Aerospace TESTING INTERNATIONAL

MARCH 2017

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NASA shakes up the JWST

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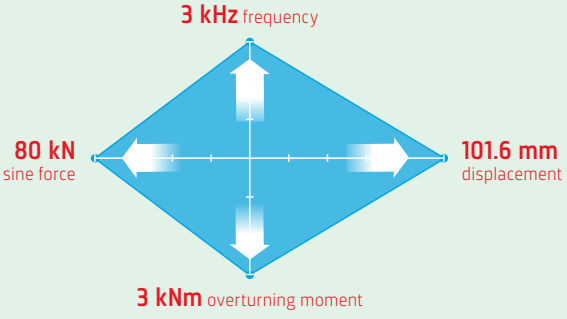

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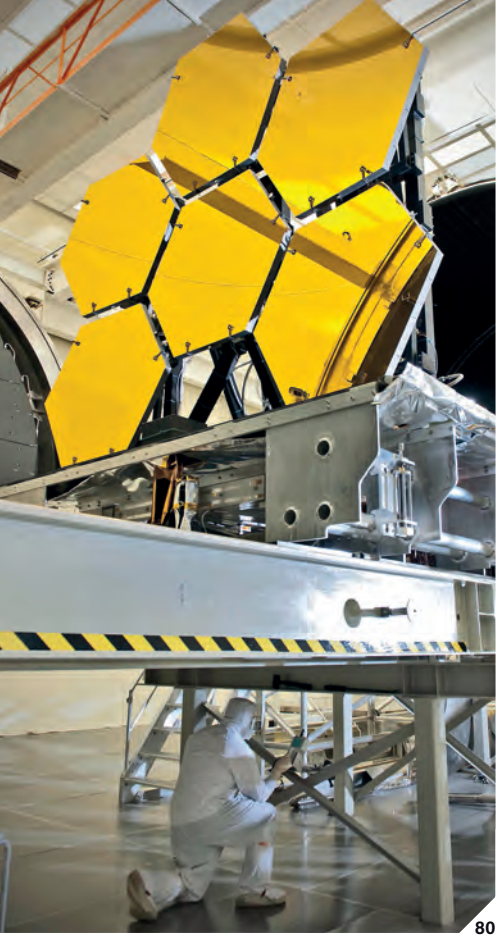

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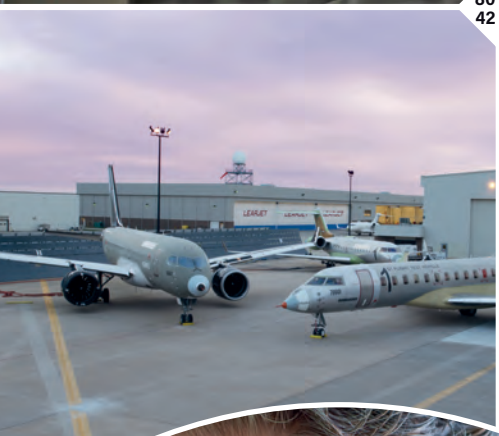

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// Full throttle

Welcome to our first issue of 2017, which at 120 pages is our biggest for quite some time. Why the sudden growth spurt? Well, we like to think it's down to our determination to produce the industry's best-designed and most innovative magazine full of in-depth features dedicated to what is a truly fascinating subject.

It also helps that the aerospace industry is itself expanding in 2017. Following years of positive – but rather subdued – growth, sector revenues are expected to grow by 2% in 2017, according to Deloitte's 2017 Global Aerospace and Defense Sector Outlook.

Airbus's Global Market Forecast for 2016-2035 sounds an even more upbeat tone. It highlights demand for commercial aircraft from 100 seats up to those with over 500 seats. The European manufacturer's forecast anticipates that air traffic will grow at 4.5% annually, requiring some 33,000 new passenger and dedicated freighter aircraft at a value of US$5.2tn over the next 20 years.

With so much expansion expected, major airframers are constantly reviewing their testing methods and technologies to ensure they can react with even greater speed and agility when developing new models to fill market niches and meet the insatiable demand for more efficient and capable aircraft.

