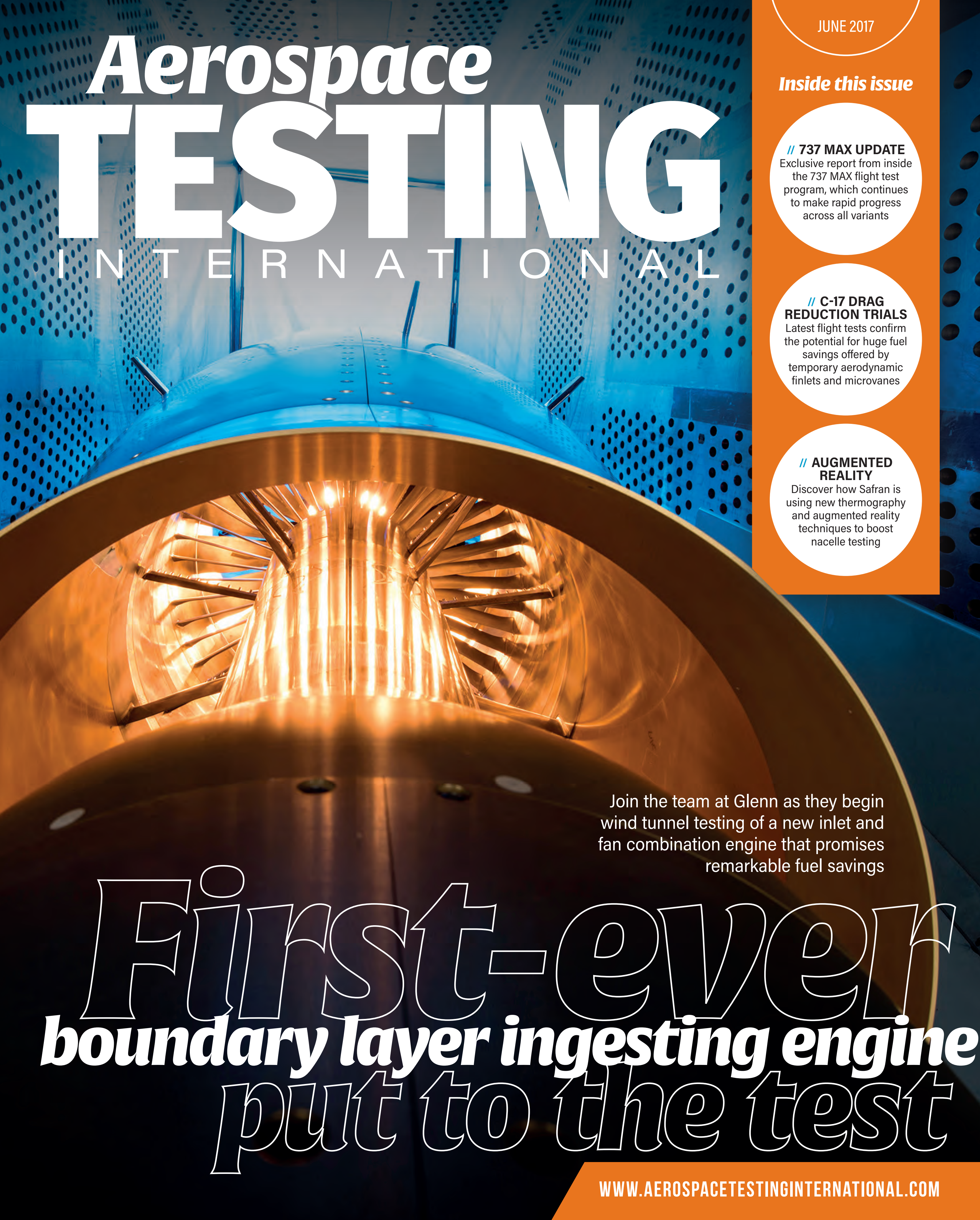

JUNE 2017

Aerospace TESTING INTERNATIONAL

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Exclusive report from inside the 737 MAX flight test program, which continues to make rapid progress across all variants

// C-17 DRAG REDUCTION TRIALS
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First-ever boundary layer ingesting engine put to the test

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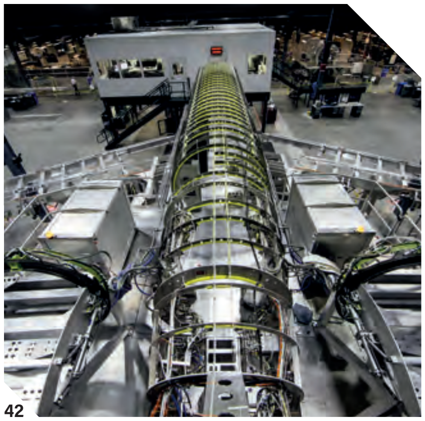

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Inside this issue

// Fuel for thought

Fuel costs are an issue everyone can understand and relate to, whether in the aerospace industry or not. For starters, as individual consumers we are all aware of rising energy prices. This is certainly the case in the UK, where eyebrows were raised at Theresa May's (still Prime Minister, at least as we went to press) manifesto pledge to remove winter fuel vouchers from pensioners (who can always be relied upon to vote) prior to what turned out to be an absolute disaster of an election campaign for her Conservative party.

I was also reminded of the importance of fuel costs at one of our exhibitions that we held recently as a publisher and organizer serving numerous industries with a range of tightly focused magazines and events. This particular show was held in Amsterdam for the marine sector, with a strong emphasis on the opportunities offered by condition-based maintenance, with which the aerospace sector is very familiar.

A young Dutch company was keen to tell visitors about its recent partnership with the Royal Netherlands Navy to trial a new technology that uses ultrasound to prevent the growth of biofouling. Biofouling growth increases the drag on a hull, which the company claims can cause a ship to consume up to 40% more fuel and correspondingly produce 40% more CO_2 emissions. To date, shipowners have relied on specialist coatings to help prevent such organisms taking hold; however, they can be environmentally suspect as well as expensive – and occasionally ineffective. The new solution deploys multiple systems to transmit ultrasonic waves of specific frequencies throughout the ship's hull to prevent and control biofouling.

"The ultrasonic generating transmitters are built into the hull to avoid interference – and the system uses low DC cables rather than high AC cables," explained the company's CEO. "We also adjust the transmitters based on the material of the ship's hull. We believe we can help the navy achieve a 5% fuel saving as a result."

Now, as anyone in the business of flying aircraft knows, 5% represents a potentially huge saving! Hence aerospace engineers continue to devise increasingly ingenious ways to improve aerodynamic efficiency and engine performance.

Take our feature on page 32 about the USAF's latest trials to quantify the drag reductions and fuel savings offered by installing finlets and microvanes on the fuselage of a particularly 'thirsty' aircraft – the C-17 Globemaster III. It is all a bit low-tech at first sight, but these 'patched' parts could deliver dramatic results: "A 1% improvement in drag reduction will result in 7.1 million gallons of fuel reduction per year," says Bogdan Wozniak, 418th FLTS project engineer. "A 1-2% drag reduction could translate to US$24-48m in fuel savings per year."

For a more 'high-tech' approach, turn to our cover story on page 22, which details NASA's current wind tunnel testing of an exciting new boundary layer ingesting engine, which, when embedded into the wing, could deliver potential fuel savings of 4-8%.

Finally, for insights into how we might one day reach a completely 'fuel-free' future, don't miss our Electric & Hybrid Aerospace Technology Symposium 2017, this November in Cologne, Germany. Enjoy the issue.

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

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COVER IMAGE: NASA 'Propulsor'

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WORLD test update

// BOEING 737 MAX 9 TAKES TO THE SKIES

The Boeing 737 MAX 9 completed its first flight on April 13, 2017. The test program achieved the milestone on schedule to begin a comprehensive flight test program leading to certification.

The airplane completed a successful 2 hour 42-minute flight, taking off from Renton Field in Renton, Washington, and landing at Boeing Field.

Piloted by Boeing Test and Evaluation Captains Christine Walsh and Ed Wilson, the aircraft performed tests on flight controls, systems and handling qualities. The MAX 9 will now undergo comprehensive flight testing before customer deliveries begin in 2018.

The MAX 9 is the second member of Boeing's industry 737 MAX family, with a maximum capacity of 220 passengers and a range of 3,515 nautical miles.

The MAX 8 and 9 will be followed in 2019 by the smaller MAX 7 and higher capacity MAX 200.

Renton, Washington, USA

READ MORE ON OUR WEBSITE!

// A319NEO PERFORMS FIRST FLIGHT

The third member of the Airbus best-selling A320neo family – the A319neo – has gone airborne, performing its maiden flight on March 31, 2017. After taking off from Hamburg-Finkenwerder Airport in Germany, one of four final assembly line sites for the single-aisle jetliner, the aircraft touched down five hours later at Airbus's Toulouse, France, headquarters.

This shortest-fuselage member of the A320neo product line is equipped with CFM International LEAP-1A engines – one of the two powerplants available on the NEO jetliners.

Once in service, the A319neo will provide the same fuel efficiency as the longer-fuselage A320neo and A321neo versions, enabling airlines to choose between three aircraft sizes accommodating from 100 to 240 seats – depending on the required cabin layout.

The A319neo's campaign will focus primarily on handling qualities, autopilot, performance and systems – building on the required engine tests that have already been performed with the A320neo and A321neo versions.

Hamburg-Finkenwerder Airport, Germany

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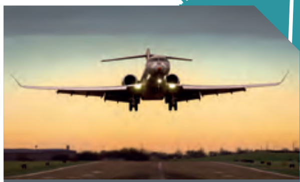

// BOMBARDIER GLOBAL 7000'S THIRD FLIGHT TEST VEHICLE JOINS FLEET

Bombardier announced on May 10 that a third Global 7000 flight test vehicle (FTV3) had completed its maiden flight. FTV3 joins a program that has been demonstrating excellent system reliability and breaking new ground since it started in November 2016. Five months into testing, the Global 7000 aircraft set a record as the largest business jet to operate so close to the sound barrier, reaching a milestone top speed of Mach 0.995.

FTV3, dubbed 'The Navigator', will be used to test the aircraft's advanced avionics and electrical system performance. It is the first production aircraft to be equipped with a dual head-up display (HUD). The dual HUD considerably improves operational efficiency and safety, in good or poor visibility, while reducing pilot workload.

Toronto, Ontario, Canada

READ MORE ON OUR WEBSITE!

// BOEING 787-10 BEGINS FLIGHT TESTING

The Boeing 787-10 Dreamliner took to the skies for the first time on March 31, 2017, at Boeing South Carolina. The airplane, which is the newest and longest model of the 787 family, completed a successful flight totaling 4 hours and 58 minutes.

"The 787-10's first flight moves us one step closer to giving our customers the most efficient airplane in its class," said Boeing Commercial Airplanes president and CEO Kevin McAllister. "The airplane will give carriers added flexibility in growing their network routes and build on the overwhelming success of the 787 Dreamliner family."

Piloted by Boeing Test and Evaluation Captains Tim Berg and Mike Bryan, the airplane performed tests on flight controls, systems and handling qualities. The 787-10 will now undergo comprehensive flight testing with customer deliveries beginning in H1 2018.

North Charleston, South Carolina, USA

// ANTONOV AN–132D MAKES ITS MAIDEN FLIGHT

Antonov's new multipurpose aircraft, the AN–132D, made its first flight on March 31, 2017, from the company's airfield in Kiev, Ukraine.

The prototype of the aircraft flew for almost two hours.

The AN–132 program is being developed following a contract with a customer from the Kingdom of Saudi Arabia in close cooperation with King Abdulaziz City for Science and Technology and the Taqnia Aeronautics Company. Leading suppliers of the global aircraft industry are involved in the project.

The AN–132D multipurpose turboprop aircraft is intended for operation on short- and medium-haul routes.

It will also perform tasks such as the transportation of raw materials, mail and other cargo, including bulk cargo, ULDs, and light self-propelled and non-self-propelled vehicles weighing up to 9.2 metric tons (20,000 lb).

Kiev, Ukraine

// COMAC C919 AIRLINER FLIES FOR THE FIRST TIME

The first COMAC C919, powered by CFM International's advanced LEAP-1C integrated propulsion system, successfully completed a 79-minute first flight on May 5, marking the launch of the certification flight test program for the 150-passenger narrow-body aircraft.

To date, more than 5,000 CFM engines have been ordered/committed to China, including orders for more than 1,000 LEAP-1C integrated propulsion systems. The LEAP-1C was simultaneously awarded Type Certificates by both the European Aviation Safety Agency (EASA) and the US Federal Aviation Administration in December 2016. Since then, COMAC has performed a series of ground tests, including low-speed and high-speed taxi tests leading up to the first flight.

Shanghai, China

SEE OUR WEBSITE FOR MORE NEWS!

// FIRST TEST FLIGHT FOR THE MC-21 AIRLINER

The Russian-built MC-21 short- and medium-haul passenger aircraft made its first flight in Irkutsk, Russia, on May 28, according to sources.

The MC-21 is a family of short- and medium-haul narrow-body airliners, which is intended to replace the Tupolev Tu-134 and Tu-154 airplanes and also to serve as competition to Boeing and Airbus single-aisle aircraft.

The MC-21 has a flight range of 4,000 miles (6,400km), while the Sukhoi Superjet 100 can fly 2,845 miles (4,580km). The regional Sukhoi Superjet 100 has, to date, been the only aircraft manufactured from scratch; it performed its first flight in 2008 and was operational in 2011.

The MC-21 airliner's first flight was scheduled for December 2016 and its initial assembly planned to begin in 2017. Later, the first flight was postponed to April 2017 and then to late May.

Irkutsk, Russia

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Pegasus takes to the chamber

The Benefield Anechoic Facility at Edwards Air Force Base in California has welcomed its first KC-46A Pegasus, which will now be subjected to a series of tests to prove it meets FAA certification requirements, as well as US DOD electromagnetic environmental effects requirements for systems. These tests include shielding effectiveness, emission control and high-intensity radiated fields.

The tests will 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 controlled.

The BAF, operated by the 772nd Test Squadron, is the largest anechoic chamber in the world and can fit most aircraft inside. It provides a location where electronic warfare tests can be conducted without radio frequency interference from the outside world. The chamber is filled with polyurethane and polyethylene pyramids designed to stop reflections of electromagnetic waves. The size of the pyramids, which are painted dark blue or black, varies depending on the particular frequency and test procedure being conducted.

"It also provides efficient testing that requires a large amount of high-power RF radiation. Outdoors this would be very restrictive, typically limited to shorter night-time test operations," said Delia Reyes, 772nd TS project lead engineer.

Participants in the test include Boeing, 772nd Test Squadron, 418th Flight Test Squadron and the Naval Surface Warfare Center Dahlgren Division.

Three specialized, high-power electromagnetic radiating trailers are being used for the tests. \\

// A Boeing KC-46 Pegasus sits on the rotating platform at the BAF, where it will undertake a series of avionics tests to prove its electronic warfare credentials

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// Ground and flightline testing will take place at the Mojave Air and Space Port (Photo: Stratolaunch Systems)

Giant aircraft takes first, small step

Stratolaunch, the company started by Paul G Allen to launch rockets from aircraft into orbit, reached a major milestone at the end of May in its journey toward providing convenient, reliable and routine access to low Earth orbit. The Stratolaunch aircraft was moved out of its hangar for the first time to conduct aircraft fueling tests, marking the completion of the initial aircraft construction and the beginning of the aircraft ground and flight testing phase.

The roll-out, which took place on May 31, followed the removal of the fabrication infrastructure, including the three-story scaffolding surrounding the aircraft, which saw the aircraft's full weight placed on its 28 wheels for the first time. This was a crucial step in preparing the aircraft for ground testing, engine runs, taxi tests and, ultimately, first flight.

Once Stratolaunch achieved weight on wheels, it was possible to weigh the airplane, which is the world's largest by wingspan 385ft (117m), for the first time. It came in at approximately 500,000 lb (227,000kg). The aircraft is 238ft (72.5m) from nose to tail, and stands 50ft (15m) tall from the ground to the top of the vertical tail.

The Stratolaunch aircraft is designed for a maximum take-off weight of 1,300,000 lb, meaning it is capable of carrying payloads up to approximately 550,000 lb.

Stratolaunch announced last autumn it will initially launch a single Orbital ATK Pegasus XL vehicle, which has the capability to launch up to three smaller Pegasus vehicles in a single mission. \\

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// Phantom Express is an autonomous, experimental spaceplane designed to transform the future of rapid, reusable space launch for small satellites

Ten tests for the Phantom Express

Boeing and the US Defense Advanced Research Projects Agency (DARPA) have announced plans to design, build and test a technology demonstration vehicle for the Experimental Spaceplane (XS-1) program. Boeing will develop an autonomous, reusable spaceplane capable of carrying and deploying a small expendable upper stage to launch small (3,000 lb/1,361kg) satellites into low Earth orbit. Once the spaceplane – called Phantom Express – reaches the edge of space, it would deploy the second stage and return to Earth. It would then land on a runway to be prepared for its next flight by applying operation and maintenance principles similar to modern aircraft.

The Aerojet Rocketdyne AR-22 engine, a version of the legacy Space Shuttle main engine, would power the spaceplane. It is designed to be reusable and operates using liquid oxygen and liquid hydrogen fuel. Coupled with an advanced airframe design, as well as third-generation thermal protection, the Phantom Express will be capable of flying at high flight velocity while carrying a smaller, more affordable expendable upper-stage to achieve the mission objectives.

In the test phase of the program, Boeing and DARPA plan to conduct a demonstration of 10 flights over 10 days. "Phantom Express is designed to disrupt and transform the satellite launch process as we know it today, creating a new, on-demand space-launch capability that can be achieved more affordably and with less risk," said Darryl Davis, president, Boeing Phantom Works. \\

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New aerospace concepts: Is testing ready for them?

Emergent technologies are providing some of the most exciting developments in the aerospace world. Is the current flight test community fit to assess them?

Once upon a time, aircraft were considered what would now be called a 'disruptive technology'; they were new, exciting and their application largely untapped. Small, agile startup companies appeared in garages and sheds across the world, and proceeded to overturn the apparently immovable status quo characterized by railways, ocean liners and horse-drawn vehicles.

Fast-forward a century, and the descendants of those pioneering startup aviation enterprises are now fulfilling the role of the corporate giants they once usurped. While this is undeniably a by-product of their success, it is not an environment conducive to innovation; this is not a breeding ground for the next emergent technology. This is not necessarily a deliberate strategy, but a result of the complexity and long lifetimes of modern aerospace products. Corporate inertia is the antithesis of innovation.

Unsurprisingly, the aerospace testing community, which evolved alongside the broader industry, is similarly ill-equipped to respond to emergent technologies. An issue is over-specialization, as the skill sets of testing organizations have become increasingly impressive in capability, but narrower in scope. This funneling effect is further compounded by the division of engineering skills into disparate streams, or 'stove piping', leaving testing organizations poorly equipped to deal with a product that differs from something they've assessed previously.

So, what can be done? The good news is that the highly specialized skill sets are very much still required when assessing emergent technologies, and although startup organizations may have a more flexible approach, they don't have access to the advantages that come with organizational inertia, i.e. deep technical competence and stakeholder relationships. The ideal solution is a structure that harnesses the agility and innovation of startups with the capability and legitimacy of established testing organizations. To make an engineering analogy, consider a retrofit digital flight control system, which imposes a 'soft' layer on top of the existing system to massively improve the capability of the vehicle through more intelligent use of the existing hardware. The alternative, as history has shown, is to continue funneling and stove piping into irrelevance and oblivion. \\

Garnet Ridgway

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

Sophie Robinson

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

The opportunity to test and evaluate truly new and emerging technologies is often a once-in-a-career opportunity for a flight test engineer – and one which is relished. The flight test community has a proven track record of testing novel technologies successfully, and there is no reason that testing of new technologies should now move outside of that sphere.

Safety culture has become ingrained in flight test over the years, and is what allows novel technologies to be tested effectively. A strong safety culture exists within the flight test community; we know how to test things and do so safely and incrementally – something which is of paramount importance when stepping into potentially unknown territories with new untried technologies.

The flight test community has also spent years developing the processes and methodologies behind test and evaluation, such that they are robust and resilient – and while the technology might be new, the existing protocols and practices are equally as applicable to new technology as they are to scenarios that have been repeated tens, if not hundreds, of times.

The flight test community has also demonstrated repeatedly that it can be practical and adaptable – how many programs have discovered an unexpected or unpredicted result, but managed to adapt to meet the required outcomes? In testing of emerging technologies, these events are more common. The experience to react and adapt to them is of the highest importance in ensuring that the required testing is completed safely and effectively. The flight test community also has the experience, and the ability to pragmatically apply that experience, to develop standard operating procedures and limitations that are non-existent for new technologies – an appreciation of the nuances and intricacies of developing such important documentation is something that inexperienced testers may lack, to the inevitable detriment of operational capability.

The flight test community benefits from its existing stakeholder relationships between military, industry and operator, which are essential to successful T&E.

The flight test community should keep testing safely and effectively and delivering exceptional capability to end users. \\

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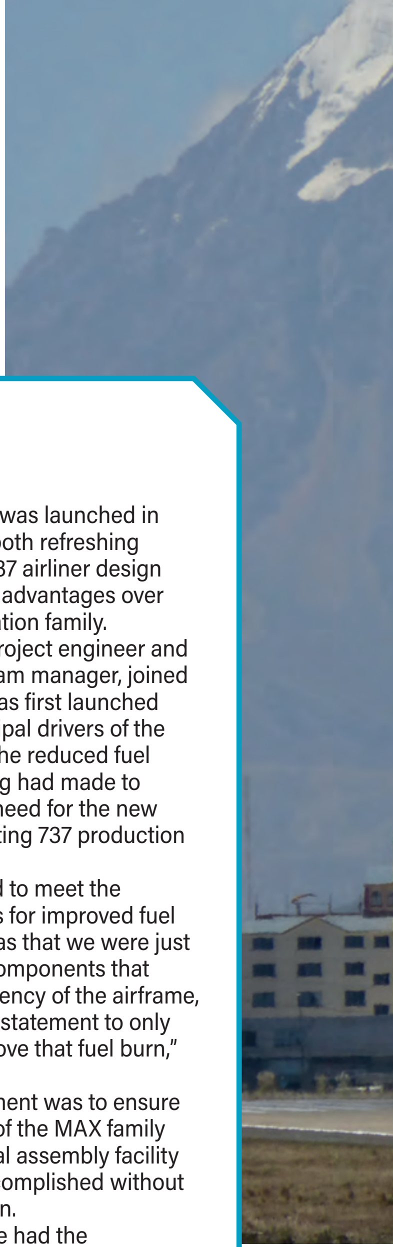
// NIGEL PITTAWAY

Te

sting to the MAX

From maiden voyage to the end of flight testing in just over a year... Boeing sets the pace with the 737 MAX

1 // The 737 MAX 8 during its first test flight on January 29, 2016



The 737 MAX 8 flight test program successfully concluded in February this year, ahead of planned deliveries to the first customer, Malindo Air, on May 16. On April 13, Boeing announced the first flight of the larger MAX 9. While the MAX 8 flight test campaign involved four aircraft, the similarity between the two variants has reduced the number of MAX 9 flight test aircraft to just two.

The next variants to fly will be the MAX 200, which is similar to the MAX 8, and the smaller MAX 7. Boeing says it is still finalizing the test schedule for the 200 and has not yet announced a schedule for the MAX 7.

The final variant to fly will be the MAX 10, which Boeing is close to launching. This will be the largest of the family, in terms of length, and will require a redesigned main landing gear and other changes, resulting in a new flight test campaign.

MAX 8 SPEEDS AHEAD

The first 737 MAX 8 made its maiden flight from Boeing's production facility at Renton, Washington on the south shore of Lake Washington on January 29, 2016.

The aircraft lifted off at 09:46 Pacific Standard Time and landed two hours and 47 minutes later at Boeing Field, the manufacturer's flight test and completion facility. Crewed by 737 MAX chief pilot Ed Wilson and Boeing's chief pilot and vice president of operations Craig Bomben, the aircraft reached a maximum altitude of 25,000ft (7,620m) and performed a series of planned maneuvers and systems tests.

