velocities in aerospace fuel nozzles. The unit takes a series of high-speed videos and uses proprietary software to provide the planar velocities in these nozzles.

The software is also available for licensing to use with any high-speed video camera that has a minimum 10kHz frame rate. In addition to sprays, the software can be used to obtain velocities in turbulent flames and two-phase flows in pipes. With the addition of the SPIvel velocimeter, En'Urga provides a full suite of



spray characterization instruments including the SETscan optical patternator and the SETXvue x-ray patternator. \\

TURBULENT ENVIRONMENTS WIND TUNNEL TESTING

To study flight in both laminar and turbulent environments, Jacobs has designed and built a multipurpose wind tunnel to study flying animal and small vehicle flight at Stanford University.

Our understanding of animal flight benefits greatly from specialized wind tunnels designed for flying animals. Existing facilities can simulate laminar flow during straight, ascending and descending flight as well as at different altitudes. However, the atmosphere in which animals fly is even more complex.

Flow can be laminar at high altitudes but highly turbulent near the ground, and gusts can rapidly change speed. Stanford University's new closed-circuit wind tunnel can produce airspeeds up to 50m/s (112mph) in a rectangular test section that is 1.0m (39in) wide, 0.82m (32in) tall and 1.73m (68in) long. Seamless honeycomb and screens in the airline, together with a carefully designed contraction, reduce center line turbulence intensities to less than or equal to 0.030% at all operating speeds. A 1.6m (63in) diameter

fan and specialized acoustic treatment allow the tunnel to operate at low noise levels of 76.4dB at 20m/s. To simulate high turbulence, an active turbulence grid can be installed to increase the turbulence intensities being created by up to 45%.

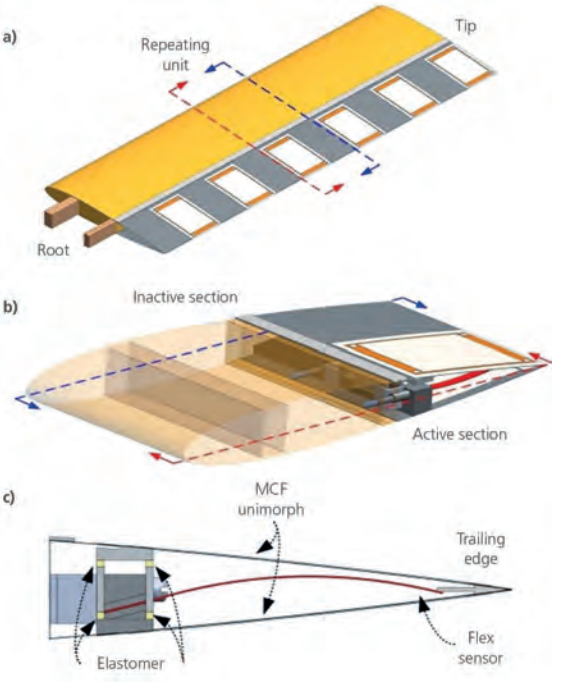
Finally, an open jet configuration enables stereo high-speed fluoroscopy for studying the control of musculoskeletal systems in turbulent flow. \\

FLY LIKE A BIRD

New knowledge in materials sciences and the continuous improvement of sensor networks open up greater possibilities for the development of adaptive aircraft technologies. For this, the Adaptive Intelligent Multifunctional Structures (AIMS) Lab at the University of Michigan takes its inspiration from birds and their ability to use their wings and tails to react flexibly to atmospheric conditions.

The AIMS Lab is investigating these adjustment skills to develop an aircraft that can adapt to atmospheric conditions. For this, the AIMS Lab is looking into the effects of changing the wing shape with the help of macro-fiber composite (MFC) actuators. The thin, flexible structures of the MFCs are able to change shape when voltages are applied. This way, the MFCs can act both as a surface and as an actuator.

For measuring aerodynamic forces and torques of these aircraft structures during tests in the wind tunnel, the AIMS Lab uses a dSpace MicroLabBox to record the large data volumes and control multiple actuators. Test results show that the morphing wings not only reduce air resistance substantially, but also handle a stall very well. The overall aim of this research is to develop a fully integrated fly-by-feel adaptive aircraft that is able to adapt to a wide range of flight situations. \\



HIGH-FLOW, HIGH-BAR PNEUMATIC TESTING

Test-Fuchs has recently unveiled its latest pneumatic technology and subsequently raised the stakes for high-flow test systems around the world. The sleekly designed PP250 High Flow Pneumatic Test System boasts features like 800°F (427°C) operating temperatures, 315psi (22 bar) operating pressures, flow rates of 250 lb/min (113kg/min), and custom designed sub-40ms valve actuation with integrated feedback control loop. Both pneumatic and electrically controlled bleed and trim air platforms are supported.