Airbus itself is a good example. It continues to make remarkable progress in ensuring its latest wide-body, the A350-1000, remains on track to enter service later this year following a flight test campaign that will take "less than one year with just three prototypes", according to chief test pilot Capt. Christophe Cail (see page 16 for our full report on the test campaign to date).

Meanwhile on page 60, you can discover how Embraer is making equally remarkable and rapid progress with the test program for its eagerly anticipated military transporter, the KC-390, having just received its IFI Provisional Type Certificate. And although not quite on the same scale as an airliner or an airlifter, Bombardier's newest bizjet, the Global 7000 (see page 42), is also speeding toward first delivery, with its maiden flight achieved in November last year.

Away from all the latest flight testing campaigns, this issue also has a very strong focus on non-destructive testing and inspection. I must admit I chuckled when I first saw the photo on page 58 of Steve Thompson, technical fellow and lead engineer of the Boeing Research & Technology In-Service Non-Destructive Inspection Group, and this issue's featured *Testing Talk* expert.

Steve is pictured performing a field test on the tarmac looking for moisture ingression in 767 flap wedges using what was then a 'scientific grade' infrared camera with a head-up display. Perhaps showing my age, it struck me as uncannily similar to some of the 'kit' used in the original *Ghostbusters* movie! "That image was taken over 20 years ago," explains Thompson. "Since then, the cameras have shrunk to a fraction of the size shown and offer much higher spatial and thermal sensitivity."

What is hard to see in the picture is the 10 lb battery belt Steve is also wearing. "The battery pack weighed more than currently available IR cameras – but only provided one hour of run-time." The perfect anecdote to underline the rapid progress the industry continues to make – we hope you enjoy the issue and can't wait to get started on the next one!

Anthony James, *editor-in-chief*

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COVER IMAGE: Mirror section from the James Webb Space Telescope (Photo: Northrup Grumman)

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WORLD *test update*

// FIRST R-R TRENT 1000 TEN 787 TAKES TO THE SKIES

The Rolls-Royce Trent 1000 TEN has powered a Boeing 787 Dreamliner flight for the first time. The flight took off from and landed at Boeing Field, in Seattle, Washington, marking the latest phase in the development program.

The Rolls-Royce engine has also been selected to power the first test flight of the Boeing 787-10 version of the Dreamliner in 2017. This means the Trent 1000 will have powered the first flight of every version of the 787.

The Trent 1000 TEN has already undergone power tests earlier this year on the Rolls-Royce Flying Test Bed aircraft, a Boeing 747, at Tucson, Arizona.

The Trent 1000 TEN (Thrust, Efficiency and New Technology) will power all variants of the Boeing 787 Dreamliner family.

READ MORE ON OUR WEBSITE!

The Trent 1000 powered the first 787-8 entry into service in 2011 and the first 787-9 into service in 2014.

Renton, Washington, USA

// GE COMPLETES GE9X CMC ENGINE TESTING

The second phase of GE9X CMC (ceramic matrix composite) component testing in a GEnx demonstrator engine has been completed, with the CMCs continuing to be the clear winner compared to conventional materials.

The demonstrator engine accumulated 1,800 cycles in the latest round of tests, which included exposure to harsh environmental conditions of dust and debris. The level of debris exposure was equivalent to approximately 3,000 take-off and landing operation cycles. The GE9X engine will power Boeing's 777X aircraft.

For the second round of tests, the GEnx demonstrator engine used the same CMC combustor liners, HPT stage 1 shrouds and HPT stage 2 nozzles from the first round of tests in September 2015, along with the addition of the HPT stage 1 CMC nozzles.

Peebles, Ohio, USA

// MRJ TESTING MOVES TO NATURAL ICING TESTS

Mitsubishi Aircraft Corporation has conducted its first test campaign at the Chicago Rockford International Airport (80 miles northwest of Chicago) in Rockford, Illinois, to collect data in natural icing conditions.

With a little help from Mother Nature and the use of dedicated flight test instrumentation, the team of global specialists obtained valuable data to analyze the airframe ice accretion and ice protection system performance. This milestone builds on recent testing activities at the Moses Lake Flight Test Center.