> ***"Boeing's design goal for the MAX is to reduce fuel burn"***

"The flight was a success, the aircraft just 'felt right' in flight, giving us complete confidence that this airplane will meet our customers' expectations," chief pilot Wilson said after landing at Boeing Field.

The first aircraft was joined in the test program by three further examples, each dedicated to a specific series of tests, ranging from stability and control, aerodynamic handling, performance and systems testing, to environmental and function and reliability testing.

Chief project engineer and deputy 737 MAX program manager Michael Teal describes the MAX 8 flight test schedule as successful, paving the way for the MAX 9 campaign.

"The performance of the MAX 8 aircraft met our expectations and we are meeting the commitments we made to the customers," he said in April. "We didn't learn anything on the MAX 8 flight test that we needed to correct on the MAX 9. The MAX 8 worked well and that's why the MAX 9 remains on schedule."

STABILITY AND CONTROL TESTING

The first MAX 8 aircraft, Boeing designation 1A001, was the aerodynamic test aircraft, tasked with defining the safe handling envelope for the MAX design. "That airplane was the stability and control airplane; the

737 MAX DESIGN PARAMETERS

The 737 MAX program was launched in August 2011, aimed at both refreshing Boeing's best-selling 737 airliner design and realizing fuel-burn advantages over the earlier Next Generation family.

Michael Teal, chief project engineer and deputy 737 MAX program manager, joined the program when it was first launched and says the two principal drivers of the design changes were the reduced fuel burn guarantees Boeing had made to its customers and the need for the new aircraft to slot into existing 737 production without disruption.

"The new design had to meet the customer requirements for improved fuel burn, so the mission was that we were just going to work on the components that improved the fuel efficiency of the airframe, so we limited the work statement to only that which would improve that fuel burn," he explains.

The second requirement was to ensure that the incorporation of the MAX family into the current 737 final assembly facility at Renton could be accomplished without affecting NG production.

"So, from day one, we had the requirement of the production system overshadowing the design," Teal says.

The firm family configuration was determined in 2013 and design of the 162-184 seat MAX 8 began in 2014. The next variant is the 180-204 seat MAX 9, which will begin to be delivered to customers in 2018. This will be followed by the 138-172 seat MAX 7, which will begin final assembly at Renton in the fourth quarter of this year and fly in April 2018. If Boeing launches the MAX 10 (now being marketed as the MAX 10X) as planned, it will seat up to 226 passengers, with the first deliveries in the 2020 timeframe.

> ***"We didn't learn anything on the MAX 8 flight test that we needed to correct on the MAX 9"***

2 // The 737 MAX 8 during high altitude flight testing in La Paz, Bolivia (Photo: John Corrigan, Boeing)

airplane we did all our flutter testing on, the aerodynamic testing, the stability and control work – everything associated with the flying qualities of the airplane," Teal explains.

Boeing's design goal for the MAX family of aircraft is to reduce fuel burn compared with its current Next Generation (NG) family and the changes to the airframe, together with the new CFMI LEAP 1B engines, drove the flight test program from an aerodynamic standpoint.

The engines are mounted further forward and higher than the CFM56-7C on the NG family and aerodynamic changes include a re-profiled tailcone, which removes the need for the large vortex generators between the horizontal stabilizer and fin. Furthermore, the nose landing gear assembly is 8in (20.3cm) taller than before and the aircraft has redesigned MAX AT split winglets and fly-by-wire spoilers.

Following the handling quality testing, the aircraft deployed to Edwards Air Force Base in California in the middle of last year for a series of runway performance tests, including take-off performance data verification, before being withdrawn from the test fleet in September.

"It was a very smooth program. It completed its mission and it's now being retrofitted back to the customer-specific configuration and getting ready to deliver to the customer," Teal says.

PERFORMANCE AND SYSTEMS TESTING

The second and third MAX 8 flight test aircraft (1A002, 1A003) were dedicated to performance and aircraft systems testing respectively, with the former largely dedicated to LEAP 1B propulsion system testing.

"The second airplane was our performance airplane as it had production-representative engines installed," Teal continues. "We performed all the fuel mileage testing, climb performance, landing performance, as well as some of the high-altitude testing and some of the cold weather testing."

After initially being engaged on fuel mileage testing in California, the aircraft performed lapse rate take-off trials in Colorado and at a higher altitude of 13,300ft (4,040m) at La Paz in Bolivia, followed by water

300
Hours of 737 MAX 8 function and reliability testing undertaken

25,000FT
Maximum altitude achieved during 737 MAX 8 initial flight

2,000
Hours of flight testing on MAX 8 program before announcement by CFM

THE MAX HICCUP

The MAX 9 flight test campaign was temporarily suspended in May for a few days, after the engine manufacturer, CFM, notified Boeing that it had discovered a "quality concern" with the low-pressure turbine (LPT) discs of Leap-1B engines during inspections. CFM outsources components of the LEAP engine and has two LPT suppliers for this model; only one of the supplier's LPTs were involved. This came just before the delivery of the MAX 8 was scheduled. At the time of the announcement, Boeing had more than 2,000 test flight hours in the 737 MAX 8 program with the LEAP-1Bs and had not detected any problems with the LPT discs.

On May 11, Boeing released the following statement: "CFM has notified us of a potential manufacturing quality escape with low-pressure turbine discs in LEAP-1B engines delivered to Boeing. We are working with CFM to inspect the discs in question. CFM and its supplier notified us after discovering the issue as a part of its quality inspection process. At no time have we experienced an issue associated with the LPT during our ongoing MAX testing.

"Out of an abundance of caution, we decided to temporarily suspend MAX flights. The step is consistent with our priority focus on safety for all who use and fly our products.

"The MAX 8 flight test program put over 2,000 hours on the engines, including abuse testing and flights lasting more than nine hours, undergoing thorough inspections throughout. Additionally, 180-minute ETOPS testing completed in March 2017 required another 3,000 simulated flight cycles on the test stand, before a complete inspection was conducted by CFM. The LEAP-1B and 737 MAX have been certified to the most stringent requirements in commercial aviation."

CFM said Boeing had several engines at its factory without the LPT components. On May 12, Boeing Commercial Airplanes spokesman Paul Bergman said in a statement, "Today we resumed some 737 MAX flight activities. Regulatory agencies support this action. We plan to begin 737 MAX deliveries in May."

Flight testing on the MAX 9 resumed and delivery of the first MAX 8 took place on May 16.

ingestion, noise and crosswind testing in Montana and Texas.

"The third airplane was used to test many of the airplane systems, including the auto-land system, and we showed that the MAX has the same auto-land capability as the NG," Teal says.

FUNCTION AND RELIABILITY TESTS

The final MAX 8 test aircraft, 1A004, was only lightly instrumented and was completed in a typical customer configuration for the Federal Aviation Administration-mandated Function and Reliability testing required for type certification.

This aircraft traveled widely during its test campaign, visiting Yakutsk in Russia for cold soak testing at temperatures down to -37°C (-34.6°F) and Darwin in Australia's Northern Territory for hot and humid ETOPS testing, both in January this year. It was also the aircraft that visited the UK in July 2016 for the Farnborough International Air Show.

"We also took the airplane to several customers and worked with them, operating like an airline. We flew it like an airline would fly it; it would do a one-and-a-half-hour flight, we refueled it, opened the doors, closed the doors, and it would take off again. We really simulated how an airline would use that airplane," Teal details.

"We put the airplane through 300 hours of demonstrated performance with the FAA on board and it performed flawlessly. We're very happy with the flight test program. The actual reliability that we've seen over the flight test program has demonstrated to us that we're not expecting the need for a large army of personnel to be on the ground to support this aircraft."

TESTING THE MAX 9

The first MAX 9, aircraft 1B001, had its initial flight on April 13, at the hands of the Boeing test and evaluation

3

4

3 // The first 737 MAX 9 pictured during its roll-out in March this year (Photo: Marian Lockhart)

4 // The 737 MAX 9 during its first flight in the skies above Puget Sound (Photo: Craig Larsen, Boeing)

"Boeing estimates that 30% of the testing performed for the MAX 8 program will need to be redone on the MAX 9 campaign"

5 // First flight of 737 MAX airplane #3, April 14, 2016

pilots, captains Christine Walsh and Ed Wilson. The two-hour 42 minute flight focused on the flight control systems and handling qualities, but also included inflight restarts of both LEAP 1B engines and cycling of the landing gear. The flight was again successfully concluded with a landing at Boeing Field.

Boeing estimates that 30% of the testing performed for the MAX 8 program will need to be redone on the MAX 9 campaign, particularly in terms of stability and control work as the aircraft is 8ft 8in (2.64m) longer.

The MAX 9 flight test campaign will involve two aircraft over an eight-month period, culminating in an entry-into-service date during 2018.

-37°C
Lowest temperature experienced during MAX 8 cold soak testing

2
Number of aircraft to be used in the 737 MAX 9 flight test campaign

4
Number of aircraft used in the 737 MAX 8 flight test campaign

GROWING THE FAMILY

Both the MAX 7 and MAX 200 are planned to enter service in 2019 and, subject to official launch in the near future, the MAX 10 will follow in 2020.

The MAX 200 is little-changed from the original MAX 8, but with a high-density cabin configuration aimed at low-cost carriers and an additional mid-cabin entry door to cater for 11 extra passengers.

A Boeing spokesperson said in May that the specific ground and/or air test program was still being finalized, but declined to provide details of the MAX 7 test program, saying it was yet to be announced.

Subject to a hard launch in the near future, the MAX 10 will be 66in (1.67m) longer again than the MAX 9, 20in (0.5m) of which will be aft of the wing, so the main landing gear will be redesigned to provide necessary clearance with the ground during take-off and landing.

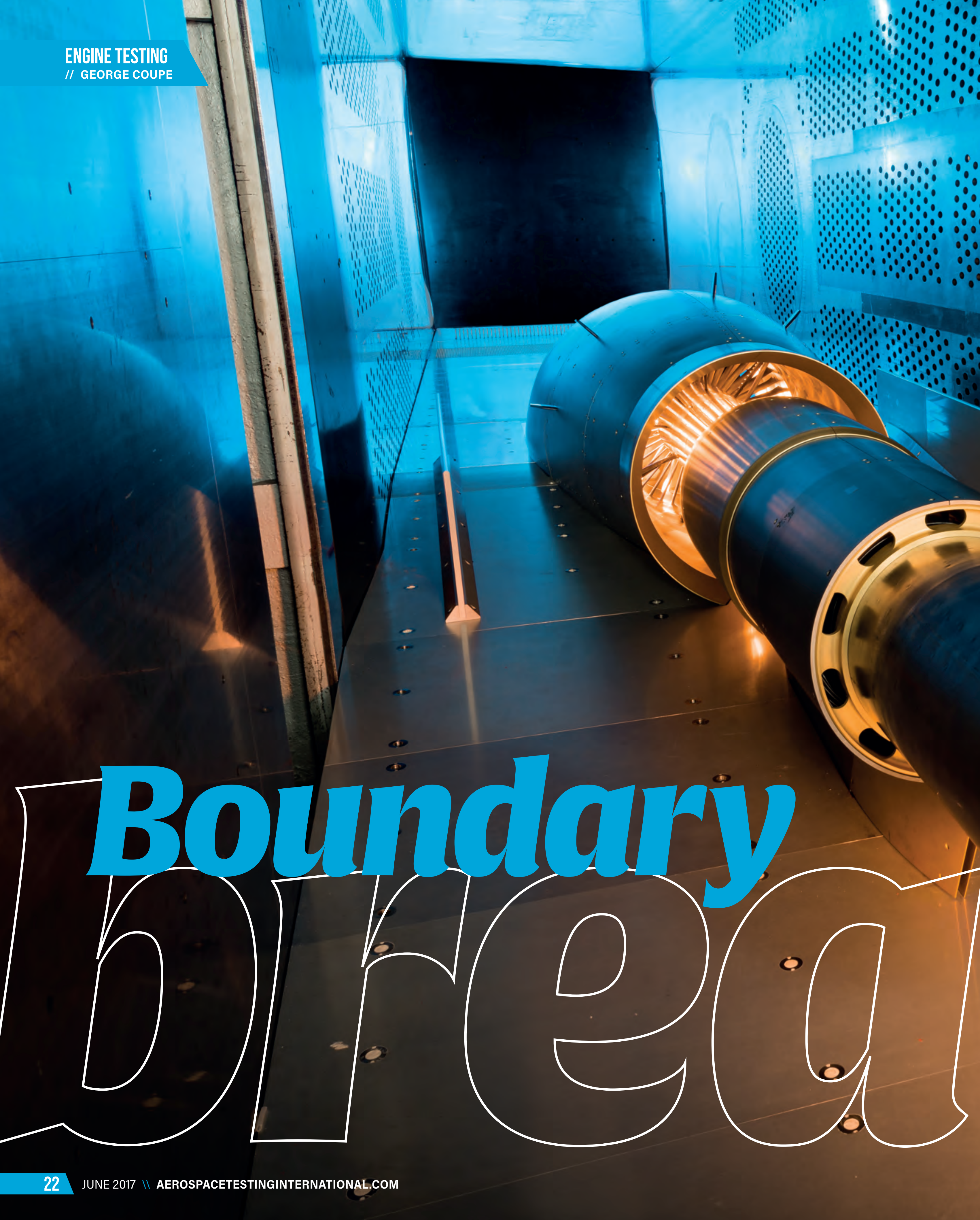
The longer fuselage and taller gear will require a further flight test campaign, but in the meantime, design and ground test work is being undertaken to finalize a configuration.

"We've looked at several different design parameters for the landing gear, but we're still not at our firm configuration. I've seen several of our concepts that we're now putting into prototype testing and it's looking really good and I don't feel we're going to have any issues with it," Teal says.

"We won't hit the firm configuration on the gear, and really the complete airplane, until the end of this year. All our development testing is proving positive and we're well on our way to firming up that configuration and moving forward in production." \\

// GEORGE COUPE

Boundary brea



NASA recently ran the first-ever test of a new jet engine technology that could radically increase fuel efficiency

ker

The aviation industry is often credited with making great strides in its effort to improve fuel efficiency and reduce emissions. Progress has been made, driven by executives hunting for margin, and to a lesser degree by the tightening of regulations on pollution. While such advances might feel like a revolution to those on the inside, on the outside the typical airliner looks decidedly unreformed.

The question is, how much more can be done through weight savings and new engine technologies to improve the efficiency of the standard tube with wings? How long will it be before the industry has to employ new aircraft shapes, such as the blended wing body (BWB), in order to continue to reduce fuel burn?

No doubt the BWB is still a long way off, but there are other modifications to the standard airliner configuration that might make a stepping-stone along the way. One such proposal, which is in development at NASA, is for a new type of engine, or 'propulsor', that lies partially embedded in the surface of the fuselage itself.

Typically, an airliner's engines are located in pods away from the body of the aircraft where they are free to ingest a relatively clean and uniform flow of air. Instead, the new engine experiment, which has just undergone a first round of research testing at the NASA Glenn Research Center in Cleveland, ingests the slower-moving and distorted stream of air that develops close to the skin of the aircraft, known as the boundary layer. It is a major cause of drag.

1 // The 'propulsor' is put through its paces inside the 8 x 6ft wind tunnel at NASA Glenn

"Approximately 3-5% fuel burn reduction could be achieved with five engines embedded into the upper aft surface of a hybrid wing body aircraft"

2 // The new propulsor is designed to be embedded in the aircraft's body, where it would ingest the slower-flowing 'boundary layer' air that normally develops along an aircraft's surface

3 // Tests have shown that the new fan and inlet design can withstand the turbulent boundary layer airflow and increase efficiency

The propulsor combines an engine inlet designed to manage the distorted flow, and an especially resilient fan stage. The team at Glenn has just completed the first ever wind tunnel tests of the inlet and fan combination.

By accelerating part of the boundary layer through an engine in this way, NASA says it is possible to reduce the drag on an aircraft and thus increase fuel efficiency by 4-8% more than the advanced engine designs that airlines are beginning to introduce.

The challenge is to build an engine that is capable of withstanding the effects of the boundary layer flow without resorting to technologies that might compromise efficiency, for example by adding weight to the aircraft.

Speaking to *Aerospace Testing International*, David Arend, a boundary layer ingestion (BLI) expert at NASA, says the propulsor has the potential to considerably improve aircraft efficiency.

"The team has successfully completed tests of the first-ever boundary layer ingesting propulsor for subsonic cruise aircraft and will begin reporting its results this summer," he says. "This was the first such test. Much research remains to be done over perhaps the next five years. Beyond that, it would be great to see this technology earn its way into mainstream aircraft design and go on to meaningfully reduce the impact of aviation on the environment."

The highly experimental engine is known as the Boundary Layer Ingesting Inlet/Distortion Tolerant Fan (BLI2DTF) and was designed with the assistance of NASA's industry and academic partners: the United Technologies Research Center and Virginia Polytechnic and State University.

The research, which began in 2009, is part of NASA's Advanced Air Transport Technologies Project. Arend says early studies indicated that approximately 3-5% fuel burn reduction could be achieved with five engines embedded into the upper aft surface of a hybrid wing body aircraft. The study also identified that up to 10% reduction was possible if additional propulsors were added to ingest more of the aircraft's boundary layer.

"The simplified objective of this research was to generate and evaluate new technologies through design, analysis and test of a multi-use single inlet-fan propulsor experiment," continues Arend. "Its ultimate goal was – if possible – to achieve significant fuel burn reduction for subsonic cruise aircraft relative to an advanced conventional baseline ultra-high bypass propulsor."

HOLISTIC APPROACH

The first challenge was the requirement for a multidisciplinary approach to the project in order to secure the best chance of making real and credible progress. The design of the combined inlet and fan stage had to be approached holistically, as Arend explains:

"From the outset, the BLI2DTF Task pursued concurrent research in the areas of inlets, turbomachinery, aeromechanics, acoustics, propulsion airframe integration and nozzles. Included therein is the requirement for a coupled, designed and integrated BLI inlet-fan stage."

The embedded BLI propulsor testbed for the transonic test section of the Supersonic Wind Tunnel and other experiment hardware was installed last year and research tests of the main wind tunnel experiment were conducted during November and December.

A jet engine creates most of its thrust by accelerating the airflow from the inlet to the nozzle at the rear. The thrust is proportional to the difference between the incoming and outgoing velocities, not the actual values

4 // The new fan and inlet design could use 4-8% less fuel than today's advanced aircraft

THE BLI CHALLENGE

As an aircraft moves through the air, a layer of slower air builds up along the fuselage and wings, causing drag. It grows in thickness from zero at the nose, to the rear of the airplane where it can be more than a foot deep.

By mounting the engines at the rear of the aircraft, for example directly on top of or behind the main fuselage, it is possible to ingest some of the boundary layer and accelerate it with the rest of the air that passes through the engine. Whether that air is compressed and burned or bypasses the engine core, by accelerating it in this way the total amount of drag created by the slower air moving over and behind the whole body of the aircraft is reduced. Less drag means that less thrust is required and so fuel burn and emissions are also reduced.

However, BLI poses a large engineering challenge in the design of the engines, specifically the fan blades, which have to withstand an unusual level of stress. Pod-mounted engines are subject to a relatively uniform stream of air entering the engine: as the fans turn, they experience the same air speed and pressure with every revolution. However, the flow of the boundary layer is more turbulent and distorted, which exposes the fan blade to additional stress. While it is possible to design an engine that can withstand this, the solution might require a heavier, less aerodynamically efficient engine. The challenge is to make sure it does not cancel out any efficiencies achieved.

of those velocities. A BLI propulsor achieves this acceleration within a lower range of inlet and outlet velocities than a conventional jet engine, and thus requires less propulsive power input (i.e. fuel burn) to produce the required amount of aircraft thrust.

Commenting on the aerodynamic advantages of the propulsor, Arend says, "Thrust generation with reduced average inflow and outflow velocities requires less propulsive power input, yielding a considerable reduction in the amount of fuel that must be consumed. This is more than enough to offset the efficiency losses incurred due to boundary layer distortion."

The next challenge for the team was to find a way to manage the impact of the distorted airflow on the performance and operability of the engine, by designing a fan that would be aerodynamically successful.

EARLY TESTS

In the tests, the BLI inlet ingested a considerable amount of simulated aircraft boundary layer airflow, as well as undistorted free stream airflow. Arend says the inlet was designed for that combination to minimize the impact of distortion on the performance of the fan stage. He adds that the fan was designed to structurally withstand and achieve aerodynamically robust performance despite the presence of the managed distortion flow provided by the inlet. "The experiment was designed to ingest the naturally occurring wind

“We completed our test program in December 2016”

tunnel boundary layer – augmented by aerodynamic roughness, which was employed to ensure it was thick enough. Combined with a boundary layer bleed system, we were able to achieve the desired amount of boundary layer ingestion for both on- and off-design operating conditions.”

The experiment included rotating instrumentation arrays at the ‘aerodynamic interface plane’ between the inlet and the fan, as well as downstream of the fan stage to measure its performance.

“It also featured a fast-acting variable area fan nozzle that was used to explore the inlet-fan map, and determine the propulsor’s stability limits when needed,” continues Arend. “The 22in diameter fan experiment was powered by NASA’s ultra-high bypass drive rig. All the instrumentation typically employed for inlet and fan tests was employed.”

The tests have achieved considerable progress: “We successfully completed our test program in December 2016 – including acquisition of the defined minimum success data and much more,” says Arend. “The operating map of our BLI propulsor has been explored and its aeromechanical robustness established over a little more than 104 hours of operation. Data was recorded across its cruise operating map, consisting of BLI inlet static pressure distributions, total pressure recovery and airflow distortion measurements.

“Measurements were also obtained of the fan’s aeromechanical response to BLI distortion and the fan stage’s efficiency and stability margin, as well as other flow physics measurements. We have acquired and are now post-processing the data needed to meet our research objectives.”

The next stage of the project is to employ the multi-use experiment to conduct certain specific research into the fan’s response to simulated BLI inflow conditions through a NASA fan rig test.