The interchange among the broad range of compatible components is fast and friendly as the user experience is forefront for all Test-Fuchs designs. Comprised of high and medium compressed air supplies, electrical heating and exceptionally accurate data measurement capabilities, the PP250 gives users wide control over each testing variable. Test-Fuchs has relied heavily on the high level of expertise accumulated over 70 years in business to develop this system.

The company's newest facility in Cleveland, Ohio will provide premium-level aerospace test capability to the entire world. \\

LOW-RISK C-BAND UPGRADES

US military ranges will need to replace L/S band telemetry equipment with C-band variants in the near future to meet new regulations. A reliable supplier will be able to de-risk this required change by paying attention to the impact of changes to equipment such as the need for more power efficient designs or requiring special filters for FCC compliant transmissions.

Curtiss-Wright has a range of C-band products, ready for delivery now, that are a simple plug-and-play replacement. The company manufactures transmitters, transponders, transceivers, receivers, re-radiation systems, antennas, and ground support hardware and software. Many of these are multiband so that L/S and C-band can function from one unit. These reliable systems help de-risk users' programs. The power-efficient designs and features (e.g. in-built filters for transmitters) ensure the solutions are compact and compatible.

Moving to C-band now has a host of benefits including becoming compliant with new regulations in a timely manner.

Using a reliable supplier with rigorous quality processes helps ensure robust products are delivered on time, while multimode equipment helps reduce risks.

Low-power designs minimize extra power required by C-band over L/S, while a compact configuration simplifies installation and optimizes space. \\

LATEST TECH IMAGING

Customized, non-destructive material evaluation solutions provided by Adaptive Energy help meet the unique testing needs of the aerospace industry. The company applies the latest imaging technologies (digital radiography, computed tomography, ultrasound, and advanced phase array ultrasonics) combined with robotic and mechanical components – off-the-shelf, or custom-engineered and manufactured. With integrated software applications for system control, data collection and analysis, Adaptive Energy's solutions address some of the world's toughest NDT challenges faced by leading companies in aviation, space, and military/defense, meeting mission-critical, time-sensitive testing needs.

With decades of experience in imaging technologies, engineering, machining and fabrication, its experts work with customer teams to design and fabricate ingenious and effective solutions with the highest-level performance, while delivering low total cost-of-ownership. Adaptive Energy's integrated systems are rapidly deployed, easy to learn and maintain, and perform reliably under pressure. A select team of partners, including Force Technologies, KUKA Robotics, and PMB, rounds out an ability to deliver high-value, innovative, effective and efficient solutions.

Capabilities include digital radiography using myriad imaging media, high-energy digital x-ray radiography, and computed tomography systems for advanced, three-dimensional digital x-ray imaging.

Adaptive Energy designs and builds robotic automated and remote scanner assemblies, custom radiation enclosures, and gantry systems. The company has helped customers test for porosity, delamination, layer separation and component placement, and perform honeycomb structure analysis. \\

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ADAPTIVE ENERGY

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REAL-TIME HIL AND MIL TEST PLATFORMS

When developing safety-critical controllers, hardware- and model-in-the-loop testing not only ensures a safer product, but also saves money. With the cost of missed defects increasing rapidly with each major program milestone, thorough and robust system testing as early as possible in a program results in big savings. A System Integration Lab from Aversan is a DO-330 certifiable real-time hardware-in-the-loop and model-in-the-loop test platform that supports controls development, system integration and formal testing in support of certification, and can be repurposed as an assembly line tester when your program enters production.

With over a decade of system integration and product development experience, Aversan understands that venue test time is often a program bottleneck. The company has developed the hardware and software of its System Integration Lab to alleviate this bottleneck. A simplified and reliable hardware architecture ensures more venue uptime and easier configuration. For testers, the full software suite is designed to provide more useful information from each test run. Testers spend less time rerunning tests at the venue and more time investigating design defects, improving the value gained from each hour of tests run.

Each System Integration Lab is based on COTS Enterprise Server hardware and I/O units, and can be scaled from testing a single controller to testing distributed, multi-LRU systems with complex avionics bus traffic and large numbers of simulation models. \\

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AVERSAN

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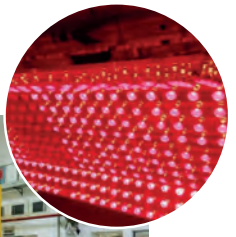
ENVIRONMENTAL TEST SOLUTIONS FOR SOPHISTICATED NEEDS



With the increasingly stringent requirements of Industry 4.0, new materials, sophisticated electronics and communication methods all need to be tested under a variety of extreme environmental conditions to ensure their quality and reliability during operation.