SEE PAGE 34 FOR MORE ON ICING

The next stop for the test aircraft is the McKinley Climatic Laboratory on the Eglin Air Force Base in Florida. There, the test aircraft will be tested to some of the most extreme temperatures it may encounter during commercial operation.

Rockford, Illinois, USA

// A350-1000 TAKES FIRST FLIGHT AND BEGINS TESTING

The first A350-1000 took off on November 24 for its maiden flight at Blagnac Airport in Toulouse, France. The aircraft is Airbus's largest and most powerful twin-engined and is equipped with Rolls-Royce Trent XWB-97 turbofans.

READ MORE ON THE A350 ON PAGE 16

Benefiting from the experience of the original A350-900 test campaign (completed in 2014), the A350-1000's development program will be shorter – under one year with three test aircraft.

The third and final Airbus A350-1000 testing prototype took its first flight on February 7. This marked a milestone in the program, which is hoping to rack up 1,600 flight hours in 10 months in its campaign to gain certification by the end of 2017.

This third flight test aircraft, MSN065, will be equipped with a full passenger interior to enable it to be used for evaluating cabin systems and to provide data on long flights and conduct route proving.

Toulouse, France

// BAF HOSTS B-52 FOR HERO TESTING

The Benefield Anechoic Facility (BAF) at Edwards Air Force Base, California, hosted a B-52 Stratofortress to undergo testing for hazards of electromagnetic radiation to ordnance (HERO).

SEE PAGE 70 FOR MORE ON THE B-52

The test was to comply with a recent mandate from the Air Force Safety Office at Tinker AFB, Oklahoma, which states all Air Force weapons platforms will conduct electromagnetic environmental effects evaluations. This B-52 testing concentrated on the HERO compliance element.

Ordnance and other devices that contain electro-explosive devices must function in their operational electromagnetic environment without inadvertently activating. To prevent the susceptibility of ordnance to radiated or conducted electromagnetic energy, HERO limits are imposed. HERO tests are conducted to classify the ordnance's susceptibility to electromagnetic radiation as HERO Safe, HERO Susceptible, or HERO Unsafe.

Edwards AFB, California, USA

// ARMY'S UH-60V PROTOTYPE BLACK HAWK ACHIEVES FIRST FLIGHT

The initial flight of the US Army's UH-60V Black Hawk helicopter on January 19 lasted a little more than an hour and included a variety of exercises including take-off, hover, track and balance, and a brief local area flight, before returning to the airfield.

READ MORE ON OUR WEBSITE!

The completion of the flight on this date was a target set more than two years ago.

The aircraft went through final maintenance actions and acceptance test procedures before being handed over to the Aviation Flight Test Directorate (AFTD). After being handed over to AFTD in mid-February, it was due to undergo further system level developmental testing to ensure that the aircraft and software performs to the US Army's requirements.

Meridianville, Alabama, USA

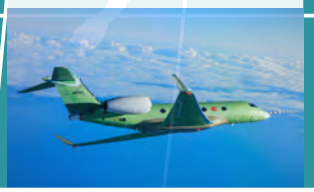
// G600 TAKES ITS FIRST FLIGHT EARLY

Gulfstream Aerospace announced on December 17 that the Gulfstream G600 has completed its first flight, officially kicking off the aircraft's flight test program. Two additional G600 test aircraft have been inducted into the flight test center in anticipation of their flights early next year.

"Launching the G600's flight test program is a milestone for us and our customers, who have guided the vision for this aircraft from the beginning," said Mark Burns, president, Gulfstream. "We look forward to delivering this aircraft to them in 2018. Today's flight, which went flawlessly, represents a significant step forward in the journey to certification and delivery of the G600."

The test flight aircraft spent 2 hours and 53 minutes in the air.

Savannah, Georgia, USA



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Latest Airbus wide-body proves its cold-weather credentials

The latest member of Airbus's all-new A350 XWB wide-body family has undergone rigorous ground and flight tests in the extreme operating conditions of Iqaluit, Canada – which provided a picturesque backdrop accentuated by the Northern Lights.