As Arend notes, there are many years of work ahead, but he is hoping that the new focus on the potential to exploit the boundary layer will make a major contribution to lowering the impact of aviation on the environment. “In this way, I hope BLI propulsion becomes a positive game-changer for the aerospace and aviation industries.” \\

5 // BLI engine designs could be incorporated into a series of X-planes NASA hopes to build and fly within the next decade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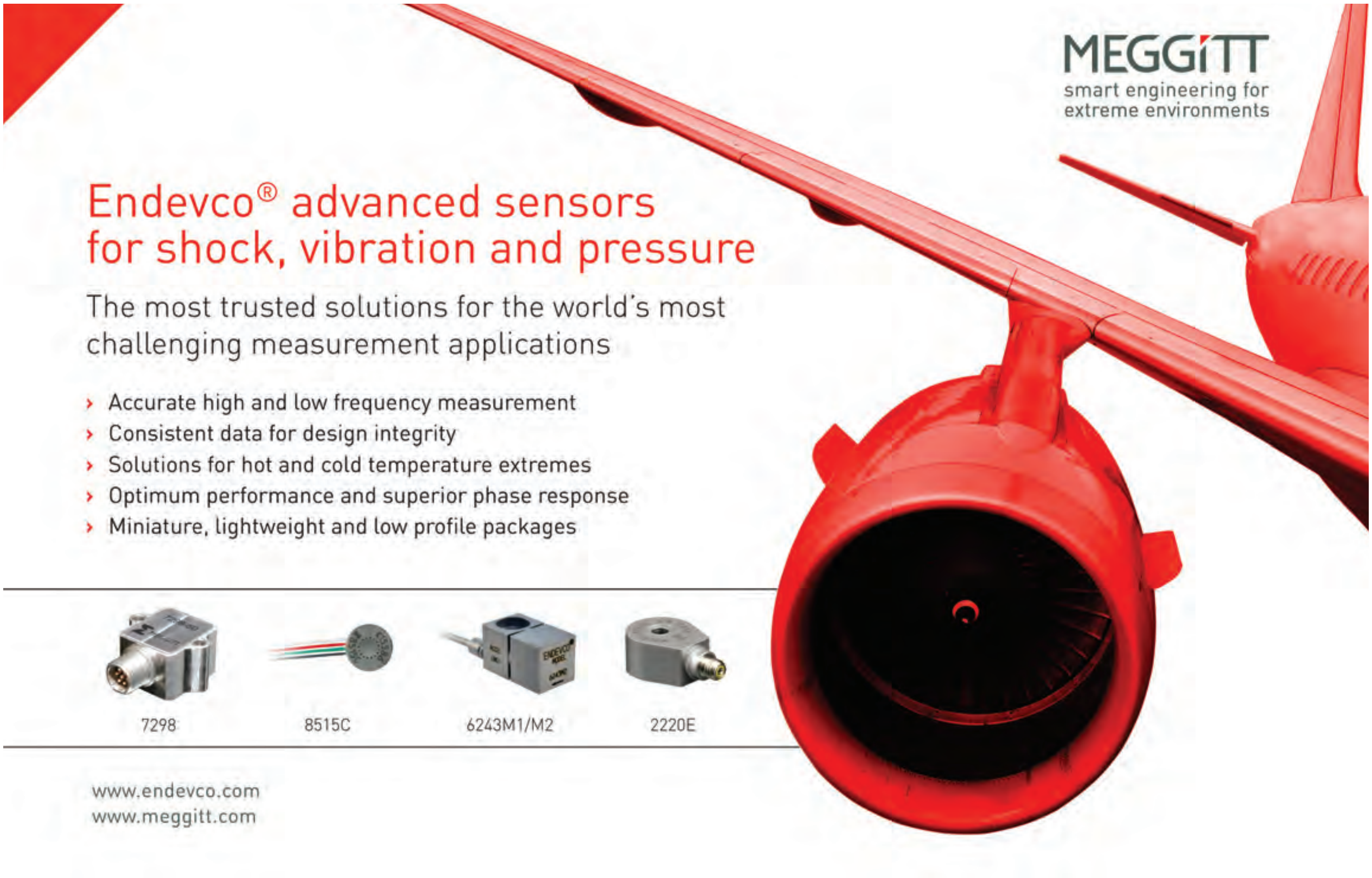
// FRANK COLUCCI

A series of C-17 flight tests have helped quantify the drag reduction and corresponding fuel savings afforded by temporary aerodynamic finlets and microvanes

More burn

// Microvanes 2.4in high by 16in long were adhesively bonded to each side of the aft fuselage of the test C-17 in Phases Three, Four and Five of the AFRL Drag Reduction Program (Photos: USAF)

for the buck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"You could replace the wings or engines, but we were looking for something more economical"

The 223 Boeing C-17 airlifters flown by the Air Mobility Command (AMC) are the biggest fuel consumers in the US Air Force. Each oversized-cargo jet burns just over 21,000 lb (9,525kg) of fuel per flight hour. Despite declining combat commitments, the AMC Globemaster III fleet logged more than 162,000 hours in the last fiscal year. Hence, Air Force leadership sought ways to reduce fleet fuel costs. Over a five-phase, 13-month flight test program, US Air Force Research Laboratory (AFRL) quantified 1-1.5% fuel savings with aerodynamic finlets and microvanes stuck temporarily to the aft fuselage of a C-17.

Savings could restore higher C-17 cruising speeds or extend range and endurance, but the original program driver was budget. "In 2012 fuel prices were much higher than now, and we had war efforts in the Middle East," explains AFRL senior aerospace engineer Dennis Carter. "We were burning a lot of fuel. The initial interest was to reduce the fuel burn for the Air Force – you could replace the wings or engines, but we were looking for something more economical."

21,097 LB
Hourly average C-17 fuel consumption in cruising flight

MACH 0.74
Currently prescribed cruising speed of the C-17 to reduce fuel consumption

1.5%
Drag reduction demonstrated with aft fuselage finlets

The 418th Flight Test Squadron of the 412th Test Wing, based at Edwards Flight Test Center, California, flew a C-17 with finlets, microvanes and less successful wing pylon and winglet fairings in various combinations. "The finlets were made of aluminum," continues Carter. "We drilled out existing rivets on the aircraft and replaced them with the finlets."

Lower-profile plastic microvanes were 3D printed and then bonded to 'speed tape' fixed to the aircraft.

The Globemaster III is simultaneously flown by the air forces of Australia, Canada, India, the UAE and the UK. AFRL has briefed AMC and the C-17 System Program Office (SPO) on the results of the test program. With final reports from the Test Wing and contractors Boeing and Lockheed Martin, AMC can perform a business case analysis to retrofit the C-17 fleet.

FINLETS AND MICROVANES

AFRL's drag reduction effort for the C-17 jet began with research on the Lockheed C-130 turboprop. Tail ramps on both airlifters impose an aerodynamic penalty. "On transport aircraft you have a large upsweep of the tail to permit loading of outsized cargo," says Carter. "When the fuselage pushes through the air, it creates

1 // The 223 C-17 Globemaster III transports in active duty, Reserve, and National Guard squadrons are the biggest fuel consumers in the US Air Force. The Air Force Research Laboratory Advanced Power Technology Office sponsored drag reduction experiments to cut fleet fuel costs


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a large low-pressure zone, resulting in a very large vortex that creates drag. Both the microvanes and the finlets break up that large vortex into very small vortices that are not as strong."

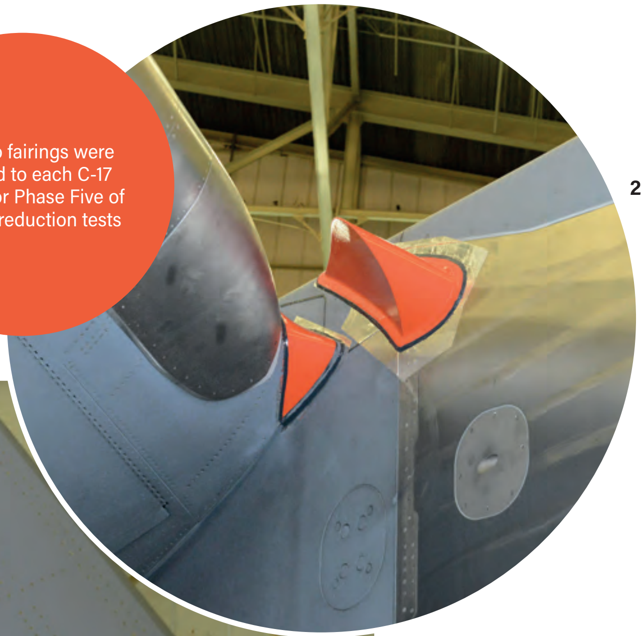
C-130 finlets made by Consulting Aviation Services in Kennesaw, Georgia, USA, were first tested on a civilian Hercules at Mojave, California, in 2011. Four large finlets were arrayed on each side of the aircraft cargo ramp. The same technology acquired by Vortex Control Technologies (VCT) flew on a later model C-130H. VCT credits its C-130H finlets with 7% fuel savings worth another 200 nautical mile range, 45 minutes of additional endurance or 3,000 lb greater payload. Microvanes developed by Lockheed Martin Aeronautics Company in Marietta, Georgia, USA, are still being tested, but the successful C-130 drag solutions have yet to win production orders.

Interest from the Royal Canadian Air Force in the Hercules drag reduction effort nevertheless led to a cooperative agreement with AFRL on the C-17. A subsequent Technical Cooperation Panel included representatives of the Australian Defence Science and Technology Group and the UK Defence Science and Technology Laboratory. AFRL and the Canadian Department of National Defence split the cost of the flight testing, while Australian and British funding helped pay for computational fluid dynamics (CFD) studies.

The wide-bodied C-17 was designed in the 1980s. "There was a crude version of CFD at the time," Carter notes. "Boeing had evolved its capabilities over the decades since, but they hadn't looked at these particular devices." Boeing engineers modeled the C-17 finlets while Lockheed Martin modeled the lower-profile microvanes. Carter recalls, "All the companies did some analytic computational studies before we went anywhere."

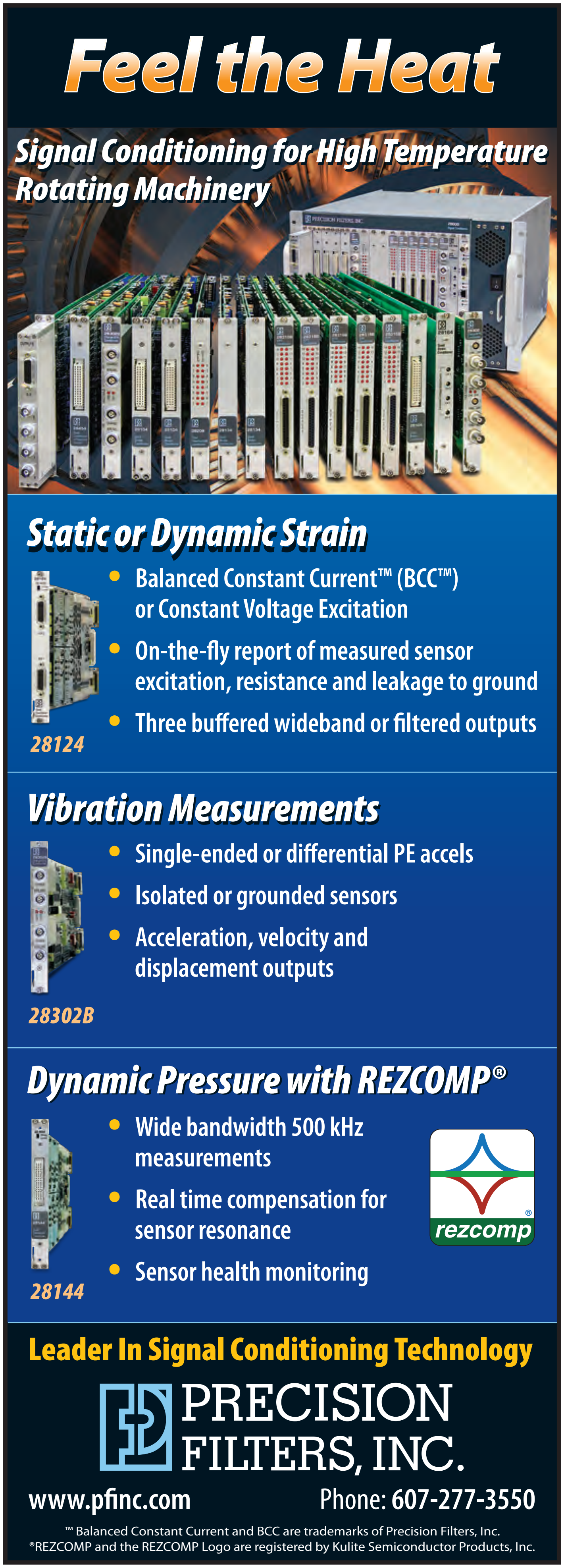
A 2.6% scale C-17 model was tested with and without finlets in the Canadian National Research Council low-speed wind tunnel in Ottawa. In addition the C-17 finlets were tested in the University of Maryland low-speed wind tunnel to establish correlation with the computer modeling. The microvanes and wing/winglet fairings were too small to test in the wind tunnel. "We had to rely on the CFD results," says Carter. "They came out very well, with good correlation between the computational and experimental results. We went to flight testing after we did that testing."

CFD modeling helped optimize the shape, quantity and locations of the C-17 microvanes. Lockheed Martin Aeronautics Company led development with engineering by the Skunk Works organization in California. Detailed design



2 // Two fairings were attached to each C-17 winglet for Phase Five of the drag reduction tests

3 // Boeing-engineered drag reduction finlets measuring about 6in high and 48 or 60in long were installed three to eight per side with and without standard C-17 aft strakes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4 // With commitments to combat operations in Afghanistan and Iraq, US Air Force C-17s logged 231,398 flight hours peak utilization in fiscal 2010. The AFRL drag reduction effort was meant to reduce fuel expenditure for the fleet

4

was performed by Skunk Works, and fabrication was performed by a contract vendor.

The microvanes for the flight test program were 3D printed with selective laser sintering (SLS) and made of a glass-bead filled nylon, DuraForm GF. Additive manufacturing technologies like SLS are typically used for rapid prototyping of complex shapes or small-lot production without tooling. Lockheed Martin Skunk Works design engineer Bryan Jenkins explains, "Each microvane is unique due to its location on the aircraft. Machining microvanes would be an expensive and time-consuming process. By using additive manufacturing processes we were able to quickly create the parts needed for this installation."

A Lockheed Martin test lab near Marietta performed coupon testing on the lightly loaded microvanes and bonded 3D-printed test samples to aluminum panels. The lab had tested both epoxy and sealant bonding techniques during the C-130 microvane program. According to Jenkins, "The sealants performed better than the more brittle epoxy, and we selected a sealant that is currently used on the F-22 canopy installation."

Pull-off tests were conducted at various temperatures and included intentional bonding flaws. "The end results showed that we had a very high margin of safety compared with the actual loading expected during the flight envelope."

Accurate placement of the finlets, microvanes and fairings was also essential to achieve the drag reductions modeled with CFD. "With the finlets, they could just go to the skin breaks and rivets and drill the holes out. That was very simple," says Carter. "For the microvanes, there was a definite position reference on the aircraft. They used laser positioning to set the location and the angle for the microvanes and the fairings on the aircraft. They're looking at alternative ways to do this if they go into fleet service."

CONSTANT ALTITUDE AND SPEED

AFRL and the 412th Test Wing planned the C-17 flight test series to characterize drag reduction combinations at two cruise speeds. The best cruise speed for the C-17 was originally Mach 0.77 at 35,000ft, but economic considerations led the Air Force to cut the prescribed speed fleet-wide to Mach 0.74 at 30,000ft. "Once we found out what the drag reduction was going to be," says Carter, "we didn't know if the service would be back up to Mach 0.77 or stay with the fuel savings at 0.74."

The C-17 test aircraft was ballasted to its maximum peacetime take-off gross weight (585,000 lb/265,352kg) and flew constant speed and altitude profiles. "That's how we calculated the drag reduction – by measuring fuel burn at a given speed and altitude with a given lift coefficient," says Carter. "We got the accuracy required out of the baseline C-17 instrumentation." Fuel flow was logged over three-minute periods throughout long flights. "That gave us the different center of lift for each hour. For each center of lift, that gave us our drag reduction through the lift range."

"We got the accuracy required out of the baseline C-17 instrumentation"

"Getting 1.5% drag reduction over the course of the life of the aircraft is going to pay it back"

Data collection flights launched from Edwards were routed over the Pacific. "We had discovered during the C-130 program that when flying over Edwards you got a lot of thermals from the desert floor that put great variation in our results," explains Carter.

Even with its drag reduction modifications, the C-17 test aircraft remained essentially uninstrumented. "We did put some accelerometers on the devices – the finlets and microvanes – to ensure they weren't adding any untoward vibration into the fuselage structure that would reduce the fatigue life of the aircraft," notes Carter. Pilots also looked for changes in handling qualities. "We kept the same pilots in the same aircraft for the entire test program. They were comfortable flying the C-17. When we made a change, they flew the same flight spectrum at slow speed, approach to stall, flaps up and down, to make sure there were no surprises in the handling qualities. They did that away from our normal test range areas. There were no problems. It flew just a like a C-17."

The standard C-17 has one big strake on each side of its cargo ramp to disrupt drag-inducing flow. The flight test program took baseline measurements with and without the strakes, and then flew drag reduction devices in various combinations. "We tested two configurations of finlet," says Carter. "First, we kept the standard strake and added three finlets above the strake on the tail of aircraft. We got over 1% drag reduction. We were not displeased with that." The second configuration dispensed with the standard strake and used eight finlets per side to achieve a 1.5% drag reduction. Smaller microvanes were arrayed six per side and provided a 1% drag reduction. Fairings on the wing/engine pylon junctures were credited with just 0.1% drag reduction.

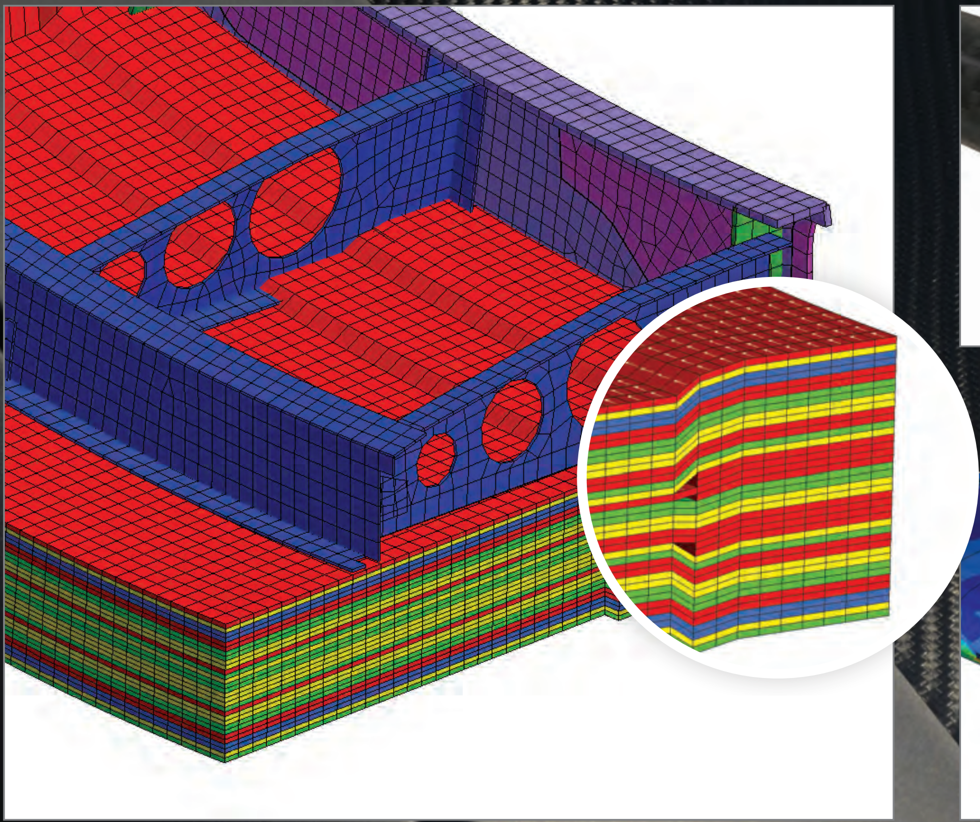
The flight test program included drops of cargo pallets and parachute mannequins. "We did a lot of cargo drops off the ramp," says Carter. "We also dropped heavy and light mannequins out of the side doors to simulate the spectrum of jumper weights with their equipment. We found no problems."

In total the C-17 drag reduction flight test program included 10 flights and 35 hours with six finlets per side, nine sorties and 34 hours wsith eight finlets per side, and eight sorties and 31 hours with microvanes. Another eight sorties and 18 flight hours tested the combined fairings. A business case analysis would have to balance fuel savings with modification costs.

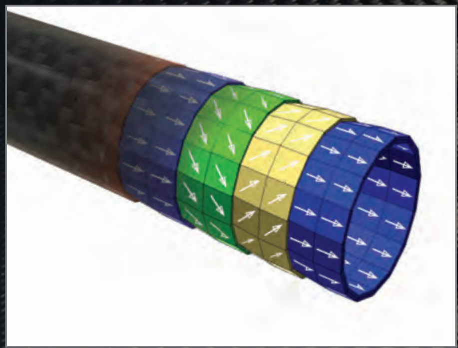
Carter concludes, "The highest drag reduction would be with eight finlets per side. They gave an additional 50% improvement over the microvanes and the three finlets per side. They're going to cost a little more, but getting about 1.5% drag reduction over the course of the life of the aircraft is undoubtedly going to pay it back. It should be straightforward to put them on, and they should last forever." \\

5

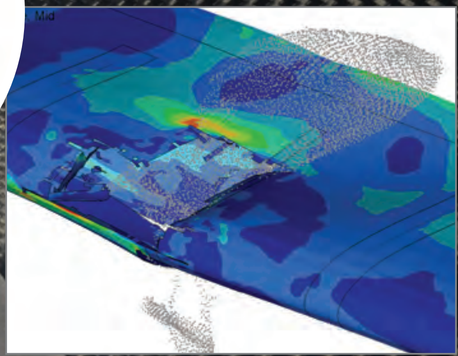
5 // Cost-saving initiatives cut the prescribed cruising speed of the C-17 fleet from Mach 0.77 to 0.74



Composite Design: HyperMesh



Optimal Lay-up: OptiStruct



Impact Analysis: RADIOSS

// PAUL E EDEN

Test tube babies

Dan Nale, Gulfstream's senior VP of programs, engineering and test, reveals the full extent of Gulfstream's huge investment in development and test laboratories for its parallel G500 and G600 programs

Gulfstream expects to achieve FAA type certification and first customer delivery of its new G500 this December. Cruising at Mach 0.85, the new jet will carry eight passengers and three crew 5,000 nautical miles, reducing to 3,800 nautical miles at Mach 0.90. Larger and heavier, the similar G600 is being developed more or less in parallel, but will cover 6,200 nautical miles at Mach 0.85 with eight passengers and four crew. Certification and first deliveries are expected in December 2018.

Both aircraft feature new wing and fuselage designs, with power from Pratt & Whitney Canada's PurePower PW800 turbofan. Up front, Gulfstream is introducing its dramatic Symmetry Flight Deck, a 10-screen system employing the manufacturer's 'immersive Phase-of-Flight' touchscreen technology and active-control sidesticks, through which pilots interact with the jets' fly-by-wire system.

In the back, Gulfstream offers an extensive equipment list, including the latest in-flight entertainment (IFE) and cabin management system (CMS) options, along with a high degree of personalization. The cabin is acoustically engineered to minimize noise and maintains 4,850ft pressure at the 51,000ft maximum altitude.

Gulfstream flew the clean-sheet G500 for the first time, from its Savannah, Georgia, USA, facility, on May 18, 2015. Typically for a maiden flight, it generated considerable media interest, but in reality represented only an entirely predictable event in an already long development and test campaign. "Even before the G500 left the ground, Gulfstream had spent more than 30,000 hours testing it in its ground-based labs," Dan Nale, Gulfstream's senior VP, Programs, Engineering and Test, reveals.

A set of brand new test laboratories was constructed specifically for the G500/G600 program. Representing an extensive investment, they added to the OEM's already comprehensive test facilities.

"Over the past decade Gulfstream has invested significantly in its research efforts, with more than 1,500 engineers and designers working at our Research and Development Center campus," says Nale. "It was established in

1 // Gulfstream is using an Iron Bird test system to rigorously evaluate representative flight controls, hydraulics, electrical systems and landing gear

"The labs have had great correlation to the aircraft, with many issues found in the labs before they're discovered on the aircraft"

2 // The Iron Bird is a spatially correct, dimensionally accurate structure, including a flight deck, specially fabricated to replicate the actual aircraft

March 2006 with a single office building and has grown to include three office buildings, a dedicated lab facility, and a combination lab and new office building for the G500/G600. It puts our engineers, maintenance experts and project pilots in the same facility as our ground labs.

"Before we had this centralized campus we carried out research, development and testing at various facilities in and around our main campus. For example, the integration test facilities for the G450, G550, G280 and G650/G650ER are all at our main manufacturing unit a couple of miles away from the R&D campus, while the G650/G650ER Iron Bird bird is located at a different location a few miles away."

By mid-April this year, the G500/G600 labs had accumulated in excess of 60,000 hours' test time, representing a huge investment in time and money. Is this work easily justified?

"We've always performed testing in advance of introducing and flying new aircraft, but the investment we've made in the brand new G500 and G600 labs is the most significant. The work done in the labs is important to the flight test program, allowing us to perform, practice and evaluate high-risk maneuvers on the ground before doing them in the air. It also enables us to identify improvements and address them prior to flight test and, ultimately, delivery to the customer.

"We're working hard to ensure a smooth certification and entry into service and it's not uncommon for our flight test aircraft to come back without a single 'squawk'. In fact, the G600 flight test aircraft once flew 22 consecutive sorties without an issue. The labs have had great correlation to the aircraft, with many issues found in the labs before they're discovered on the aircraft, allowing us to drive the maturity and reliability of the development and test programs. The investment is paying off."