Today, Hardy Test can provide a wide range of environmental test equipment, and comprehensive and professional test solutions, that have already been developed to meet the strictest standards and are ready to be supplied from Asia to its customers around world. \\

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HARDY TEST

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BRINGING 4K TO AEROSPACE RESEARCH

The aerospace industry has long employed high-speed cameras for research and development of materials, fuel systems, engine design and safety testing. The image data that these cameras produce, combined with motion analysis software, provides the information needed to make critical decisions during product development.

Digital high-speed cameras are often limited to one-megapixel (MP) resolution because of an inherent sensor trade-off between frame rate, pixel resolution and sensitivity – the three critical elements of high-speed imaging. In many cases, 1MP video is sufficient, but when it comes to subjects with fine detail or those that require high magnification, these lower resolutions can be problematic. Vision Research, manufacturer of Phantom cameras, offers several camera models with 4MP sensors. The higher-resolution cameras offer superior image quality and detail, making them popular in the aerospace industry.

The all new Phantom VEO4K goes even further, incorporating a 4K, 9.4MP CMOS sensor with global shutter in the versatile VEO product line. This new camera provides the ability to capture images with incredible detail and quality with an established camera platform accessible to researchers across a variety of industries. Specifically, the VEO4K-990 is a compact, lightweight camera that will capture up to 1,000fpsat 4096x2160 resolution, and higher rates as the vertical resolution is windowed down; 10Gb Ethernet connectivity and removable CFast media are options that maximize the overall workflow by minimizing downtime between shots.

For motion analysis, higher resolution means more detail and better data. For many tests, the 500-1000fps range is sufficient. Capturing these events with a 9.4MP resolution enables small elements of the subject to be visible that would be otherwise lost or too soft to get a good data point. This difference will certainly go a long way in advancing research with many aerospace applications. \\

NIAR UTILIZES BENEFITS OF X-RAY CT

This July, the National Institute for Aviation Research (NIAR) at Wichita State University, Kansas, took delivery of a North Star Imaging X7000 CT system. The system is capable of both digital radiography (2D imaging from x-ray) and full 3D CT scanning, and can be used for internal and external inspection of components, as well as for metrology purposes.

The system consists of a shielded cabinet, which contains two x-ray sources and two detectors. The system can inspect objects up to 5ft long without the need for sectioning. It can visualize the interior features of objects and is ideal for inspection of composite aircraft sections for applications such as void detection, as well as the inspection of additively manufactured metal structures to look for features such as porosity and unmelted powder, and also to perform dimensional inspection.

As with medical x-ray, images captured are 2D, North Star Imaging's efX-CT software can then generate 3D reconstructions from these 2D images, which can be processed further, allowing for tasks like CT to CAD comparison and porosity analysis to be performed.

This is the first machine at NIAR to offer such capabilities and it has already proved a valuable resource. \\

Index to advertisers

Refreshing a retired tester

In the Midwestern state of Indiana, a retired supersonic bomber used for flight testing, supersonic bomb dropping and training pilots is getting a new coat of paint

Among the Cold War bombers built for the US Air Force, the delta-wing Convair B-58 Hustler was among the most significant – and it looked stunning. The distinctive aircraft had a wasp-waisted fuselage and was the USAF's first supersonic operational bomber. It featured a wide range of innovations including a sophisticated inertial guidance navigation and bombing system. The extensive use of heat-resistant honeycomb sandwich skin panels on the wings and fuselage meant the fuselage was unable to carry bombs internally; instead an external, droppable, two-part pod was carried below. This could carry extra fuel as well as a nuclear weapon, reconnaissance equipment, or other specialized gear.

Power came from four General Electric J79-GE-5A/5B axial flow turbojets, normally rated at 9,700 lb thrust. Their military power produced 10,300 lb thrust and maximum thrust was 15,600 lb using the afterburner, which provided almost enough power to reach Mach 2.

Due to the speed and altitude of the aircraft – up to 1,325mph at 70,000ft – a specialized ejection pod was needed for each crew member. A clamshell closure, designed by Stanley Aircraft, used guard bars to pull the legs backward and upward to allow the shell to close before ejection from the aircraft.

The first flight test of the B-58 occurred on November 11, 1956; supersonic flight followed a little over a month later on December 30.

One Hustler in preservation, a test flight aircraft, can be found at the Grissom Air Force Base Museum in Peru, Indiana. This aircraft is currently undergoing external restoration. In 1969, a cockpit fire gutted all three crew stations, grounding the aircraft for good. It became a 'guard' on display at the entrance to the then operational Grissom Air Force Base.