Iqaluit, a Canadian territory with a polar climate caused by the Labrador Current, provided Airbus's longest-fuselage A350-1000 version with the perfect opportunity to test itself against one of the most challenging environments for an aircraft. The jetliner successfully completed five days of intensive testing at an outside air temperature that fluctuated between -28°C and -37°C.

"The A350-1000 has responded successfully to the ground and flight tests performed in the freezing temperatures of Iqaluit, which demonstrates the already-proven maturity and reliability of the A350 XWB," said Emanuele Costanzo, a flight test engineer at Airbus.

All three A350-1000 flight test aircraft have been engaged in the type certification campaign. These latest tests come three years after the A350-1000's sister – the A350-900 – successfully overcame the uniquely challenging environment in Iqaluit, Canada. \\

// The A350-1000 had a spectacular view of aurora borealis during its cold-weather testing in Iqaluit, Canada

FOR THE LATEST ON THE A350-1000'S FLIGHT TEST CAMPAIGN, SEE PAGE 16

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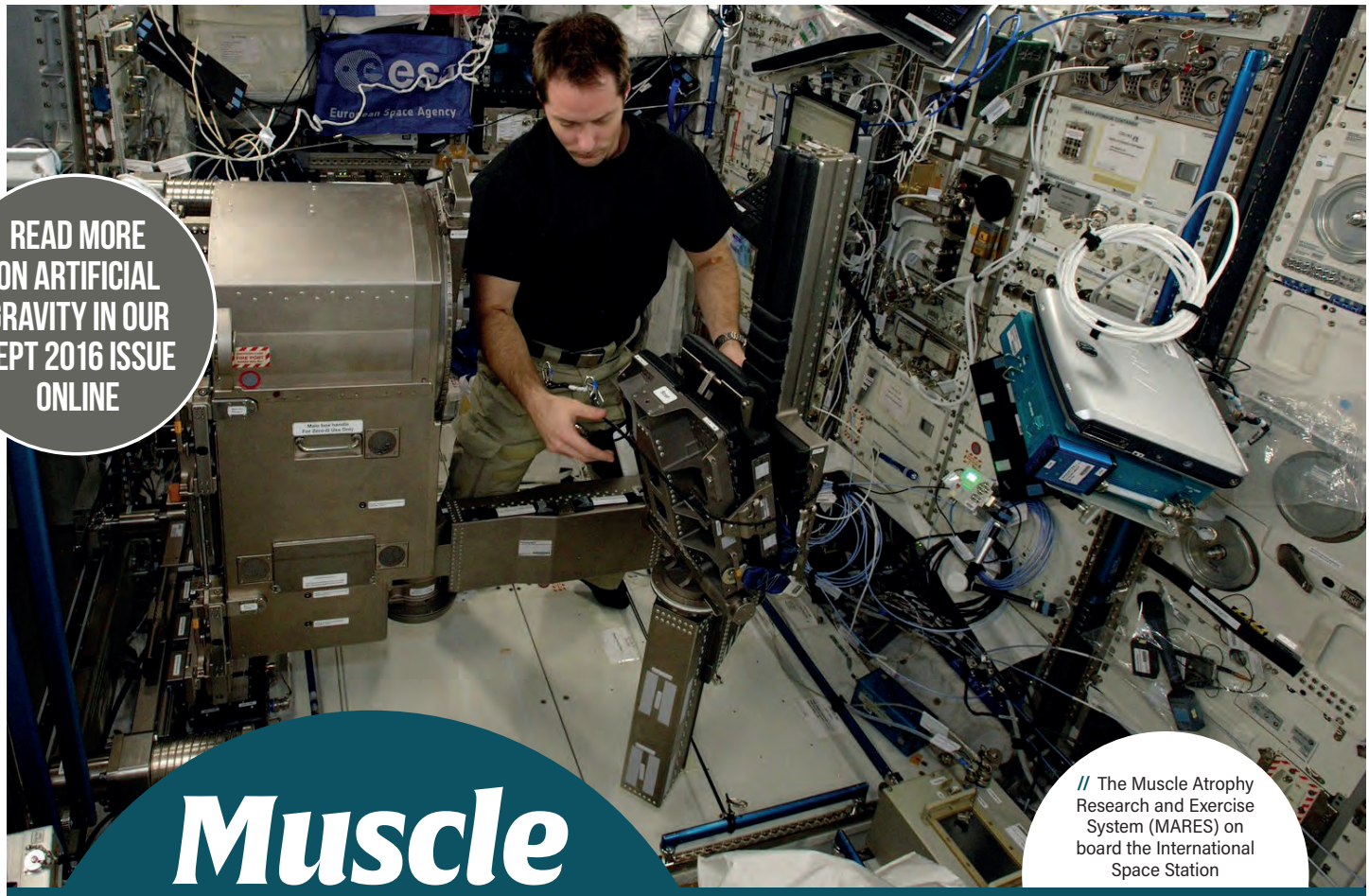