MACH 0.925
G500/G600 maximum operating speed

76,850 LB
(34,860kg)
G500 maximum take-off weight

91,600 LB
(41,550kg)
G600 maximum take-off weight

CASE & ITF

Four labs are dedicated to the G500: the Integration Test Facility (ITF) for the flight deck, which includes a Cabin ITF; the Iron Bird; the System Integration Bench (SIB) and the Conceptual Advanced Simulation Environment (CASE). Separate G600 labs include a flight deck/cabin ITF and an Iron Bird; the CASE and SIB labs are shared.

3

3 // Gulfstream celebrated the successful first flight of the G600 Iron Bird in February 2016

4

4 // Gulfstream's Acoustic Test Facility features advanced acoustic chambers for testing materials, systems and methods to minimize cabin noise

"Separately, we also have an acoustics test facility supporting work on in-development and in-production aircraft; a cabin lab dedicated to advancements in cabin technology, including IFE and CMS; a composites lab, where we evaluate new materials; and a tooling lab where we explore advances in tooling," says Nale.

The CASE lab investigates the relationship between the new Symmetry Flight Deck and its human operators. "In a fly-by-wire aircraft, when a pilot provides input to a control mechanism, an electrical signal replaces the mechanical connection between the pilot controls and the flight control surfaces, the signal simulating the control reaction, or what the pilot feels. To make adjustments to the algorithm responsible for the control laws or control modes that tell the aircraft what to do as well as how that will feel to the pilots, we use the CASE.

"We also use it to test the changes we made to the G500 and G600 flight decks. We moved from a control yoke to an active-control sidestick; shifted the cursor control devices from outboard to the center column; installed touchscreens in place of buttons, dials and switches; and developed new pilot seats. All of these elements need to be evaluated and tested across a broad range of pilots – short/tall, female/male, strong/weak, thin/robust, and so on.

"The CASE and the ITF are great tools for evaluating the functionality of various flight deck elements and the pilots' interaction with them. Basically, pilots of different backgrounds 'fly' the aircraft while the human factors team evaluates how they interface with the flight deck, whether it's the touchscreens, the sidesticks or the cursor control devices.

"For the G500, we brought in five crews of pilots, including some from the regulatory authorities, to different test sessions exposing them to all aspects of the Symmetry Flight Deck. We basically did 100% of the human factors testing in the labs."

A degree of overlap between the test and certification programs has seen Federal Aviation Authority officials involved at the lab stage, particularly with this human factors testing, which was done entirely in collaboration with the FAA. The manufacturer has gone a step further, working with the regulator to develop the Flight Test Efficiency Initiative (FTEI). "By leveraging the lab work to integrate and mature the flight systems prior to an aircraft flying in the test program, it increases the safety and efficiency of the flight test certification program, with improved entry-into-service timing and configuration."

PRE-INTEGRATION TESTING

Gulfstream actually undertakes considerable systems integration and test work on the SIB before those systems are introduced into the ITF. "Based on supplier testing and our own work, we know each system works independently. The SIB helps us determine whether

DEDICATED G600 TEST FACILITIES

Integration Test Facility
Flight deck and cabin integration

Iron Bird
Major mechanical systems, flight controls and hydraulics integration

5

6

5&6 // The G600 Iron Bird 'first flight' ensured the landing gear, brakes and hydraulics were safely put through their paces well ahead of the actual first flight, which followed in December 2016

systems still function just as well when they're linked to one another on the aircraft. Information from most airplane systems flows through the data concentration network [DCN]. Components put information onto the DCN and pull off the information they need to perform their key functions. The SIB ensures all those systems play nicely together.

"The ITF builds on the pre-integration work done on the SIB. Once we've checked that systems work well together, they're incorporated into the ITF. It features a complete flight deck and cabin. You can't 'fly' on the SIB... it's more of an engineering tool, but the ITF allows us to ensure systems work in 'flight'. We use it to find and fix problems, prove reliability, develop interfaces and generate design improvements," says Nale.

"The cabin ITF, which is connected to the flight deck ITF, enables us to test a full range of cabin features. We're especially focused on seat functionality, tables, sideledge lids and other equipment. We've tested a variety of seats, differing in details including lumbar support; seat pan width and length; armrest height, length and shape; and foam density for the seat and back.

"We do simulated flights in the ITF, employees spending several hours assessing seat comfort. We also have a flight attendant who berths the seats and prepares meals, testing the galley and cabin layout, its functionality, and the location and volume of available storage. This feedback is incorporated into our interior design and cabin outfitting efforts. A fully outfitted G500 test aircraft complements the cabin ITF. It's part of our flight test program and is being used to ensure functionality, comfort, ergonomics and performance in flight and over the long term."

IRON BIRD

In a familiar aerospace testing concept, the G500/G600 Iron Birds represent all major systems in an architecture and geometry identical to that of the aircraft, although they include the ITF controls and displays. "It means the wiring bundles are the same, the aircraft connections are the same, the bend radii are the same and the installation proximity to high-powered wires is the same," says Nale.

"But in the Iron Birds we focus on the mechanical systems, flight controls and hydraulics. They're represented rather than simulated, so the pilots really do fly the Iron Bird, testing the flight control surfaces relative to the flight profile. Simulation software provides backforce into the system, so the 'aircraft' knows how fast it's going, how high it is, and so on."

PREPARING FOR FLIGHT

FlightSafety International has a long pedigree in Gulfstream flight simulation and created a G500 full-motion simulator (FMS) at its Savannah facility – the G500 flight test crews using it and the labs to prepare for first flight. Its ongoing role in

5,000NM
G500 maximum range at Mach 0.85 cruise with eight passengers and three crew

6,200NM
G600 maximum range at Mach 0.85 cruise with eight passengers and four crew

19
Number of passengers maximum in typical G500/G600 layout

7 // Gulfstream's Conceptual Advanced Simulation Environment (CASE)

8 // CASE is used for human-factors evaluations, fly-by-wire control law development and integration of the Altitude Control and Stabilization system

G500 TEST FACILITIES

Laboratories
- Conceptual Advanced Simulation Environment (shared with G600)
- Development of control laws and human factors evaluations
- System Integration Bench (shared with G600)
- Pre-integration of Honeywell avionics and the DCN

Integration Test Facility
- Major avionics systems, including cockpit, electrical power, FADEC, systems control and cabin systems
- System software debugging, aircraft test specification development
- Human factors development
- Cabin systems integration

Iron Bird
- Major mechanical systems, flight controls and hydraulics integration

Cabin Integration Facility
- Used to refine cabin technical and creature comforts before first aircraft installation

flight test is slightly more limited, however, says Nale: "Most of our development testing is done in the labs, which are located adjacent to our pilots and engineers, allowing us to make changes and test them immediately in the lab environment."

Static test and ultimate load testing on the G500 are complete, fulfilling FAA and European Aviation Safety Agency certification requirements – limit load represents the maximum load the aircraft is likely to experience during its lifetime, while ultimate load represents 150% of limit load.

BEND TO THE TASK

Structural testing focuses on the fuselage, wing, fin and tailplane, nose and main landing gear, and control surfaces. It involves multiple test conditions, including wing up-and-down bending, horizontal up-and-down bending, and wing torsion. For the G500, more than 6,000 channels of instrumentation were employed, including load cells, strain gauges, displacement transducers and instrumented links/pins. Cameras inside the wing, empennage and fuselage gave technicians real-time insight into the structure's behavior.

Gulfstream's structural test hangar accommodates a G500 test article dedicated to fatigue. "It will simulate more than three lifetimes of airframe operation over several years, making thousands of simulated flights, from taxi to landing and everything in between, without ever leaving the ground. It'll be subjected to structural loads mimicking every phase of flight and the cabin will be pressurized and depressurized. "The tail and wings will bend and flex under the force exerted by precisely positioned actuators or jacks, our Fatigue and Damage Tolerance Group having developed the loads for each actuator. The loads are programmed into the actuators, simulating flight, and represent distinct missions, each with different durations, weights and severity levels," explains Nale.

"The test article is equipped with a data acquisition system employing strategically placed gauges that measure strain on the wings and fuselage for every load case. Data is captured throughout the process and relayed to a suite of computers."

Gulfstream's investment in the G500/G600 test program is impressive, but with G500 service entry imminent and the G600 entering its final year of test, will the labs become redundant? Certainly not! "We still use the G450 integration test facility 10 years after the aircraft entered service. It's a good way for us to test software updates as well as new services before installing them on the aircraft. We also use the ITF to accelerate resolutions to potential in-service challenges, further supporting our customers." \\

The all-seeing red

1 // Safran recently invested in Diota, a leading French publisher of augmented reality software solutions for industry

eye

Via a combination of infrared and augmented reality, one company may have changed the face of nacelle testing

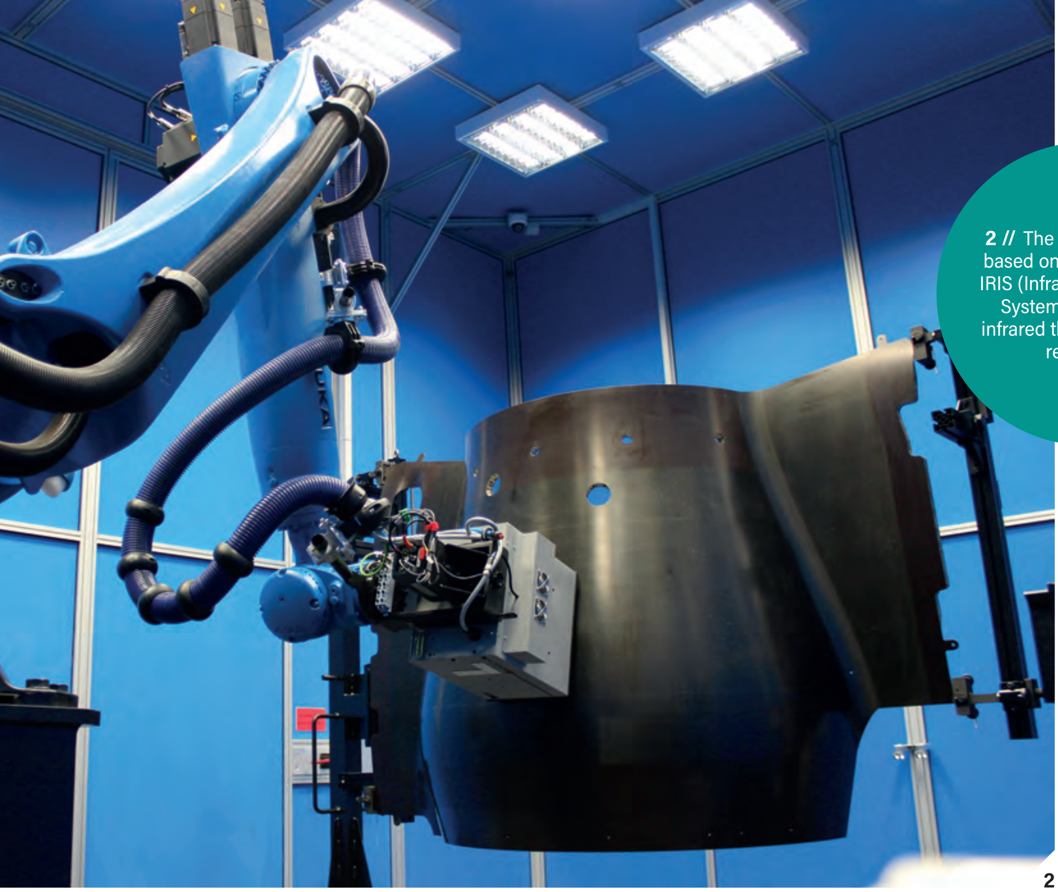
Engine nacelles are subject to massive thermal and aerodynamic stresses, so it is critical they are tested to withstand the enormous strain commensurate with their positioning.

"Until recently, the non-destructive testing of our complex composite parts was realized by water-jet ultrasonic testing," says Bertrand Leroyer, research and technology manufacturing director with Safran Nacelles, the world's second-largest manufacturer of aircraft nacelles and provider of solutions for the Airbus A320 and A330 series.

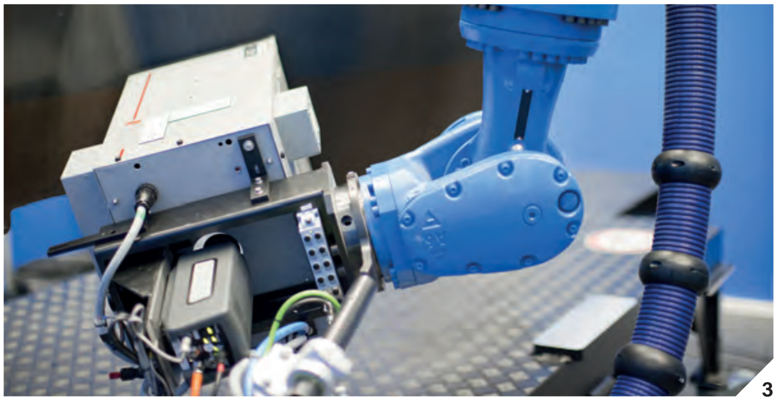
"Two water jets are placed facing each other to allow the transmission of the ultrasonic wave. This configuration allows the attenuation of energy in the wave crossing the part to be measured. The attenuation is represented by a scale of color, which allows us to quickly highlight zones to be verified. With the machine or by hand, the inspector marks the areas to be checked, then checks them himself."

This solution, while adequate, can be time-consuming and expensive, and on occasion leads to a more destructive test, which can result in costly components being ruined.

In 2012 it was therefore decided to mobilize the expertise of five Safran companies in the fields of composites, infrared technologies, software development, thermography, integration, industrialization, augmented reality (AR)



2 // The NDT process is based on a robot named IRIS (Infra Red Inspection System), which uses infrared thermography to read data



3 // A close-up showing the infrared camera and excitation device used to scan the composite nacelle panels

and automation. As an umbrella company, Safran benefits from huge digital facilities and continuity in this process.

"The initial aim of the project was to move away from using a water-based solution," says project team leader Nicolas Serre. "Fairly soon, the greatest challenge was sharing the project over so many Safran sites. There were people from our offices in Le Havre, Toulouse, from outside Paris, as well as outside France. It was not simple to have so many employees working together toward a shared goal, but we made it. The system is completely our own."

INTRODUCING IRIS

Fast-forward to the end of 2016 and the production model of a new and innovative solution was in operation, a solution that may alter aspects of aerospace testing in the future. "This NDT process is based on a robotic system named IRIS – or InfraRed Inspection System – which uses infrared thermography to read data," says Leroyer. "An infrared camera and an excitation device embedded on a robot are moved to cover the composite panels. Surface temperature due to the heat propagation is observed in the bulk thickness of the part, using an infrared camera. The system then acquires the generated data. After data processing, the information is analyzed by an inspector using special viewing software developed by Safran. Finally, the developed system gives direct access to the data report generated by IRIS and uses AR to project the areas to be checked onto the part. Previously it was tough work to put film on the part, to protect it against water. Now we don't have to do this; we just inspect the part without any preparation. The AR means 30% less time spent on checking, and increased availability of the part."

After analyzing several technologies, Safran Nacelles decided on infrared thermography as the NDT inspection method since it was already being used by Herakles, another company in the Safran group. Infrared thermography is very well adapted to Safran Nacelles' needs in terms of data processing, along with development costs and implementation of the robot.

"The use of infrared thermography on such large and complex composite parts of varying thickness is a world first," says Leroyer. "Meanwhile the augmented reality system, instantaneously projecting all the areas to be checked directly onto parts measuring from 3-12m², is the first to be deployed by Safran."

VIRTUAL REALITY CUTTING COSTS IN MATERIALS TESTING

Aeroblaze is a Texas-based laboratory specializing in flammability testing for aircraft interiors. It is also the first company in the world to offer customers the chance to watch their tests taking place in real time from anywhere. "To my knowledge, virtual reality is not common in aerospace testing, at least not in materials testing," says Andrew Feghali, CEO of Aeroblaze. "Almost all labs offer a video of the test if requested by the customer, but I'm not aware of any that have begun to use VR videos. The key benefit of VR is as a cost-saving measure."

As things stand, companies require one of their engineers to physically witness testing, and the FAA requests their designated engineering representative (DER) to observe all tests related to certification projects. This costs organizations in travel time and money, and can be inconvenient for the test labs as it involves stopping other tests taking place to ensure confidentiality. Some aerospace companies have begun to witness their own testing via a live stream, but the FAA still requires a DER to physically witness testing.

"When VR technology becomes more common, I think we will start to see companies allowing their engineers to witness testing from their desks," says Feghali. "Maybe the FAA will allow that in the future, although don't hold your breath. We currently provide VR videos as an option to customers who request them and will send them a VR headset to view the test. As the technology evolves, our goal is to provide real-time VR testing for all in the future."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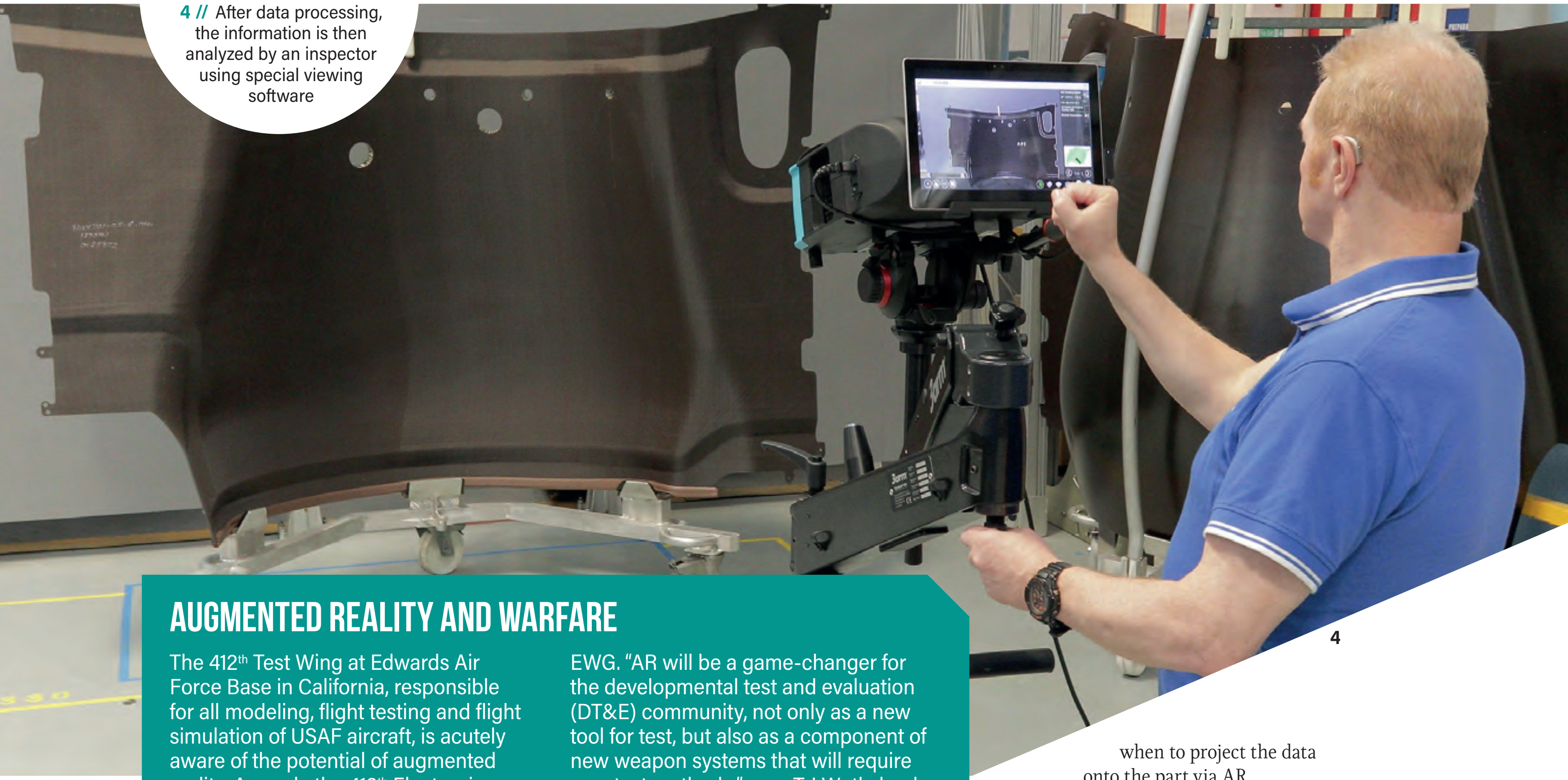


4 // After data processing, the information is then analyzed by an inspector using special viewing software

AUGMENTED REALITY AND WARFARE

The 412th Test Wing at Edwards Air Force Base in California, responsible for all modeling, flight testing and flight simulation of USAF aircraft, is acutely aware of the potential of augmented reality. As such, the 412th Electronic Warfare Group's modeling and simulation fight department plans to acquire several HoloLens holographic computers and head-mounted displays from Microsoft, along with a number of Meta 2 AR systems, in an effort to seamlessly integrate the use of AR into its workflow, to extend its capabilities. The possibility of viewing different test scenarios, donning an AR visor to see a test setup, or knowing the effects of electromagnetic interference before it's happened, is a big opportunity for the EWG. "AR will be a game-changer for the developmental test and evaluation (DT&E) community, not only as a new tool for test, but also as a component of new weapon systems that will require new test methods," says T J Wuth, lead engineer, 412th Test Engineering Group Instrumentation Division. "From the battleground to the maintenance hangar, AR will have a disruptive impact on how we currently operate and it directly ties into human-machine teaming to help us make decisions faster with better data. AR has the potential to bring sensor fusion to the individual warfighter and, as a test community, we need to be ready to test and evaluate those systems and platforms to mature the technology at an accelerated pace."

The process was devised specifically for the A320neo LEAP-1A and A330neo Trent 7000 nacelle programs, for which production is expected to boom over the next three years. The results live up to expectations: 50% less inspection cycle time and an increase of availability of the equipment thanks to the separation of the control and marking activities. Working conditions are also improved thanks to enhanced ergonomic software and easier controls, also designed by Safran.

To prevent the company from slipping behind on its timeline, Safran Nacelles ensured its NDT inspectors were trained on the prototype while it was in development and received their certification for inspection to coincide with IRIS going live. Such certification will include the specifics of how and when to project the data onto the part via AR.

"After the acquisition program has been launched, the inspector starts the analysis of the part via the software views," says Leroyer. "If the part is good, he doesn't need to complete the control. If IRIS does indicate a potential fault by projecting spots on the part, thanks to the software, the inspector is able to define the defect at that point and consider further inspection. The points to be checked are projected on the part via AR, so the inspector is quickly able to do a visual or hearing test, for instance an ultrasonic, radioscopic or tap test. The technology requires looking at the part from many points of view. The data analysis is very complex and Safran Nacelles is continuing its work on further improving efficiency."

TIME SAVINGS

As the company ramps up its Airbus nacelle production, inspection time saved

"Results live up to expectations: 50% less inspection cycle time and an increase of availability"

5 // The augmented reality system can instantaneously project all the areas to be checked directly on to the parts being inspected

6 // The new method has resulted in 50% less inspection cycle time, as well as an increase in the availability of equipment

by avoiding the delay in water-jet ultrasonic NDT is already proving invaluable. Not only does Leroyer see this as an example of the company's ability to increase production at will, but he also believes this innovative process may be more widely deployed in the NDT field and could become an industry standard.