The museum's bomber, serial number 55-663, made its first flight on August 12, 1957, and was engaged in flight testing activities. It successfully executed the first supersonic pod drop on September 30, 1957, and the first Mach 2 pod drop on December 20, 1957. It was used by NASA for sonic boom tests in 1962 and was one of eight converted to a TB-58A for training Hustler pilots.

A total of 116 B-58s were produced: 30 trial aircraft and 86 production B-58A models. Of these, most were scrapped when their operation was halted after about a decade. There are only eight survivors; the one at Grissom Air Force Base Museum is the oldest and officially a TB-58A (for training).

The Hustler was an exceptional aircraft; it set 19 world records for speed and altitude and won the Bleriot, Harmon, Bendix, McKay, Thompson, and Saunders trophies. No other aircraft has won this many trophies and most of these records still stand. On October 16, 1962, aircraft 61-2059, 'Greased Lightning', crewed by Major Sidney Kubesch, Major John Barrett and Capt. Gerard Williamson, flew supersonically from Tokyo, Japan, to London, UK, spending five hours at supersonic speed. The flight set five world records.

While still an in-service B-58, the museum's aircraft wore Convair's red and white paint scheme through its career and now that is being renewed. \\

NOV 11, 1956
First flight

B-58
Model number

58FT 10IN
Span

96FT 10IN
Length

163,000 LB
Max weight

1,325MPH
Top speed

610MPH
Cruising speed

4,400 MILES
Range at full load

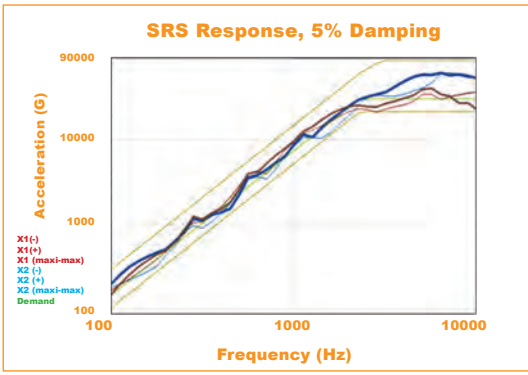
64,800FT
Ceiling

15,600 LBF
Thrust of each of the four GE engines using the afterburners

3 CREW
pilot, navigator/ bombardier, defensive systems operator

URL for first flight film:
WWW.YOUTUBE.COM/WATCH?V=SAEEJPWQTHW

HIGH G DYNAMICS TESTING



Experior Laboratories, a Southern California based independent third party test laboratory, is MIL-STD-790 approved and ISO-17025:2005 accredited. Experior Labs operates multiple state-of-the-art Unholtz-Dickie electrodynamic shaker systems that can handle the most demanding vibration and shock test specifications.

Shakers used in tandem can provide a combined 50,000 lbf for extreme vibration profiles of large articles. For near or midfield Pyroshock/SRS Shock requirements that exceed the limits of an electrodynamic shaker, Experior Laboratories offers a custom Kinetic Impact Pyroshock Simulation system.

Unholtz-Dickie Shakers

Model T2000

#1	25,000 lbf	3" Stroke
#2	25,000 lbf	3" Stroke
#3	20,000 lbf	2" Stroke

Model R16C

#1	13,000 lbf	2" Stroke
#2	13,000 lbf	2" Stroke

MIL-STD-790 approved by the Defense Logistic Agency (DLA) Land and Maritime

ITAR Registered

ISO/IEC-17025: 2005 Accredited

Applications

- Sine Sweep
- Sine Dwell
- Sine Burst
- Random
- Sine on Random
- Random on Random
- Classical Shock
- SRS Shock
- Windmilling
- Gunfire

Capabilities

- Sine sweep vibration: >220 G pk
- Random vibration: >175 G rms
- Cargo and Transportation Vibration
- SRS Shaker Shock: >5000 G
- SRS Pyroshock Simulation: >30,000 G
- Cleanroom option
- Combined environment: cryogenic to > 200˚C
- Up to 128 channels of data recording
- Data recording at a sample rate up to 200 kHz
- Custom fabricated vibration fixtures and slip plates

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Headquartered in Oxnard, California, Experior Laboratories Inc. specializes in providing independent, third-party, design verification and qualification test and calibration services to component manufacturers, integrators and system providers within the telecom, datacom, military, aerospace, space and industrial markets.


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Ingenuity for life
Today's dreams need tomorrow's engineering.
Simcenter: Predictive engineering analytics for the new era of smart innovation.
Getting a dream off the ground has never been more challenging. Products need to be smarter. Manufacturing processes are more complex. And design cycles are shorter than ever. Simcenter software can help. With its unique combination of multi-disciplinary simulation, advanced testing and data analytics, Simcenter gives you the power to explore alternatives faster, predict performance more accurately... and deliver innovation with greater confidence.
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