// The Muscle Atrophy Research and Exercise System (MARES) on board the International Space Station

READ MORE ON ARTIFICIAL GRAVITY IN OUR SEPT 2016 ISSUE ONLINE

Muscle atrophy measured on ISS

The first experiment to measure the muscle atrophy of astronauts serving on board the International Space Station (ISS) has been conducted, using a Muscle Atrophy Research and Exercise System (MARES) developed by SENER.

As part of the Proxima mission, French astronaut Thomas Pesquet completed the first two sessions of the Sarcolab experiment, which involved electrical stimulation and measurement of knee and ankle muscles. The sessions took place on the ISS at the end of 2016, and were supervised from the space station operations control room in Toulouse, France.

MARES is a European Space Agency scientific system designed and built by SENER's space life-support experts. It is integrated in the Columbus module of the ISS and is part of the NASA space laboratory, the Human Research Facility. The system is designed to research the effects of microgravity on the human muscular system, which include atrophy, a decline in muscular strength, and osteoporosis due to a loss of calcium in the bones, as well as its effects on neuromuscular interactions.

Currently, astronauts on the ISS are following exercise routines to counter these effects, but proper analysis of their results has not yet been possible. MARES enables them to monitor the benefits of the gym exercises they are performing while still in orbit. This makes it possible to establish effective training protocols and to compare the physical condition of astronauts before and after their stays on the ISS. //

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Supersonic flight a step closer as QueSST takes to the tunnel

// Mechanical technician Dan Pitts prepares a 9% scale model of Lockheed Martin's QueSST X-plane *(Photo: NASA)*

NASA and Lockheed Martin have begun the first high-speed wind tunnel tests for the Quiet Supersonic Technology (QueSST) X-plane preliminary design at NASA's Glenn Research Center in Cleveland. The agency is testing a 9% scale model of Lockheed Martin's X-plane design in Glenn's 8 x 6ft supersonic wind tunnel. During the next eight weeks, engineers will expose the model to wind speeds ranging from Mach 0.3 to Mach 1.6 (approximately 150-950mph) to understand the aerodynamics of the X-plane design, as well as aspects of the propulsion system. NASA expects QueSST to pave the way for supersonic flight over land in the not too distant future.

"We'll be measuring the lift, drag and side forces on the model at different angles of attack to verify that it performs as expected," said aerospace engineer Ray Castner, who leads propulsion testing for NASA's QueSST effort. "We also want to make sure the air flows smoothly into the engine under all operating conditions."

The Glenn wind tunnel is uniquely suited for the test because of its size and ability to create a wide range of wind speeds. "We need to see how the design performs from just after take-off, up to cruising at supersonic speed, back to the start of the landing approach," said David Stark, facility manager. "The 8 x 6ft supersonic wind tunnel allows us to test that sweet spot range of speeds all in one wind tunnel."

Recent research has shown it is possible for a supersonic airplane to be shaped in such a way that the shockwaves it forms when flying faster than the speed of sound can generate a sound at ground level so quiet it will hardly be noticed by the public, if at all. \\

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Highs and lows

Is it easier to test at high or low altitude? While high-altitude testing brings its own set of human challenges, flight in a low-level environment brings completely different conditions and difficulties

When conducting flight test activities, the effects of altitude are surely beyond compare in terms of challenging conditions. This is particularly true for manned test activities because the human in the loop simultaneously provides the majority of both risk and risk mitigation.