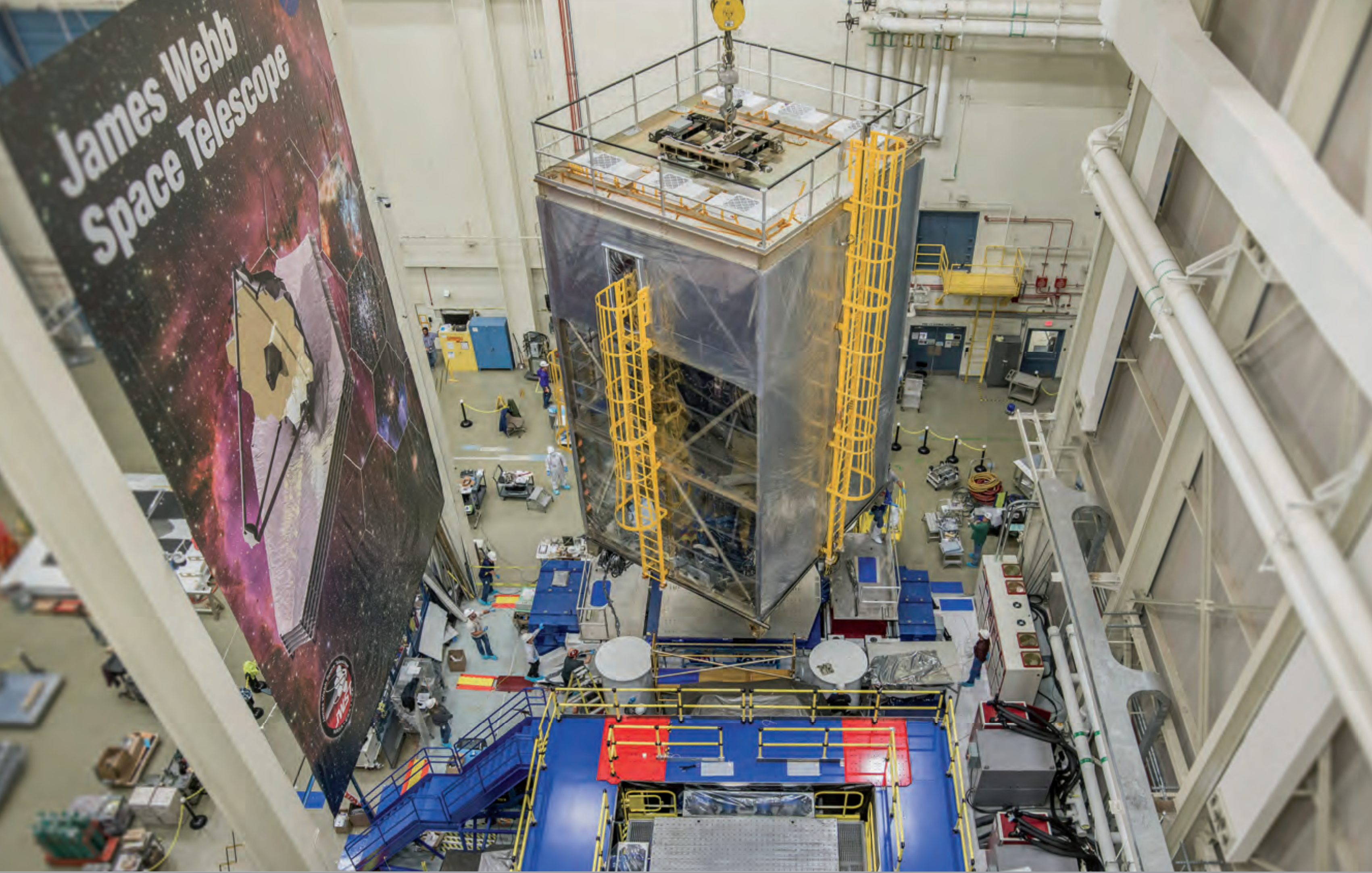
"The automated NDT solution using infrared thermography and AR might be deployed at MRO stations to complete final inspection of repaired composite parts," he says. "The solution may be licensed, with such consideration to be made in the future, although IRIS was mainly developed to meet our own ramp-up needs. It cannot, however, be moved to aircraft engines on wing because of the large size of the robotic equipment."

HEY PRESTO

Concerning on-wing repair, Safran Nacelles recently developed a portable infrared solution called PRESTO. This NDT technology enables the on-wing assessment of the effects of engine overheating on inner fixed structure (IFS) panels. In the NDT field, this technology is a complementary control solution to ultrasonic or tap testing, with the inspector using an infrared spectrometer sensor, connected to software, to deliver a report.

Meanwhile, with the A320neo nacelle system program, Safran Nacelles has set the goal of obtaining the same level of quality in three years that it achieved with the A320ceo in 30 years. To give another example, the development cycle has been reduced from 74 months for the A380 nacelle system to 42 months for the A330neo.

"We will train more inspectors and in the future we will need additional IRIS machines," says Serre. "We are lucky in our company's positioning. Too much of the aerospace industry is behind the curve. There are lots of facilities that clearly have to transform themselves to be more efficient in the digital arena. We have the ability and knowledge about NDT in general, but we have many other digital projects, such as virtual reality and robots, in our facilities, so for us it's all part of the same move forward." \\


James Webb
Space Telescope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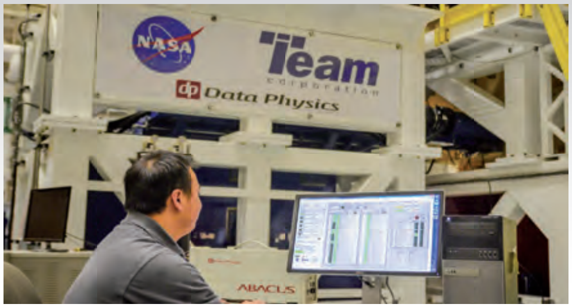
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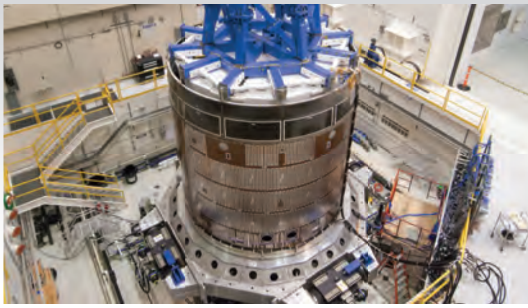

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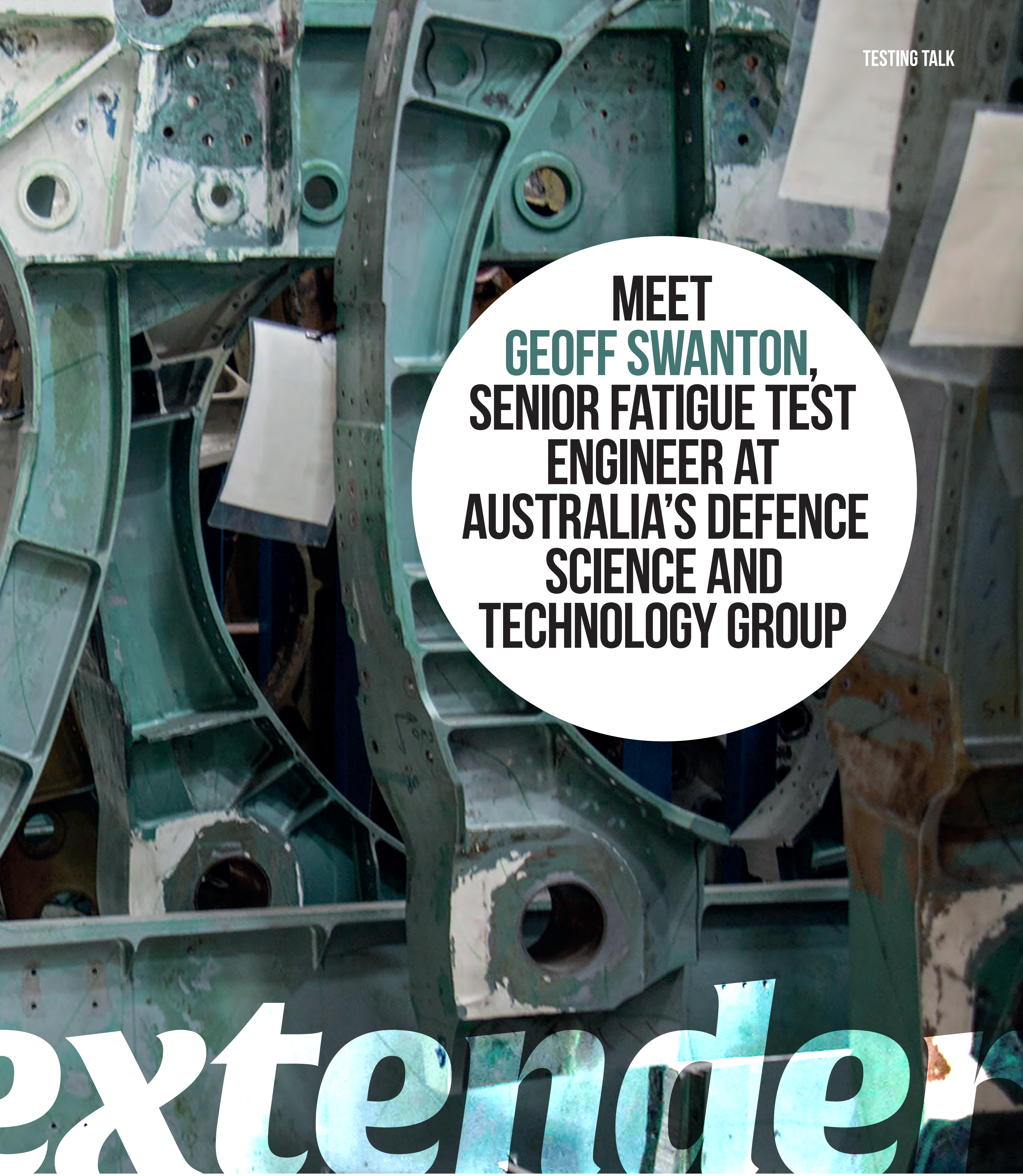
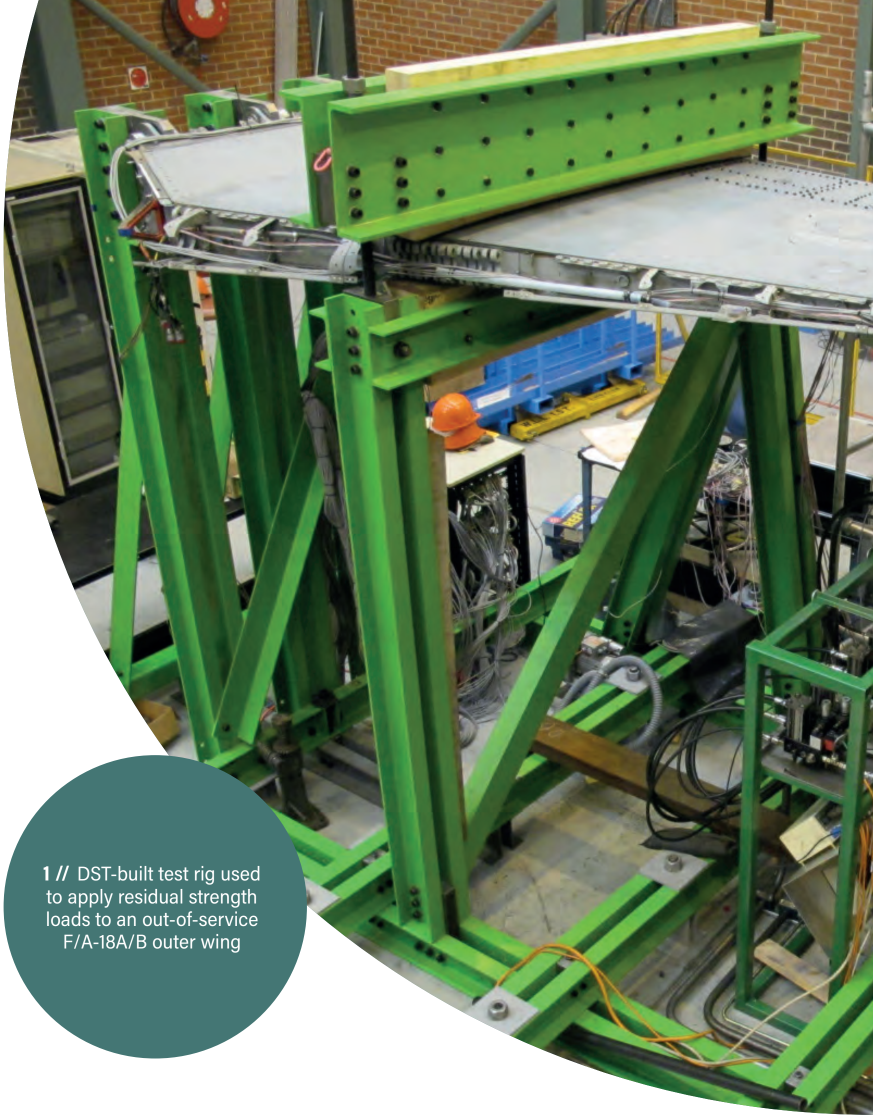


MEET GEOFF SWANTON, SENIOR FATIGUE TEST ENGINEER AT AUSTRALIA'S DEFENCE SCIENCE AND TECHNOLOGY GROUP

extender



1 // DST-built test rig used to apply residual strength loads to an out-of-service F/A-18A/B outer wing

// WHAT FIRST INTERESTED YOU IN TESTING?

My father started working for the airlines shortly after I was born, and consequently we moved close to Tullamarine [Melbourne] Airport, where I spent many childhood hours watching aircraft on their approach or departure flight paths. Dad also served with the Royal Australian Air Force [RAAF] and obtained his private pilot's license before I was born, so hearing about those stories probably also influenced my interest in aviation. I ended up studying Aerospace Engineering at the Royal Melbourne Institute of Technology and my first job upon graduating was a casual position in the composite structures manufacturing facility at what was then AeroSpace Technologies Australia [ASTA – now Boeing Australia], assisting the senior engineers write non-conformance reports on undercarriage doors for Airbus A330/A340 aircraft at the time. Shortly thereafter, I took up a six-month contract position at DST Group to support F-111 structural integrity tasks and have been working there ever since.

// WHAT SORT OF TESTING ACTIVITIES DID YOU CARRY OUT AT THE START OF YOUR CAREER?

My first testing job was not a full-scale aircraft test *per se*, but rather a standalone component test to assess a novel loading system that had been developed by DST specifically for the joint Australian-Canadian International Follow-On Structural Test Project [IFOSTP] on a full-scale aft fuselage and empennage of an F/A-18A/B. To provide some background, DST's IFOSTP fatigue test was considerably more complex than conventional fatigue tests in that it simultaneously applied maneuver and dynamic [buffet induced] loading. To facilitate this requirement, DST developed pneumatic rolling sleeve airbags as the method of applying the maneuver loads, which eliminated the added mass and stiffness of more conventional steel whiffle tree load distribution arrangements, and therefore allowed the dynamic loads to be applied without impediment or compromise using electromagnetic actuators. In order to assess the performance of these airbags under high-frequency loads, my task was to design a test rig and conduct the testing to demonstrate the suitability of these airbags for use on the full-scale IFOSTP test article.

// WHAT WERE SOME OF THE MOST VALUABLE LESSONS FROM THAT TIME?

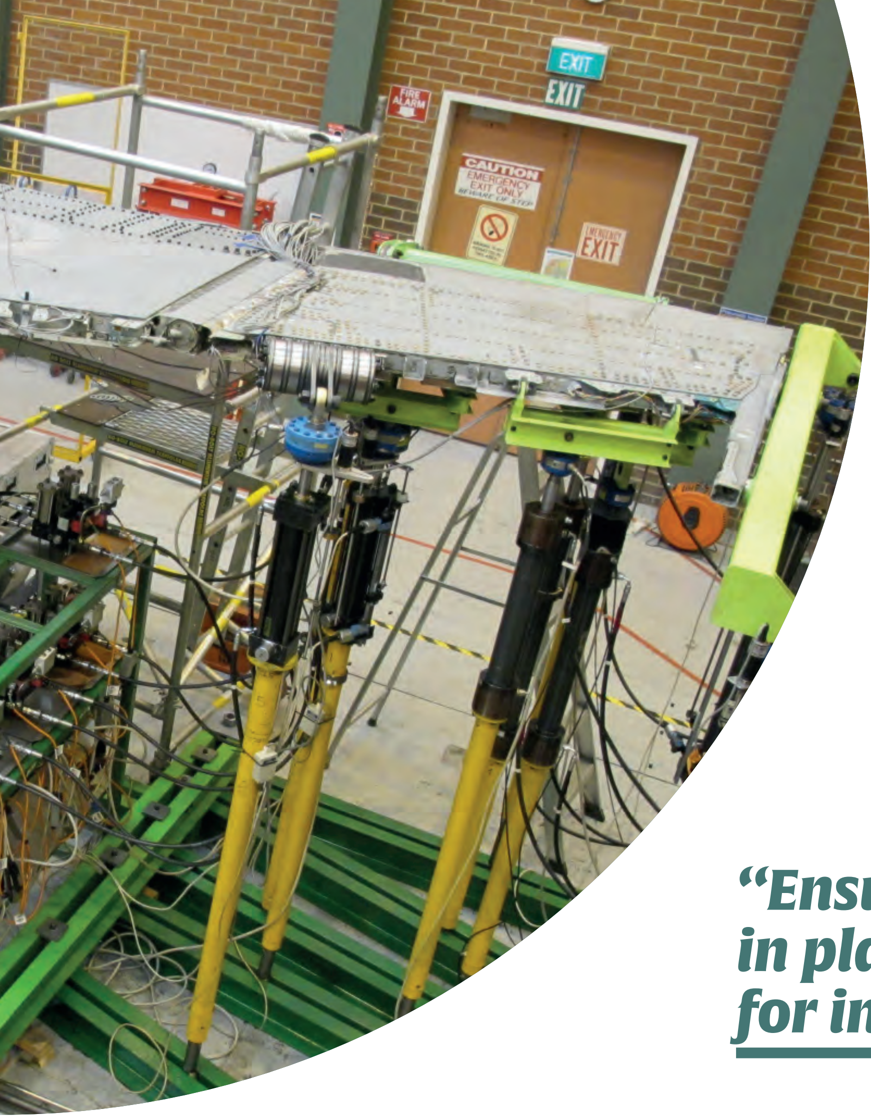
Conducting data integrity checks early on in the test, such as strain surveys, has always been an important step to assess the performance of the loading system and strain gauges, and to ensure the test article is behaving as expected. DST is fortunate to have many staff who have spent much of their careers developing years of collective experience and expertise on designing and operating full-scale tests, so the most important thing is tapping into that knowledge base to ensure the successful conduct of a test.

Equally important to ensuring a successful, or useful, test outcome are the staff who work in the area of failure analysis and quantitative fractography [i.e. the ability to relate progression marks on a crack surface to loads or events in the test history] as well as having a test interpretation plan in place before the test commences. Lab staff, airframe technicians, engineers, material scientists, instrumentation installers, test control and data acquisition operators, project managers – everyone plays a vital role in our full-scale test programs.

Another lesson that has endured to this day is to ensure that a test log is in place and used, even for what might seem like insignificant events, because sometimes these might provide the context of why certain decisions were made at a later date. For similar reasons, I make sure I retain all test-related emails, and take lots of photos of details at various points throughout a test.

// WHAT IS YOUR CURRENT POSITION?

I'm an F/A-18A/B and PC-9/A aircraft structural integrity engineer, for the Defence Science and Technology [DST] Group's Aerospace Division, based in Melbourne, Australia. I'm currently split between two primary tasks. I have been the task lead for trainer aircraft structural integrity for the past few years, which specifically refers to the RAAF's current advanced turboprop trainer, the Pilatus PC-9/A. It's an aging platform, nearing the end of its service life [current retirement date is 2019] so there have been several typical aging aircraft issues arising, such as nuisance cracking and environmental degradation that have been sent to DST for assessment, mainly through our forensics group. A couple of years ago I also organized the preparation activities to facilitate the tear-down of a retired PC-9/A to satisfy the requirement of an aging aircraft structural audit. The



which can inform these decisions is the importance of having a formally agreed Test Interpretation and Repair document in place before the start of testing]. Another challenge is the ability to find damage when it is small with current non-destructive inspection technology.

Similarly, assessing the integrity of additive manufacturing materials or bonded reinforcements has limitations, so we've advocated the use of alternative sensing technologies such as thermoelastic stress analysis or various thermography techniques such as sonic and lock-in.

Other challenges can present themselves when attempting specific loading conditions, for example, residual strength tests. In these instances, there have been times when we discovered that the desired strain levels at particular structural details could not be achieved, so we've had to make novel modifications to the test rig or test article in order to change the loading conditions.

As with many technical undertakings, full-scale fatigue testing is not immune from cost and schedule

"Ensure that a test log is in place and used, even for insignificant events"

other main task I have worked on has been supporting the larger structural integrity task for the F/A-18A/B, and much of that time has been managing the fatigue testing and analysis of retired center barrel structures.

// DESCRIBE A TYPICAL DAY

An interesting day I had recently was when I organized a demonstration of a field portable supersonic particle deposition [also known as cold spray] unit by RUAG Australia, for applying aluminum alloy coatings on an F/A-18 center barrel. This involved escorting the RUAG staff, assisting them in the lab, taking photos and making notes. Between this, I was also finishing up a conference paper for the International Committee on Aeronautical Fatigue [ICAF] on a proposed fastener hole rework investigation we undertook on behalf of the Royal Canadian Air Force and Canadian industry (L-3 MAS). Additionally, I manage the task funds for the F/A-18 work, and with our end of financial year approaching on June 30, I have also been writing requisitions and chasing up others to ensure our accounting deadlines are met.

// WHAT ARE SOME OF THE CHALLENGES POSED BY YOUR CURRENT JOB?

One of the biggest technical challenges comes from what course of action to take when cracking is detected in the test article, whether to excise and repair the damaged location, or leave it and continue testing while monitoring the damage growth. [One lesson I have learned

considerations. While more data is always good, financial constraints sometimes dictate the quantity of instrumentation, so careful consideration needs to be given to what is essential.

// WHAT IN-HOUSE FACILITIES ARE AT YOUR DISPOSAL?

DST has two major NATA-accredited full-scale structural test laboratories, one currently housing the F/A-18 center barrel fatigue and outer wing static tests [floorplan of approximately 12,000ft^2 (1,100m^2) and 28ft (8.5m) under the gantry crane], and the other housing the Hawk 127 test [floorplan of approximately 13,000ft^2 (1,200m^2) and 56ft (17m) under the gantry crane], making these one of the biggest full-scale testing facilities in the southern hemisphere.

The labs feature meter-thick-concrete strong floors with threaded anchor points rated to 22,500 lbf (100kN) embedded into the floor at regular intervals. Electrical supply is from a 22kVA substation, but with 1,200A for the testing areas. The hydraulic supply for the lab housing the center barrel has a capacity of 1,200 l/min at 21MPa and the compressed air supply has a capacity of 690kPa at around 34,000 l/min. Each lab has its purpose-built test control room overlooking the test floor, and also adjacent workshops and storage areas.

In addition, DST has an adjacent large coupon testing laboratory that holds around 25 standalone uni-axial test machines, which also provides an in-house capability for calibrating the load cells used on the full-scale tests.

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

The length of a 'typical' full-scale fatigue test varies greatly. The F/A-18 center barrel tests I work on average around three months of cycling time before all three bulkheads have failed, with an additional month or two on either side of that building up the test article and rig and installing instrumentation, and then tearing it down in preparation for the quantitative fractography investigations. The shortest center barrel test took around one month, after we deliberately applied artificially high fatigue loads to fail the article quickly so that the crack features could be studied to support an urgent airframe lifing analysis.

The F/A-18 center barrel tests are typically instrumented with conventional foil strain gauges, mainly uni-axial, although there are generally some multi-axial rosettes. Only the strains are recorded from the test article, and these are compared with the strains recorded from the original IFOSTP fatigue life substantiation test to ensure consistent loading. Strains are measured at incremental load steps during strain surveys, or at every load spectrum turning point [maximum and minimum points in a cycle] during fatigue loading. The data is captured by a data acquisition system, and generally ranges from the megabyte to gigabyte scale. On more recent tests, fiber-optic strain sensors in the form of Bragg gratings or distributed systems have also been demonstrated and have been shown to perform well. These systems have used their own standalone data acquisition units.

The strain information is presented visually by generating plots for each strain gauge reading along with comparative plots from other center barrel tests and the reference IFOSTP test. The parameters describing the strain plots [e.g. slope and intercept] are also presented in a tabular format. In addition, we generate defect reports and more detailed quantitative fractography reports analyzing the cracking, which are also presented to the client. All of this information supporting fleet management decisions is collated and analyzed in an overall test report.

// WHAT IS YOUR LARGEST FULL-SCALE RIG?

The current Hawk rig is the biggest test rig right now. It comprises four platform storys at a height of approximately 12m and accommodates an entire

"The F/A-18 center barrel tests average around three months of cycling time before all three bulkheads have failed"

Hawk 127 airframe. It has 84 hydraulic actuators acting on the airframe to apply maneuver loads, including the air-to-air refueling probe, while cockpit and fuel tank pressurization loads are applied via six pneumatic channels. There are approximately 1,200 strain gauges on this test article.

2 // DST Group is undertaking fatigue tests on the Hawk Mk 127 Lead-In Fighter to establish the airframe's endurance limits

// ANY EXCITING PROJECTS IN THE PIPELINE?

DST is currently conducting innovative research activities into a demonstrator program aimed at very high speed and accurate fatigue testing for a full-scale helicopter airframe, and therefore a more viable option for OEMs and structural integrity managers. Although some full-scale helicopter airframe fatigue tests have been conducted in the past, the advances in computational 'horsepower' and multi-axial control systems have provided the means to explore more accurate and advanced loading mechanisms for reasonable cost and realistic timeframes. DST's HAFT-TD [Helicopter Advanced Fatigue Test – Technology Demonstrator] project aims to demonstrate a cycling rate and level of spectrum truncation sufficient to complete the equivalent of two lifetimes of high-fidelity variable amplitude loading in 2.5 years or less, something that has not been possible to date.

The first round of spectrum verification coupon tests have already been completed and a large-scale crucifix-form testbed has been constructed for the test system development trials. Known as the 6 Degree of Freedom Dynamic Demonstrator (6DDD), it has been designed to increase the cyclic rate at which helicopter applied forces can be generated

3 // Geoff Swanton examining one of the supersonic particle deposition coatings on the current F/A-18 center barrel test article

experimentally in up to 6DOF while providing an acceptable accuracy on control parameters such as load, displacement or strain.

Meanwhile, as the US Army is currently formulating more stringent rotorcraft structural fatigue certification requirements, there is a real possibility that the next generation of military helicopters will also be required to undergo full-scale testing. Therefore, the technologies being matured through the HAFT-TD program would support the implementation of such requirements.

// HOW HAVE YOU HELPED TO IMPROVE TESTING EFFICIENCY?

One technique I used to expedite final testing was to tear down subject hotspot locations after limited cycling and then use the DST-developed lead crack framework to extrapolate the detected small cracks to their critical size, providing an equivalent test life for lifing purposes. A similar process was used in IFOSTP. Another technique for improving schedule efficiencies is to ensure that an adequately truncated test load spectrum is applied to the test article [i.e. small magnitude, non-damaging cycles are removed]. As part of the pre-test activities for our full-scale and component-level variable amplitude fatigue test programs, we conduct analytical and coupon studies to determine an appropriate truncation level for each test spectrum.

Yet another technique that DST has refined is 'marker band' technology, whereby a different set of loads [e.g. constant amplitude] is applied at intermittent stages throughout the test program. These marker band loads are designed to leave a distinct pattern on the crack's surface, and while they do not impact the testing speed or significantly affect the resulting fatigue lives, they certainly aid the fractographer and therefore result in a quicker turnaround of crack growth data for test interpretation. The importance of this has been demonstrated in the F-35 full-scale fatigue test program, as DST-developed marker bands have been applied to the third life-of-type cycling in two of the test articles as well as horizontal tail tests.

// DOES ANY PARTICULAR TEST OR EXPERIENCE STICK IN THE MIND?

I was actually posted interstate, working as an embedded DST liaison officer at the RAAF's F-111 base at the time that DST was conducting a full-scale fatigue test of an F-111C wing. This test was aimed at substantiating the life of the wing under RAAF usage, as well as establishing the durability of a shape-optimized structural modification at the wing root. There was an unexpected failure in the lower wing skin, from a poorly manufactured fastener hole, at a location not inspected in the fleet. The impact of the failure was immediate as the fleet was temporarily grounded while a way forward was developed. The outcomes of this single test result led to build-quality surveys being conducted on fleet wings, the introduction of an automated non-destructive inspection process, and ultimately, the retrieval of later-production 'F-model' wings from retired USAF aircraft in the Arizona 'boneyard' to replace the RAAF's 'C-model' wings. Seeing firsthand the flow-on effects of this test failure from the operator's and maintainer's point of view was an experience that test engineers would not normally have, as well as emphasizing the role that DST plays in contributing to the safe operation of defense aviation assets.

// WHAT IS YOUR FAVORITE ANECDOTE FOR VISITORS?

The center barrels tend to groan and creak quite loudly under the cyclic loading, so I normally quip to aircrew visitors that this is what their aircraft would sound like if it wasn't for the din of the jet engines! This particular test program was also instrumental in the government's decision to reduce the number of center barrel replacements on the RAAF fleet, which resulted in a saving of around A$400m (US$300m), so that's always worth mentioning too.

// HOW DO YOU SEE FATIGUE TESTING CHANGING IN THE FUTURE?

DST has recently proposed a road map toward the concept of the virtual fatigue test, by the name of Blueprint TITANS (Transglobal Integrated Tests & Analyses Network for Structures), and a paper on this was presented at the International Congress on Aeronautical Fatigue and Structural Integrity (ICAF 2017) in Nagoya, Japan, in June.

While Blueprint TITANS proposes a way forward toward the ideals of a virtual fatigue test, the reality is that factors such as build quality or rogue flaws may never completely negate the requirement to conduct a physical fatigue test. However, by working toward this concept, there might come the time when full-scale tests may not need to run their full course, therefore still representing considerable savings in cost and schedule. \\

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// ROB COPPINGER

The cloud, remote data storage, greater automation and advanced sensors are part of the new concept for data acquisition at the German Aerospace Center's rocket engine test stands

Rocket sc

Whether it is an aerodynamic body, a turbofan or a rocket engine, measuring test results needs a complex arrangement of sensors to acquire that all-important data. The German Aerospace Center's (DLR) Institute of Space Propulsion has been working on upgrading its data acquisition equipment at its rocket engine test site in Lampoldshausen in southern Germany.

"Our goal is a concept based on the Industry 4.0 requirements," DLR researcher Wolfgang Stuchlik tells *Aerospace Testing International*. The Industry 4.0 (see sidebar, page 72) network needs intelligent sensors, control elements and communication channels via a local area network or the internet. The quantity of data collected is vast. The current test bench data acquisition system that exists will archive five million samples per second. A sample is a string of analog data from the sensor, which would be converted to a digital format for computer analysis.

The acquisition system has both analog and digital data feeds from the sensors.

"For the analog inputs, we have an archiving rate from two up to 500 points per second," explains Stuchlik. "For all channels, we have a constant scanning rate of 1,000 samples per second." This rate can also be described as a bandwidth of 20kHz.

The signals sent to control the test bench and engine, and the returning sensor data, will arrive within 1ms of being sent. There is a total of 1,600 analog and digital channels for data being sent to open and close the rocket engine test bench's valves and to receive signals from pressure, temperature, vibration, flow and force sensors.

Of the 1,600 channels, 500 are command channels for automatic valves operating at 4-20mA. A further 1,000 are digital feedback channels for the valves. Then there are 16 analog output channels for control valves, also operating at 4-20mA.

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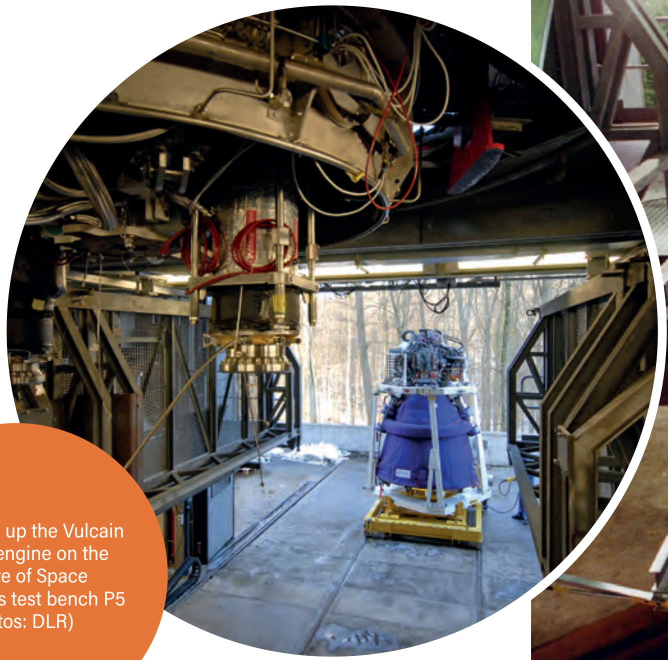


1

1 // Setting up the Vulcain 2 rocket engine on the Institute of Space Propulsion's test bench P5 (Photos: DLR)

2

2 // Firing the Vulcain 2 rocket engine on the P5 test bench in Lampoldshausen

Stuchlik has been working on improving data acquisition for what the institute calls its 'test benches'. "The next step will be to find solutions regarding Industry 4.0, for example intelligent sensors and amplifiers, data exchange by data clouds, and providing data from tests for customers with data security," says Stuchlik, referring to a recommendation in his 2016 technical paper, *Evolution of real-time computer systems for test benches.*

Otherwise known as P5, P4.1 and P4.2, these three benches were the focus of Stuchlik's work, although DLR has other test stands. The benches, P5, P4.1 and P4.2, are used to test and qualify the rocket engines Vulcain 2, Vinci and Aestus. Vulcain 2 powers the first stage of Airbus Safran Launchers' (ASL) Ariane 5 rocket and Aestus propels the launcher's upper stage. The Vinci engine is also designed for an upper stage, but will actually contribute to propulsion advances for ASL's in-development Ariane 6 launch vehicle. In May, ASL announced that it would be changing its name to ArianeGroup from the start of the Paris Air Show in mid-June.

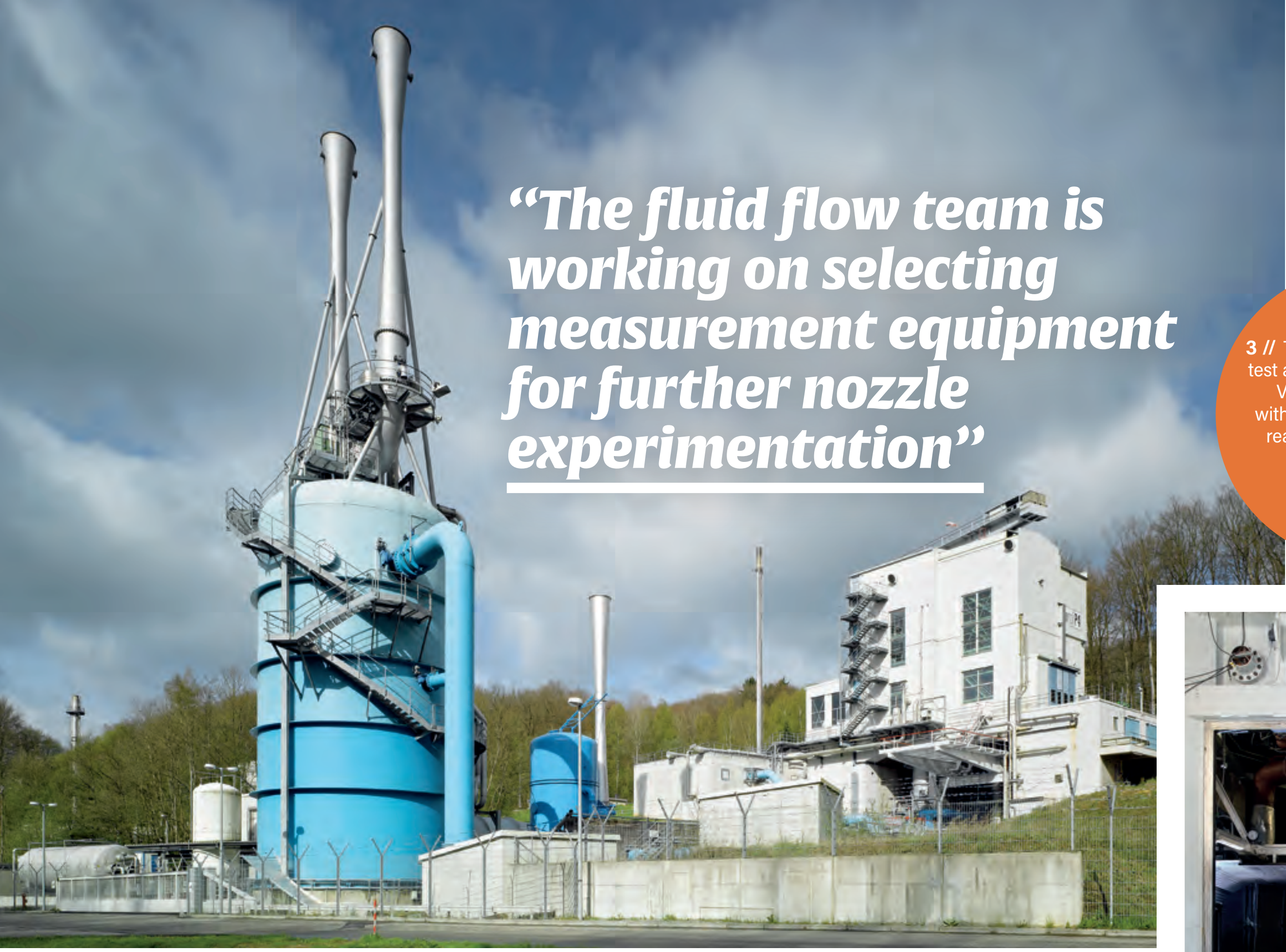
WIRED OR WIRELESS?

One technology that will not be used for Stuchlik's bench improvement, but would be synonymous with Industry 4.0 in the eyes of many, is wireless data transmission. "Wireless signal transmission is not an option, because the data from the tests is not available for all persons and companies. The data and details are for the customer only," says Stuchlik, citing security as the reason for only using wired data transmission.

He adds, "The alternative to long cables is the installation of the computer front ends – the real-time system, the data archiving system, the command and control system, the amplifier and the digital interface on the test bench – about 30m from the test cell in a specially protected room." The cable between this protected room and the server where the data is stored could be an optical fiber.

The current 1,600 channels are not enough and Stuchlik wants more high- and low-frequency data channels with a high sample rate. He also wants to be able to halt incoming data when the load on the computers' central processing unit becomes to great. He describes it as "on demand" subsystem connect and disconnect.

Stuchlik is under no illusion that this is a task that can be completed relatively quickly. He expects the technical specification will take two years alone, with all the internal consultation that has to be carried out. Calling for industry bids and selecting a supplier will take another year, he says. And this is only the first stage. "After the critical design review, we start the realization of the system, the



"The fluid flow team is working on selecting measurement equipment for further nozzle experimentation"

3 // The P4.1 test facility can test all configurations of the Vinci engine (with or without nozzle). Maximum reachable running time of the engine is approximately 770 seconds

4 // The upper stage Vinci engine is in development. A version may be used for the forthcoming Ariane 6 rocket

hardware and the software," he explains. "After factory acceptance we have to install it on the test bench. Finally, after the installation, the system needs to be accepted."

Data acquisition improvement has been included in a number of DLR projects. The DLR's *Institute of Space Propulsion Status Report 2011-2017* was published in February this year and sets out the various projects the rocket testing site has undertaken to overhaul its data acquisition. Rocket testing installations are capital intensive and will not undergo major refurbishment and technology improvement without reinvestment approved at the highest level of management.

Two projects described in the report have improved methods of data acquisition as one of their goals. They are Antriebstechnologien und Komponenten für Trägersysteme (ATEK), which means drive technologies and components for carrier systems, and Flexible Structures. Flexible Structures ended last year after seven years of work, while ATEK, which started in 2015, will continue until 2018. Flexible Structures and ATEK's respective primary goals are to examine rocket nozzle deformation and develop reusable engine components.

The results from Flexible Structures, a €60,000 (US$67,300) European Space Agency-financed project, are being presented at the Joint Propulsion Conference in Atlanta, Georgia, USA, in July, according to its Lampoldshausen supervisor Joerg Riccius.

Based on the results of the work that has been done for the project, Riccius explains that the Lampoldshausen fluid flow team is to start work in mid-July on selecting suitable measurement equipment for further nozzle experimentation. One of Flexible Structures' goals was to put forward recommendations for the test setup and data acquisition rates for the nozzle experiments. The recommendations have not yet been finalized.

100,000
Data samples acquired per second

1,600
Analog and digital data channels

IN CAMERA

ATEK deployed a camera with a large memory as its improved data acquisition technology. ATEK is primarily about the fundamental analysis of hybrid rocket combustion, especially for liquefying paraffin based fuels.

The experiments were carried out with a basic hybrid rocket combustion chamber with windows for data collection by cameras. The researchers analyze the boundary layer combustion of the hybrid rocket using high-speed video imaging and Schlieren videos. Schlieren imaging shows the effect of a medium – in this case the boundary layer – on the passage of light, manifesting itself in

"The increased memory enables higher frame rates"

dark streaks across a picture where the light was blocked by the medium.

Led by the DLR Institute of Hypersonics in Cologne, Mario Kobald oversaw the ATEK-related work at Lampoldshausen. "We used two high-speed cameras," notes Kobald. "A Photron Fastcam 1024 PCI was used for the initial tests. Later an improved new model, the Photron SA1.1, was bought and used, mainly with higher memory for higher frame rates and longer acquisition times."

The Photron Fastcam uses a light-sensitive 10bit analog-to-digital converter sensor with large 17µm square pixels. The camera operates from 60-1,000fps at full 1024x1024 pixel resolution, and at reduced resolution it has a maximum frame rate of 109,500fps. "The improvements only concern the internal camera storage, which was increased. This enables the acquisition of larger amounts of test data," explains Kobald. "The increased memory enables higher frame rates, which improves the quality and resolution of both POD [proper orthogonal decomposition] and ICA [independent component analysis] techniques."

1MS
Time (one millisecond) needed for a signal to arrive

109,500FPS
Maximum frame rate

POD produces the raw data from, in this case, the hybrid rocket combustion boundary layer that is being imaged by the camera, but this is not the video data. The ICA technique will find relationships between the POD data points that will describe and resemble the physical process, the boundary layer, being imaged.

"These techniques are novel and unique in the working field of hybrid rocket propulsion, especially with these high frame rates and details – 10,000fps and a maximum resolution of 1024x1024 pixels," adds Kobald.

A great deal of work is yet to be done by DLR researchers on improving their data acquisition; they are still in the process of finding suppliers for the Industry 4.0 test bench.

However, what is not in doubt is that advances in modern computers, LAN capacity, internet protocols and sensors will realize test benches with faster acquisition, greater integrity and ultimately better analyses. \\

INDUSTRY 4.0

The DLR's Project Management Agency definition of Industry 4.0 includes the integration of product development within intelligent networks with models in a virtual world, where every aspect can be simulated for evaluation. It also defines it as the integration of product development, production, logistics and customers within these intelligent networks. Materials and precursor products, production machines and consumer products will connect with the digital network. Production processes, logistics, sales, service and entire business models can be simulated on a computer to evaluate and assess their viability. This requires intelligent sensors, control elements and safe communication channels via the internet.

5 // Test bench P3 (left) and high altitude simulation test bench P4 (right)

5

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20

As Mitsubishi Aircraft tests the first new Japanese commercial aircraft for 50 years, it has had to delay the project for a fifth time and surrender oversight to its parent company

1 // MRJ FTA-3 (right) joined FTA-1 (left), FTA-2 (center) and FTA-4 at Mitsubishi's Moses Lake flight test center in April 2017

20 foresight?

Planned design changes to the Mitsubishi Regional Jet (MRJ) that have driven a further delay to the Japanese program should be completed in coming months. "We intend to finalize the design revisions and design specifications in the fall of 2017," says Mitsubishi Aircraft Corporation (MitAC).

If it holds, this fifth rescheduling means that the 88-passenger twinjet – the country's first new commercial aircraft since the 1960s' NAMC YS-11 twin-turboprop airliner – will enter service in 2020, almost seven years later than first planned.

The need for changes became evident in late 2016 when airworthiness authorities concluded that the design did not comply with all the latest certification requirements. With four of five planned flight test aircraft (FTA) already flying, MitAC estimates that an additional 18 to 24 months will be needed to develop, introduce and receive approval for the necessary design modifications (which include moving some components and rerouting electric-cable harnesses).

It is not only the design that is changing: parent company Mitsubishi Heavy Industries (MHI) stepped in last November to take charge, with newly appointed MitAC president Hisakazu Mizutani confident about its future. "Development projects come with a range of difficulties," says Mizutani. "But when everyone involved in the MRJ project pulls together, I am sure we will make a success of it."

By late April, at test centers in Japan and the USA, the four FTAs had logged more than 650 flight hours, which

2

> **“Mitsubishi could hardly have expected to reschedule the program five times”**

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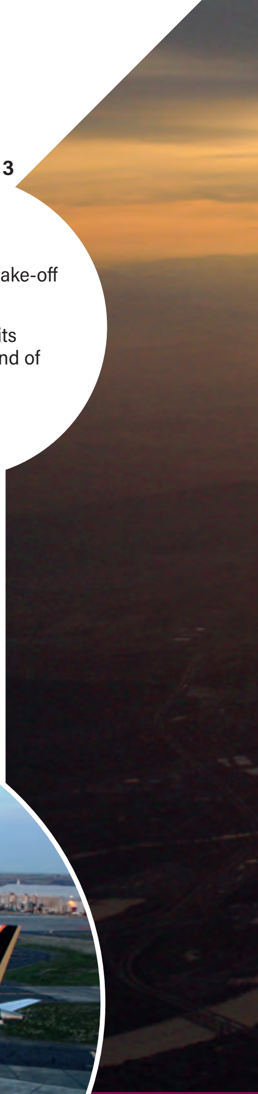


2 // FTA-2 before take-off at Nagoya Airport

3 // FTA-3 during its ferry flight at the end of March 2017

4

4 // FTA-3 was the fourth MRJ90 flight test aircraft to transfer to Moses Lake, Washington, USA

include at least 70 hours accrued during transpacific ferry flights. (Such time is not wasted, since engineers monitor test equipment to gather inflight data.)

Of course, in suffering delays while introducing its 21st century airliner, the Japanese manufacturer is keeping company with more established names. Airbus, Bombardier and Boeing all underwent schedule trauma with their respective A380 double-deck quadjet, single-aisle C Series aircraft, and 787 twin-aisle twinjet.

Moreover, MitAC will hope to avoid the operational hiccups that also afflicted those designs after entry into service. It has “commitments” covering more than 420 aircraft, of which more than half are firm orders.

However brave its decision to re-enter the market, having built only a couple of business-aircraft models in the past 50 years, Mitsubishi can hardly have expected to reschedule the program five times – and then cede project management to its illustrious ‘heavy’ owner.

AMERICAN VALUES

MitAC’s lack of recent certification experience and prospectively better weather contributed to the decision to engage a US partner and a US location for MRJ flight testing. In 2015 the manufacturer opened the Seattle Engineering Center with development specialist Aerospace Testing Engineering & Certification (AeroTEC).

5
Program delays

5
MRJ flight test aircraft

2
Possible additional flight test aircraft

When taking office in April, Mizutani was looking forward to an intensified flight test program: “Having completed the ferry flight of FTA-3 on March 31 [preceded by FTA-1, -4 and -2, in that order], we have a four-aircraft test capability in the USA. We will now move into an accelerated, full-fledged program of test flights to obtain type certification.”

Unfortunately, the manufacturer’s deep reluctance to share test details, even less divulge results, will frustrate aerospace observers. While MitAC does answer many questions in detail, the most interesting points regarding flight testing often elicit answers of the “We don’t disclose figures”, “There is steady progress with multiple flight tests on a daily basis”, and “We hope to make an announcement when we are ready” variety.

Three engineering bases are involved in MRJ testing, including two in the USA: Moses Lake Flight Test Center and Seattle Engineering Center (both in the state of Washington) and MitAC headquarters (Nagoya, Japan).

The need for additional design work and flight test capacity has implications for MitAC’s original production plans, since early customer airframes might be pressed into such service. “We will use the current test aircraft

MITSUBISHI REGIONAL JET FIRST- AND FERRY-FLIGHT LOG

Before the four MRJ flight test aircraft were ferried from the Mitsubishi factory at Nagoya in Japan to Moses Lake in the USA, modifications and systems upgrades that had been introduced early last year on FTA-1 after initial flight trials were incorporated on the other three test machines. The first aircraft flew a more northerly, summer route through Russia, while FTA-2, -3 and -4 each made a longer winter trek by way of Guam, the Marshall and Hawaiian Island groups and California. The FTAs have been fitted with heavy or light levels of flight test equipment according to their planned roles. For example, the fourth and fifth aircraft sport cabins configured with passenger seats, galleys and toilets.

Mitsubishi Regional Jet flight test fleet*

Aircraft	MSN*/registration	First flight	Ferry flight[†]	Distance[‡]	Flight time
FTA-1	10001/JA21MJ	Nov 11, 2015	Sep 28, 2016	4,480NM (8,300km)	13h 08min
FTA-2	10002/JA22MJ	May 31, 2016	Dec 19, 2016	8,560NM (14,000km)	20h 10min
FTA-3	10003/JA23MJ	Nov 22, 2016	Mar 31, 2017	8,560NM (14,000km)	19h 48min
FTA-4	10004/JA24MJ	Sep 25, 2016	Nov 18, 2016	8,560NM (14,000km)	18h 40min

*Sources: Mitsubishi Aircraft and aircraft production website www.abcdlist.nl/mrj/mrjf.html. *Manufacturer's serial number; [†]US arrival; [‡]FTA-1 was ferried from Nagoya via New Chitose Airport (Japan), Yelizovo Airport (Kamchatka, Russia) and Anchorage International Airport (Alaska). FTA-2, -3, and -4 were ferried by a longer route via Guam International Airport, Majuro International Airport (Marshall Islands), Honolulu International Airport and San Jose International Airport (California)*

just as we have up to now, [to obtain approval] for components not affected by the design changes," says a Mitsubishi spokesperson. "We are taking a close look at our flight test program, reflecting the recent change and how much time will be needed, or which aircraft are to be used – including how many additional FTAs are required for type certification." Airworthiness approval to meet the latest requirements could require up to 500 flight hours of additional testing and one or two extra aircraft.

In April FTA-5 – always intended for Japanese testing only – was ground tested at MitAC's MRJ Final Assembly Hangar, which came into operation nine months ago. The company would say only that FTA-5's target flight date remained "under consideration", as did that for completion of the following MRJ (manufacturer's serial number [MSN] 10006), which might become FTA-6).

That machine had been earmarked as the first for delivery to launch operator All Nippon Airways: "We are in deliberations on manufacturing that take development-schedule revision into consideration," says the company. Until schedules are revised, it is not clear how many aircraft will have been built by the end of 2017, since MitAC might suspend production to introduce design changes during final assembly, thus avoiding retrospective modification.

In late April MitAC was considering whether to take the MRJ to the Paris Airshow in June, which would depend "on progress in handling technical issues according to the revised schedule. Nothing has been finalized."

FTA-3's March 31 arrival at Moses Lake, albeit three months later than planned, came "after comprehensive consideration, including about weather and aircraft conditions," says MitAC. Indeed, it has acknowledged

5

6

to *Aerospace Testing International* that the ferry flight had been interrupted.

"Right after FTA-3 took off from Honolulu on March 16, an anomaly was detected in one of the three hydraulic systems. The aircraft returned safely to Honolulu, where we investigated and exchanged hydraulic parts [made by MHI]. These issues were specific to FTA-3, with no effects on other aircraft." With FTA-3 available, "Flight tests continued daily at Moses Lake to accelerate development."

EXPERTISE SOUGHT

In anticipation of accelerated development and to address certification requirements, the MitAC/AeroTEC partnership has been recruiting engineers, with particular emphasis on overseas nationals. MitAC says, "We are increasing the workforce of global experts with aerospace experience and expertise. There are 2,200 employees in Japan and the USA – including non-engineers – 15% of whom are not Japanese."

US ground-testing continued in February, with FTA-4 – which arrived at Moses Lake in mid-November – undergoing cold- and hot-soak "extreme environment" tests in the McKinley Climatic Laboratory at Eglin Air Force Base in Florida. This was to "ensure operational capability of the airframe and system components" by simulating extreme temperatures between -40°C/F and 50°C (122°F).

"These tests confirmed that the engines, auxiliary power units and other key components operated as planned, even in harsh environments," says the manufacturer. On its way to Eglin, FTA-4 visited Chicago's Rockford Airport to gather natural-icing data "to analyze airframe ice accretion and ice-protection system performance".

Other "out stations" scheduled for use in MRJ testing include Gunnison-Crested Butte Regional Airport in Colorado (for high-altitude take-off and landing performance) and New Mexico's Roswell International Air Center ("special runway test").

Apart from being the first to fly, FTA-1 has been assigned to flight envelope expansion and systems testing, while the second machine conducts functional and performance tests.

FTA-3 is earmarked for avionics trials and to establish MRJ flight characteristics, with FTA-4 sporting a cabin interior and being used for noise and anti-ice tests. Finally, FTA-5, also with a passenger configuration and which by May had not yet flown, is to test the autopilot.

Meanwhile, MRJ manufacture is continuing with completion of the fuselage sections of MSN 10006. It has entered final assembly to join FTA-5, which by August 2016 was undergoing engineering and function tests.

MitAC noted after last year's Farnborough Air Show in July that the first two aircraft had completed more than 50 flights. FTA-1 had expanded the flight envelope to the Mach 0.78 and 39,000ft (11,900m) maximum speed and altitude targets and successfully completed flutter testing. FTA-2 testing had included "flying with one engine inoperative, activation of emergency power units, and stall tests".

Ahead of the first planned ferry flight to the USA in August, MitAC was making two flight tests a day and preparing FTA-3 and -4 for engine tests. Later, when asked about other completed trials beyond reported

5 // FTA-4 pictured during icing trials at Rockford, Illinois

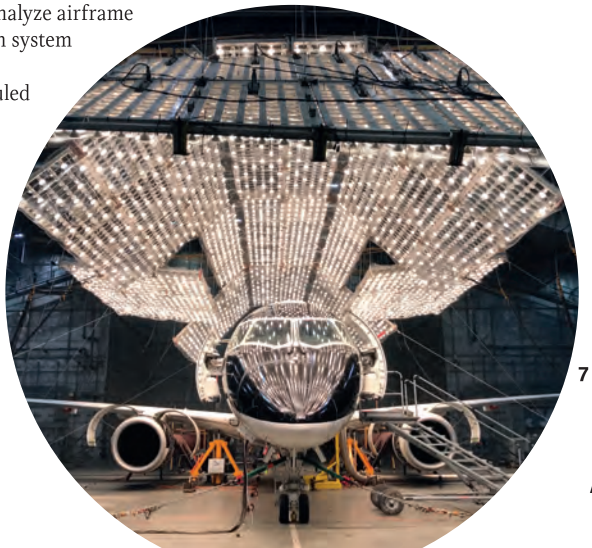
6 // Cold soak test underway at the McKinley Climatic Laboratory at Eglin Air Force Base, Florida

7 // During the hot soak test, the MRJ had to withstand temperatures as high as 50°C

MITSUBISHI MRJ FLIGHT TEST FLEET DUTIES

Aircraft	Flight test function
FTA-1	Flight envelope expansion, systems tests
FTA-2	Performance assessment and function tests
FTA-3	Detailed flight characteristics measurement, avionics tests
FTA-4	System and interior test, community noise tests, icing tests
FTA-5	Autopilot tests

Source: Mitsubishi Aircraft Corporation



7

"FTA-2 began test flying in early January"

environment performance testing, the ever-cautious manufacturer would say only: "We will update you with any progress after the tests."

This reticence did not lessen when the first two attempts to ferry FTA-1 across the Pacific on August 27 and 28 were aborted. Anomalies arose with signals from cabin air pressurization and temperature management system sensors.

In September, MitAC was resolved "to achieve better integrated aircraft". With no recent airliner production experience, the challenge was "to enhance the capability of manufacturing parts by structuring product procurement and logistics. We are considering a parts-supply center that enables just-in-time delivery."

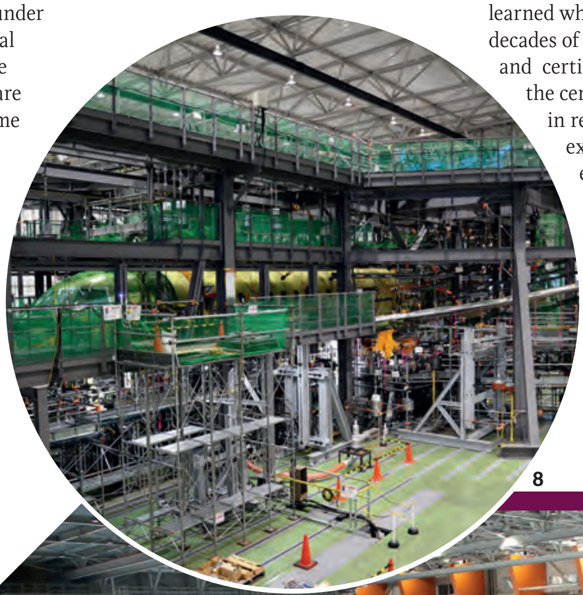
Nevertheless, the troubled program remained under scrutiny, with MitAC forced in October to deny local Japanese reports of a further MRJ delivery-schedule delay: "At present, no decision has been made. We are moving forward with development … as we overcome issues one by one," said the manufacturer. But it promised to report any such decision "promptly".

Some welcome news came on September 25, when FTA-4 became the third MRJ to fly, soon followed (after a month's holdup) by FTA-1's arrival at Moses Lake on September 28. The aircraft had flown from Nagoya via Japan's New Chitose Airport, Yelizovo (in Petropavlovsk-Kamchatsky, Russia) and Anchorage International Airport, Alaska. The 13-hour flight time was comfortably quicker than those for the three subsequent FTAs, which were ferried by a southerly route via Honolulu.

FTA-1 began US testing when its flight envelope and systems functionality were confirmed in a 3.5-hour flight on October 17. Two weeks later, on November 1, MitAC completed two years of strength tests with the MRJ static-test aircraft. "The maximum load calculated from simulation of all flight conditions was applied to all of the test aircraft.

"These tests confirmed that the airframe had no deformation that might inhibit flight safety, and that it could withstand 1.5 times the maximum load for the specified time." MitAC says that the work confirmed the MRJ structure is strong enough for type certification. "All technical data necessary for certification was also successfully acquired."

Meanwhile, fatigue testing that began in mid-August 2016 is still going on. "We are gathering design data from repeated application of weight stress, amounting to 240,000 stress cycles [or three times a service life of 80,000 flights]," says MitAC.



8 // MRJ wing 'up-bending' test at maximum load

9 // Mitsubishi's Final Assembly Hangar, located at its headquarters in Nagoya

50
Years since Japan developed a commercial airliner

240,000
Stress cycles applied to MRJ 'iron bird' fatigue-test specimen

Further encouragement for MitAC followed on November 18 when FTA-4 arrived at Moses Lake via Guam, Majuro (Marshall Islands), Honolulu and San Jose (California). Next, FTA-3 flew for the first time on November 22 with a two-hour flight, as FTA-4 prepared to begin its US flight test campaign three days later.

MANAGEMENT TAKEOVER

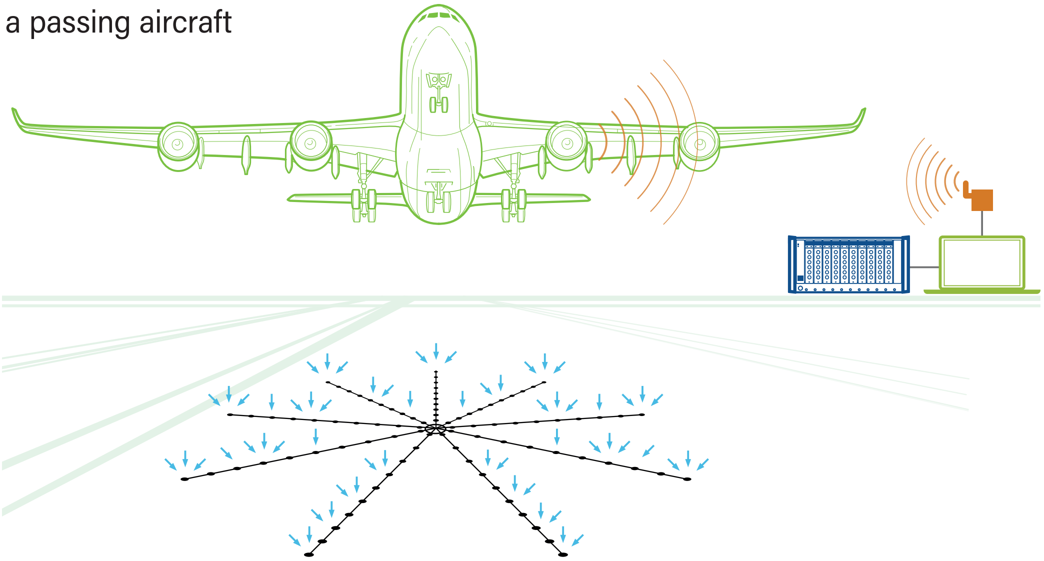
Then, on November 30, MHI revealed it had assumed program management, with the establishment of the MRJ Business Promotion Committee. Whatever the encouragement generated by the winter flurry in US flight-testing, the committee's first response has been to delay the program for a fifth time as it mulls design changes and a possible requirement for two additional FTAs.

In late May, MRJ executive chief engineer and MitAC senior executive vice-president Nobuo Kishi concluded: "What we learned while developing the MRJ is that even with decades of expertise in aviation engineering, testing and certification, we underestimated how much the certification of commercial aircraft has evolved in recent years. We have learned from the experience and remain more determined than ever to establish a new benchmark by delivering the MRJ."

Meanwhile, as the manufacturer finalizes design revisions and specifications later this year, it will have been happy on May 31 to pass another milestone: formal US Federal Aviation Administration type certification of the MRJ's Pratt & Whitney PW1200G geared-turbofan engine. \\

FLYOVER BEAMFORMING

Acoustic testing techniques are used to localize and quantify noise sources on a passing aircraft



Beamforming is based on simultaneous recording with all microphones of an array deployed on a rigid surface on the ground. However, because there is no external trigger for data synchronization, very accurate aircraft position and orientation data must also be available (typically recorded in the aircraft). The microphone data must be synchronized with the position and orientation data sets. This synchronization is typically achieved by including GPS timestamps in both data sets.

Brüel & Kjaer has two flyover beamforming systems based on the above principles. Both systems have been constructed with a specific emphasis on quick and easy deployment, for example, on a runway.

The first system is a basic setup of 108 microphones integrated in a star-shaped aluminum grid with nine identical radial arms and a total diameter of 12m. Microphone cabling is integrated into the grid, and two six-channel cables connect the 12 microphones of each arm to a LAN-XI front end. That basic system covers a frequency range of 700Hz to 5kHz.

The second system adds six microphones to each arm in order to extend the frequency range down to 300Hz. The additional microphone extensions increase the diameter to 29m. The extended system also includes the necessary LAN-XI channels. The microphone spacing for each of the nine line-array extensions is controlled using microphone holders attached to a steel wire.

To know the exact 3D coordinates of all microphones, the vertical coordinates need to be measured. This can be done for each microphone using an optional rotating laser, or provided the surface has a simple piecewise planar structure, measuring a few slopes of the rigid surface upon which the array is deployed is quicker. The horizontal coordinates are controlled by the aluminum frame and the steel wires.

Beamforming processing is performed using the Flyover Moving Source Beamforming option for Brüel & Kjaer's acoustic beamforming software. First, flight track (position and orientation versus GPS time) data must be imported. A mapping plane is then typically chosen near the underside of the aircraft, and a mesh of mapping points is defined. For each mesh point, a time-domain tracking delay-and-sum (DAS) beamforming is performed, followed by averaging of FFT spectra for each one of a set of position intervals of the aircraft. Once a DAS map is available, deconvolution processing can be performed in the frequency domain to reduce sidelobes, enhance resolution and get absolute scaling of the source maps. Two different scalings are available: contribution to the sound pressure at the array center; and sound intensity, assuming omnidirectional radiation (monopole sources).

The array design and the processing has been optimized to obtain the best possible resolution and sidelobe suppression, considering the air turbulence that will always be present. Turbulence will distort the wave fronts randomly and thereby degrade the coherence between widely spaced microphones. The speed with which coherence degrades as a function of separation is proportional with frequency, so the coherence diameter is roughly inverse with frequency.

The system has been used to measure a business jet in a cooperative research project with Japan Aerospace Exploration Agency (JAXA), from which some very good results have been published at two international conferences. And recently, a successful application of the system was used to determine source strengths and directivities on a fighter jet, the results of which have been published in cooperation with Airbus Defence and Space. \\

// The Brüel & Kjær basic Flyover Beamforming system features 108 microphones in an array

AT-SOURCE DATA RECORDING

Distributed data acquisition systems enable engineers to acquire large amounts of data from physical measurements at the source while monitoring and analyzing the data over a network or via cloud services

1

There is no shortage of testing requirements in the aerospace field. Temperatures, pressures, voltages, currents and timing signals are physical phenomena that need to be measured in the design, verification and validation of a project. One of the big challenges of this type of testing is to have the acquisition hardware close enough to the physical measurements while being able to monitor, review and analyze large volumes of data over a network. Another challenge is to ensure the recording of critical data regardless of network status or cloud connectivity. AstroNova's distributed data acquisition systems provide the tools to meet these challenges.

Distributed data acquisition systems must provide for high-quality measurements, a wide variety of measurement types, and high acquisition rates without creating an undue burden on local area networks. Using modular hardware with isolated signal conditioning and analog-to-digital conversion that will work with most sensor types will improve measurement quality and reduce costs. Real-time digital signal processing (with the appropriate anti-aliasing measures in place) and ample local storage can reduce the amount of data sent over the network. AstroNova has fully integrated these various components into the Daxus family of data acquisition systems.

Data can be transferred across the network in real time (streaming) and post-acquisition. Local storage ensures critical data is preserved, even if the network or cloud becomes unavailable. While it is often feasible to stream static signals such as temperatures, real-time streaming of dynamic strain or pressures is subject to the bandwidth and reliability limitations of the network. Where the engineer needs to monitor dynamic or waveform data in real time, local analytics can be used to reduce the data while preserving the amplitude and spectral content of the signal regardless of the network transfer rate.

For post-acquisition transfer, the software should provide an intuitive graphical user interface and advanced visualization methods that allow selecting all or any portion of the recorded information to be transferred. Verification and validation testing, for example, usually require the entire test data file to be archived. Others such as research and development testing or troubleshooting problems, which may only require a portion of data around an area of interest, are also served well by this method.

A typical scenario is an aerospace test cell where the test article may be in a closed room or chamber. The distributed data acquisition system acquires data from sensors and signals on the test article and is connected to the network via Ethernet or wireless. Real-time test data can be monitored by local personnel as well as transferred via network or cloud services to off-site engineers. The review and analysis software provides dashboard metrics in real time or a full waveform analysis as required. Local storage gives the capacity for the large amounts of data required for a full test cycle. The system takes the data transfer burden off the network, providing only data necessary to make decisions as the test progresses. Multiple test cells can also be monitored simultaneously due to the distributed nature of the system.

AstroNova's Daxus family of distributed data acquisition systems provides everything needed to condition, acquire, process, store and transfer data efficiently through a network or cloud services. \\

1 // The AstroNova Daxus offers data acquisition for up to 32 channels, 200k samples/second, wireless connectivity, a 500GB internal hard drive (SSD optional) and real-time data capture via Android phone or tablet app

2 // The Daxus units are a mobile, stackable data acquisition system

2

A FLYING SIL

An airborne system integration laboratory can provide a critical resource for test flighting and can shorten development time

The first flight is a defining moment for every project. For the first time, a project will face the full power of an unforgiving reality and be in the direct line of harsh natural forces. The experience of real-world dynamics forms critical knowledge for every project and it is good practice to try to make the first flight happen as early as possible in the project development and design cycle.

However, it is not recommended to install the latest and most novel ideas directly into the target platform; this is where a flying testbed is needed. The flying testbed is an aircraft that, in a safe and controlled manner, enables the system integration laboratory (SIL) to be taken into the air.

The Swedish Defence Materiel Administration's Flight Test Centre (FMV FTC) has a lot of experience in operating a variety of fixed- and rotary-wing aircraft as flying testbeds. FMV FTC has the knowledge, the resources and the mandate to install novel systems into real aircraft to take these high-flying ideas on their first flight and beyond.

One of the workhorses at FMV FTC is the Sabreliner, which since the early 1990s has been used as a research aircraft and flying testbed for advanced radar research, electronic warfare and electro-optical (EO) sensor trials.

The Swedish Defence Research Agency (FOI) has used this aircraft for flight trials with two airborne demonstrator systems: Carabas (foliage and camouflage penetration radar) and LORA (low frequency radar). The flight trials have supported research regarding synthetic aperture radar (SAR) and ground moving target indication (GMTI) applications. Other activities in the Sabreliner have included test and evaluation of radar warning and countermeasure systems for the Gripen fighter and trials with optical sensor systems such as IR-spectrometers.

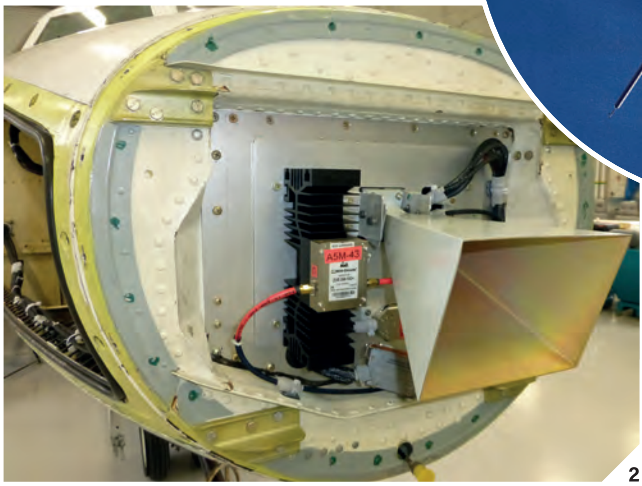
The FMV FTC-operated Sabreliner has several hard point attachment locations, including centerline and wingtip positions. For installation of optical sensor heads and turrets, the aircraft also has a through-mounting hole in the belly centerline. The cabin can house several racks of flight test instrumentation as well as operator consoles for flight test engineers and technical subject matter experts.

The Sabreliner is not just well suited for installation of prototype systems, it is also an excellent platform for electronic warfare test, training and exercise applications. On behalf of the Swedish Armed Forces we have installed the Astor III jammer and threat system simulator. With Astor III on board, the Sabreliner can act as a jammer and threat simulator resource for test and evaluation (T&E), and tactical training scenarios.

For T&E, the Astor-equipped Sabreliner can act as a threat simulator to evaluate new radar warning designs or as a jammer to test a system's jamming resistance.

From a training and exercise perspective, Astor III gives the opportunity to perform basic to advanced electronic warfare (EW) training as well as flying tactical EW scenarios, for example using 'red air' tactics.

1



2

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1 // FMV FTC has supported the Swedish Defence Research Agency (FOI) with the Sabreliner as a flying SIL for Carabas and LORA since the early 1990s

2 // The Astor III jammer installed on the Sabreliner enables basic to advanced EW training. The forward antenna is shown mounted on the aircraft

3 // Sabreliner with an electro-optical pod on its versatile centerline station

The Sabreliner flying testbed is a versatile test and training asset and FMV FTC is happy to provide the T&E community with this resource in support of future projects or as an asset in training and exercise events.

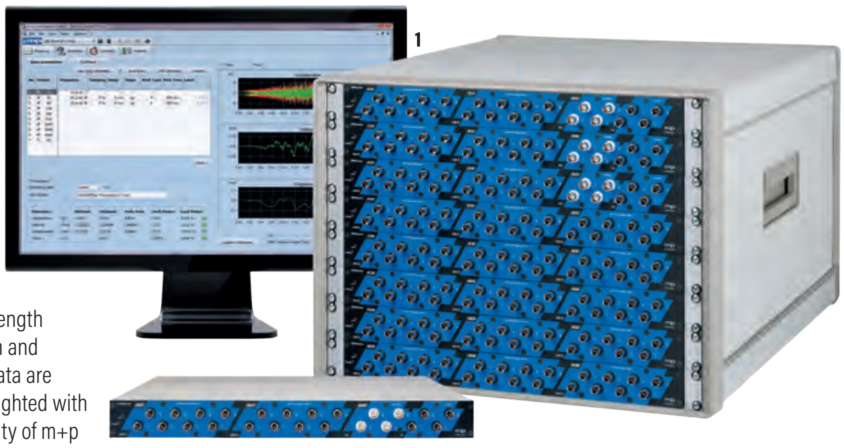
As well as supplying fixed- and rotary-wing platforms – JAS39 Gripen, ASC 890 (Saab 340), HKP14 (NH90), HKP 15 (Agusta A1090), HKP 16 (UH-60 Black Hawk) – as flying testbeds, FMV FTC also has extensive experience and expertise in the T&E domain.

FMV FTC's experimental test pilots and flight test engineers can provide support through the T&E stages and assist with test management and subject matter expertise for subsystems such as avionics, weapons and electronic warfare.

FMV FTC can also take full responsibility for flight test activities and serve as a 'flight test department' for as long as required. \\

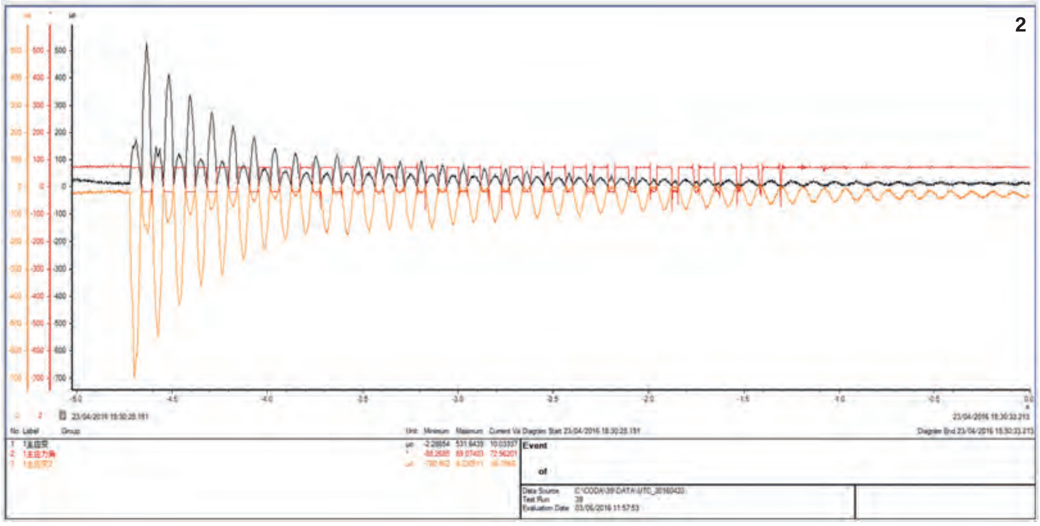
STABLE HIGH-END TESTING SYSTEM

For aircraft strength and vibration testing, China's Aircraft Strength Research Institute chose systems from m+p international, which offer the required flexibility for setup and control



1 // Multichannel m+p system for desktop use or rack mount

The Aviation Industry Corporation of China's (AVIC) Aircraft Strength Research Institute (ASRI) is the national test center for verifying structural strength in newly developed aircraft in the country. It provides ground testing facilities for full-size aircraft, which help to predict vital performance data before an aircraft embarks on its maiden flight. Estimates of component lifetime and reliability can also be provided. ASRI plays a key role in the country's aircraft development program and has contributed substantially to the success of the Chinese aircraft industry.



2 // Strain test data using m+p Coda showing the principle strain 1, principle strain 2 and the angle of principle direction

ASRI chose m+p VibControl and m+p Coda software from m+p international for its vibration control and strain tests. The hardware platform employed is an m+p VibRunner providing 16 analog input channels, 64 bridge input channels, and four analog output channels.

Tests for aircraft strength testing include swept sine vibration, random vibration, noise, classic shock, and shock response spectrum analysis. Analog and strain signals can be measured simultaneously.

For high-end vibration and strength testing, the stability of the system and absolute confidence in the test data are crucial. Engineers at ASRI are delighted with the excellent stability and reliability of m+p international's advanced test equipment.

The new 102.4 kSa/s per channel bridge module is designed for dynamic strain measurements, experimental stress analysis and fatigue testing of mechanical structures. It enables connection of eight strain gauges in full-, half-, or quarter-bridge configurations. Two versions are available – one with RJ45 connectors and the other one with nine pin LEMO connectors. These robust and reliable connectors have proved ideal for flexible strain measurement configurations. 120Ω, 350Ω and 1,000Ω resistors can be connected. When the principle direction of strain is unknown, m+p Coda software allows strain rosettes to be used, so that separately oriented gauges can measure normal strains along different directions in the surface of the part. The principle strain and angle are calculated and displayed in real time. The strain rosettes can also be used for temperature compensation.

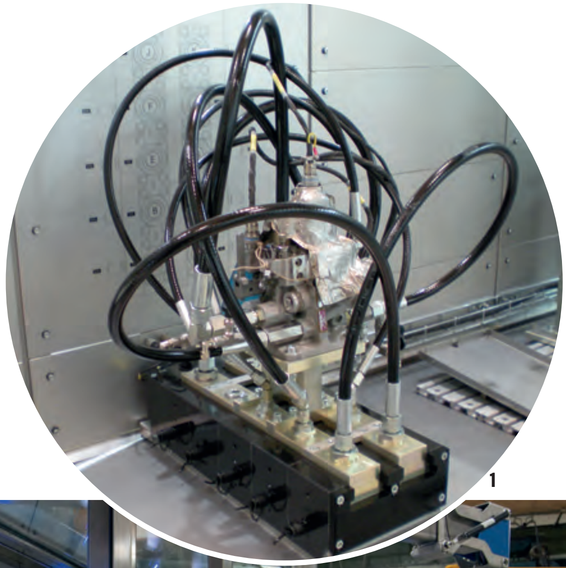
The built-in bridge excitation and completion is individually programmable for each channel, making time-consuming hardware reconfiguration of different gauge types unnecessary. All channels support TEDS to ensure fast, convenient and secure transfer of transducer details to the m+p VibRunner bridge module. An Ethernet interface allows remote operation so the VibRunner system can be positioned close to the measurement point. This reduces the sensor wire lengths and helps optimize low-noise performance.

ASRI also uses the m+p VibControl software and m+p VibRunner instrumentation for acoustic fatigue testing using progressive wave tubes (PWT) and vibration testing (with a shaker) for evaluating the environmental and reliability characteristics of aircraft parts.

The advanced functionality, stability and user-friendliness of the m+p system are greatly appreciated at the institute. An ASRI engineer comments: "Over a period of extensive testing, the high stability and reliability of the m+p system were proved conclusively. The software is easy to use and convenient for us. With the great support from m+p international, we can tackle any test situation." \\

FUTURE-PROOF HYDRAULIC TESTING

Testing hydraulic components during maintenance and repair requires a flexible, rapidly setup solution able to handle new test requirements as they arise



1

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1 // Universal manifold for quick UUT change with installed hydraulic control unit ATA 78-31-53

2 // Hydraulic component test system for non-rotating components

Maintenance, repair and overhaul (MRO) companies are constantly challenged with testing requirements for new components. To remain competitive, they should be flexible and able to test higher volumes of components in less time. When new components come on line, the procurement of new test benches to meet the new testing requirements can be expensive, but may not be necessary.

Test-Fuchs has created a new form of test system that grows with business's and customers' requirements. Many major MROs already profit from the numerous benefits of this test solution in their global locations.

To remain reliable partners for their customers, MROs use Test-Fuchs 'modular test systems'. This equipment can be upgraded and enhanced as their businesses grow. There are different test stand options for non-rotating components (servo valves, valves, actuators, accumulators, etc), rotating components (pumps, motors, power transfer units) or actuators and flight controls. It is possible to assemble an optimized test solution and if requirements change, the system can be upgraded or amplified and modules, additional setups and necessary software can be easily added.

Modular test systems are extremely versatile. A complete solution can cover up to 100 different units under test (UUT). MROs benefit from the high degree of flexibility because they can choose from so many different functions. Modular test systems are highly reliable because they were developed in cooperation with experienced MROs and reflect their specific needs, are simple to use, and have low maintenance costs because they share many identical components, which eases procurement and logistics support.

Modular test systems are designed to optimize test times so MROs can accurately test more components in less time. Setups are arranged quickly and UUTs can be mounted using a number of modular adaptors without tools or time-consuming attachment procedures. The automated test software is fully compatible with the respective Component Maintenance Manual (CMM) systems. Repeat tests for the same component will provide extremely high reliability with reduced human errors. The operator selects the corresponding test program and uses semi- or fully automated test runs while keeping control of the testing cycle. The system generates comprehensive test reports according to the CMM or other test procedure without any additional effort and even provides final test reports with all recorded values. Completely manual operation and testing is also possible.

MROs can choose from a vast pool of test setups and automatic software programs for a large number of UUTs. Whenever a new unit is tested on a modular test stand, Test-Fuchs provides the solution. Its engineers serve as a hub for solutions, common in the MRO world. Test-Fuch's own development test stand can also develop new setups and programs. Tools for UUT repair and overhaul can also be developed, if the MRO requires them.

One of the many benefits of a Test-Fuchs modular test system is illustrated in the hydraulic block system with integrated control valves and measuring sensors. This concept saves space, works without maintenance intensive hoses, and in case of failure, can be exchanged quickly and easily, thus reducing interruptions to production.

MROs can even select different oil or pressure options. Hydraulic components for 3,000psi or 5,000psi can be tested on one test solution. Although the different modules follow a standard product line, the individual customer requirements are met by customization of the various modules. \\

MEASURING COMBUSTION INSTABILITY

Today's gas turbine engines are lean-burn or low NO_x designs with a low fuel-to-air ratio to comply with regulations demanding increased fuel efficiency and lower exhaust emissions. Burning a leaner flame can produce a heat release pressure oscillation problem. This instability can damage the combustion chamber and downstream components, resulting in downtime and revenue loss. On-turbine pressure sensors monitor this instability so that the engine's gas/air ratio can be fine-tuned before the instability causes damage.

PCB Piezotronics' pressure sensors used in this application feature UHT-12, a crystal designed for more accurate, lower noise measurement output during large temperature variations. This technology reduces the effects of the pyroelectric phenomenon, thereby eliminating data spikes and ensuring valid test results.

The proprietary crystal technology is sealed in a hermetic package and has proven reliable performance in hundreds of gas turbine installations for research, testing and monitoring.

For quick detection of combustion instability and accurate high-temperature vibration measurements, UHT-12 crystals are incorporated into several PCB pressure sensors and accelerometers. The pressure sensors operate in continuous temperatres up to 1200°F (650°C). \\

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PCB PIEZOTRONICS

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RELIABLE CANBUS DATALOGGER

Vector developed the GL1020FTE datalogger for analyzing CAN (controller area network) bus communications in aircraft. The logger is currently used on board the Airbus A350-1000 test aircraft. The device fulfills stringent requirements to be used as aircraft equipment and was designed according to the RTCA DO-160E standard.

The logger records up to 32GB of data from two CAN and four analog channels. It operates on layer 2 of the CAN protocol and can acquire error frames, bus load and bus timing. Both long-term and event-triggered loggings are possible. The configurator software is used to define extensive filters and trigger conditions, quickly upload the logged data and to convert the data to various formats for evaluation. Vector offers high-performance software tools for offline data analysis such as CANoe, CANalyzer, CANape and vSignalizer.

The hardware can withstand accelerations up to 6*g* and concurrent vibrations. It can handle temperatures between -40°C and +85°C and flight altitudes up to 36,000ft. It offers protection against indirect effects of lightning strikes as well. The logger is supplied with 28V DC, can withstand peak voltages of up to 33V DC, and can buffer voltage interruptions of up to 200ms. \\

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VECTOR

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HIGH-SPEED DATA ACQUISITION

Elsys Instruments offers fast high-precision data acquisition (DAQ) instruments and solutions which are successfully implemented across a wide range of applications and promote efficiency and output-driven developments.

Fast sampling rates from 2-240MHz make the product suitable for variable frequency drive tests, power converter tests, high-voltage circuit breaker tests, power distribution monitoring, spike detection on power lines, and many other applications where fast transients occur.

The robust TraNET FE devices from Elsys are extensible from four up to 32 channels and suitable for field measurements or service and maintenance tasks. Their compact size makes them handy for traveling maintenance personnel. Larger systems can be built in a standard 19in industrial chassis or created by synchronizing several smaller DAQ devices.

The outstanding strength of Elsys DAQ solutions is flexibility for customer needs from a modified instrument chassis, integration of additional third-party hardware, or modified or additional software functionality in the software TranAX. Several open software interfaces allow integrating the DAQ solution in almost any environment. Elsys can provide integration, know-how and support in many different programming languages. \\

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ELSYS INSTRUMENTS

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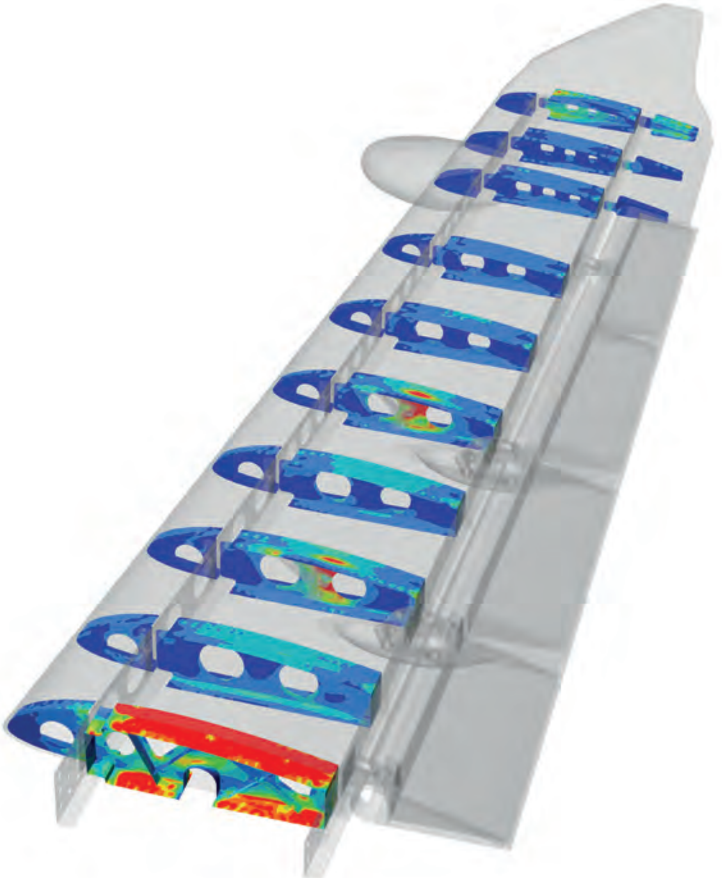
THE FEM STANDARD WINS

Altair has won a benchmarking competition, and as a result Airbus will implement a new pre- and post-processing tool based on Altair's solutions HyperMesh and HyperView as the new platform worldwide. Part of the HyperWorks CAE simulation platform, the two products are the de facto standard for finite element modeling (FEM), results analysis and reporting in the aerospace and automotive industries.

The competition, initiated in early 2016, led to this agreement, which confirms a worldwide Airbus migration to use of the HyperWorks CAE Desktop. It demonstrates competencies in pre- and post-processing and confirms Altair's position as a major player in the aerospace industry.

The agreement will begin a worldwide employment of the HyperWorks Desktop solutions for all Airbus aircraft. Altair has also committed tighter collaboration between itself and Airbus teams, to set up a deployment roadmap. Customization of Altair software according to the needs and requirements of Airbus will also be provided along with training.

The agreement also complements and tightly aligns with the long-term consulting collaboration between the two companies. \\



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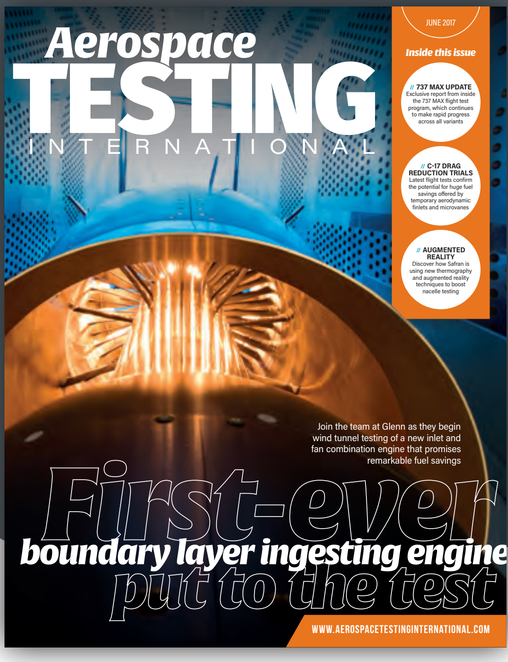

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A GATEWAY SOLUTION

TechSAT's latest product development is Tiffi, a software solution that simulates parts of the SCI (secure communication interface), which is a gateway between Airbus's Avionics Full-Duplex Switched Ethernet (AFDX) network and the open-world Ethernet side.

The SCI is a technology within Airbus aircraft such as the A380, A400M and A350 that translates the maintenance and health information (from the BITE) and the software data loading protocol.

In addition to the real SCI, Airbus has used a third-party solution based on a standalone industrial Linux PC with AFDX hardware for its tests on the ground. This solution has become obsolete and is not available anymore, but there is still a need for protocol translations at many test facilities.

Tiffi is a form-fit-function software replacement for this obsolete hardware and can be installed on any Windows or Linux computer, for example on the PC that hosts the CMS (centralized maintenance system) and DLCS (data loading and configuration system) tools.

Tiffi only uses a TechSAT A664 USB-network interface controller device, which combines a two-port Ethernet interface and dongle features for licensing. No further expensive AFDX hardware is necessary. \\

64BIT SUPERVISORY CONTROLLER

Jacobs Technology has given its premier data acquisition and supervisory control software package a 64bit overhaul along with new real-time (RT) control capability.

Test SLATE has been used in the most challenging aerospace testing environments for the past 20 years due to its ability to unite complex systems into a single, simple control and data-acquisition interface.

The latest 64bit, RT-capable Test SLATE V14 has demonstrated the ability to operate at system rates 100% faster than previous versions when 64bit hardware was utilized during laboratory testing. The new version of Test SLATE allows for the creation of complex test sequences incorporating an almost infinite number of conditional intricacies built on all the I/O available in the test cell, regardless of system origin.

RT data acquisition, control and monitoring capabilities are also available using the new NI Veristand RT plug-in.

Jacobs is confident the new upgrades will greatly benefit test facilities catering to turbine and rotorcraft research and development, or any other testing facilities where high-resolution control and data collection are required. \\

MODULAR, COMPACT AND EVOLUTIVE

ECA Group has developed its novel 'T-Cell' technology to solve challenges with mixed hardware in test benches, component obsolescence and software issues due to operating system upgrades.

This solution is based on smart electronic modules capable of acquiring, generating or switching all types of aircraft electrical signals. In less than five minutes, these hot-plugged modules can be arranged to perform avionics bus and analog testing in or around the aircraft.

This modular and streamlined architecture allows for offering unlimited tooling form factors, ranging from handheld testers (<10 test points) to a distributed functional testing system (>2,000 distributed test points).

For example, 50 T-Cells can be gathered in ECA Group's TB500 functional tester, reaching up to 500 testing points. Customers are using it in their aerospace assembly lines with an availability rate greater than 98% and the capability to reconfigure the testing modules depending on their manufacturing workflow.

In a maintenance environment, our TC200 universal E-GSE (ground support equipment) allows for collection of up to 200 testing points in a cabin-luggage sized tool, bringing complex and versatile testing capabilities to aircraft.

T-Cell technology benefits from 30 years of ECA Group's experience in aerospace testing tools design, manufacturing and maintenance, including full hardware and software obsolescence management.

With T-Cell, complex and oversized test benches become outdated in favor of compact and agile testing products. \\

// MICHAEL JONES

From test flights to air shows

Now restored to flying condition by the Commemorative Air Force in the USA, this Bell Aircraft Kingcobra P-63-6 flew first as a test aircraft before becoming an air show performer

Restoration of the WWII-vintage Kingcobra P-63-6 took 16 years, overcame 40 years of disuse and the flooding of its hangar during its restoration when the Mississippi River overflowed in 1993. After the flood, members of the Missouri Wing of Commemorative Air Force (CAF) went out in the fields and picked up pieces of the aircraft one by one. Literally.

The restoration was taken over in 1999 by the dedicated volunteers of the Dixie Wing (Georgia, USA), who moved the aircraft to Georgia. Their efforts finally saw the aircraft returned to flight on February 18, 2017. The P-63 was a development and improvement on the very successful Bell P-39 Aircobra and shared its innovative layout. The water-cooled Allison V-12 engine in the fuselage behind the pilot drove the propeller via a long shaft. The propeller drive arrangement allowed a 37mm M4 cannon to fire through the propeller spinner. Both aircraft were fitted with four .50cal machine guns, two in gondolas under the wings and two on the cowling, firing through the four-bladed propeller.

The P-39 was the first US fighter fitted with a tricycle undercarriage – a feature retained on the P-63.

Of the 3,303 P-63s produced from 1943 to 1945, about 2,400 were sent to the Soviet Union under Lend-Lease, and France used some in Indo-China after World War II. The CAF's Kingcobra, made at Bell Aircraft's plant in Niagara Falls, New York, rolled out on February 24, 1944 and was accepted by the US Army Air Force as a P-63A-6, but it was retained by Bell for its flight testing program. Little is officially recorded of the testing activities of this aircraft, but the CAF has pieced together details based on other P-63 flight tests to explain the modifications discovered during the restoration. Many of these were later incorporated into the P-63C and P-63E models.

One modification shows that a ventral fin was mounted below the aft fuselage – a standard feature on the P-63C and later models but absent on the production P-63A. This may be a modification added by Bell to test aircraft handling with the fin.

A front window defroster is installed, which is not a feature on production P-63As, but was planned for a series of never-built P-63Es.

After Bell flight testing ended, on January 27, 1945 the aircraft arrived at the National Advisory Committee for Aeronautics' (NACA) Moffet Field at the NACA Ames Research Center, California.

At Ames, P-63s were involved in aileron flutter tests and evidence of this comes from the static pressure test ports drilled into the surface of the left aileron. It is hard to know for certain if this was the purpose of the ports – records are scarce or non-existent. In April 1946 the aircraft was declared surplus and a private owner flew it on the air racing circuit for a few years but afterwards it sat unused in Texas. At the time of its last airworthiness certificate application in 1975, the airframe had only 366.15 hours. For its first post-restoration flight, pilot Jim 'J D' Dale was asked to fly the aircraft as he is one of the highest time P-63 pilots in the US, and director of maintenance for the Lewis Air Legends Collection. Just after 13:00, Dale took off from the Atlanta Regional Airport, home of the Dixie Wing, marking a return to flight for the special test aircraft. Over two days he performed four further flights. \\

A video can be seen here:
HTTPS://WWW.YOUTUBE.COM/WATCH?V=NFON45KS-OM

FEB 24,1944
Factory roll-out

P-63A-6
Model number

38FT 4IN
(11.7m)
Wingspan

32FT 8IN
(9.95m)
Length

10,700 LB
(4,850kg)
Maximum weight

410MPH
(650km/h)
Top speed at 25,000ft and 450-mile (725km) range

43,000FT
Service ceiling

2,200 MILES
(3,540km)
Ferry range

1,800HP
Power of single Allison V-1710-117 liquid-cooled V-12 engine

3,303
Number built


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