A physiological fact is that humans are poorly adapted to operating at high altitude. Activities as simple as walking up a high mountain are transformed into epic feats of human endurance by the reduced air density; even elite athletes trudge at a snail's pace, feeling the throbbing of their own racing heartbeats. For an aircrew, these effects are usually mitigated by their aircraft, but their presence is a latent menace that sets the context in which high-altitude operations are conducted.

Hypoxia (the deprivation of an adequate supply of oxygen to the body) features several characteristics that make it the worst nightmare of the team responsible for flight test safety. Its onset can be subtle, starting with a sensation of being lightheaded and reduced general well-being, which makes self-assessment of its occurrence extremely difficult. Unless rectifying action is taken immediately, symptoms quickly develop into hallucinations, irrational behavior and loss of consciousness. Given the emphasis placed on the human operator to provide risk mitigation to the test activity, this really is a worst-case scenario. Not only is the primary source of risk mitigation suddenly removed, but an operator acting irrationally introduces a plethora of hazards that need to be considered during test planning.

Another facet of hypoxia is that is it not fully understood, particularly its subtler effects. For example, recent research has shown that some individuals exhibit mild symptoms such as a degraded ability to distinguish between certain colors at altitudes as low as 8,000ft – far lower than traditionally understood. While the safety implications of this are not as obvious as for the scenario described previously, it could lead to warning lights or other safety-critical information being missed.

While it is true that height can be a pilot's best friend in many aircraft emergencies, this is not always the case. In the event of a catastrophic failure, for example one initiated by hypoxic crew, it simply means a longer fall to the ground. \\

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Proximity to terrain introduces the potential for a hazardous situations to very quickly become an accident, the pilot having much less time and vertical height available to execute a forced landing. Landing site choices will also be limited to what is immediately available and within reach. Ground proximity also makes real-time fault diagnosis very difficult, leaving pilots having to make split-second life-or-death decisions.

Low-level flight also introduces potential terrain-related phenomena like whiteout or brownout, caused by recirculating snow, dust or sand, which causes spatial disorientation and loss of situational awareness, leading to accidents. In maritime environments, spray can cause similar problems. Loss of visibility can also put aircraft into situations where they face risk of dynamic rollover on uneven terrain. Brownout has caused more helicopter accidents in recent military operations than all other threats combined; testing in these conditions can be just as risky. Add to this the complexities of testing some of the novel systems designed to restore visual cues in this type of environment, such as helmet-mounted displays or head-up displays, and what could be perceived as a simple trial can very quickly become incredibly complex.

Alongside this complexity, flight in low-level environments is already a high workload task; introducing any additional elements (such as giving pilot ratings) for evaluation purposes cannot be done without very careful consideration. Low flight also involves far more pilot interaction with the aircraft than at high altitude, meaning the overall pilot-vehicle system is more complex and therefore more difficult to assess.

The low-level environment can be unpredictable and changeable. Terrain masking, a smaller landscape feature obscured by a larger one, can result in collisions. Previously inspected test sites are liable to change through human interference – with masts or wires appearing in a matter of minutes.

The bottom line is that if something happens when you are testing in the low-level environment, it will happen faster, in a much less predictable setting and with potentially much more severe consequences than at altitude, making low-level flight one of the more challenging areas of test. \\

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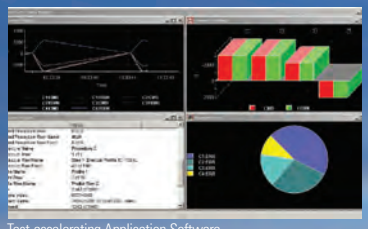

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// IAN GOOLD

Home stretch

Airbus flew its new A350-1000 twin-aisle twinjet for the first time in November 2016, marking the start of a flight test program that will see three prototypes logging 1,600 flight-hours as the new variant prepares for entry into service later this year

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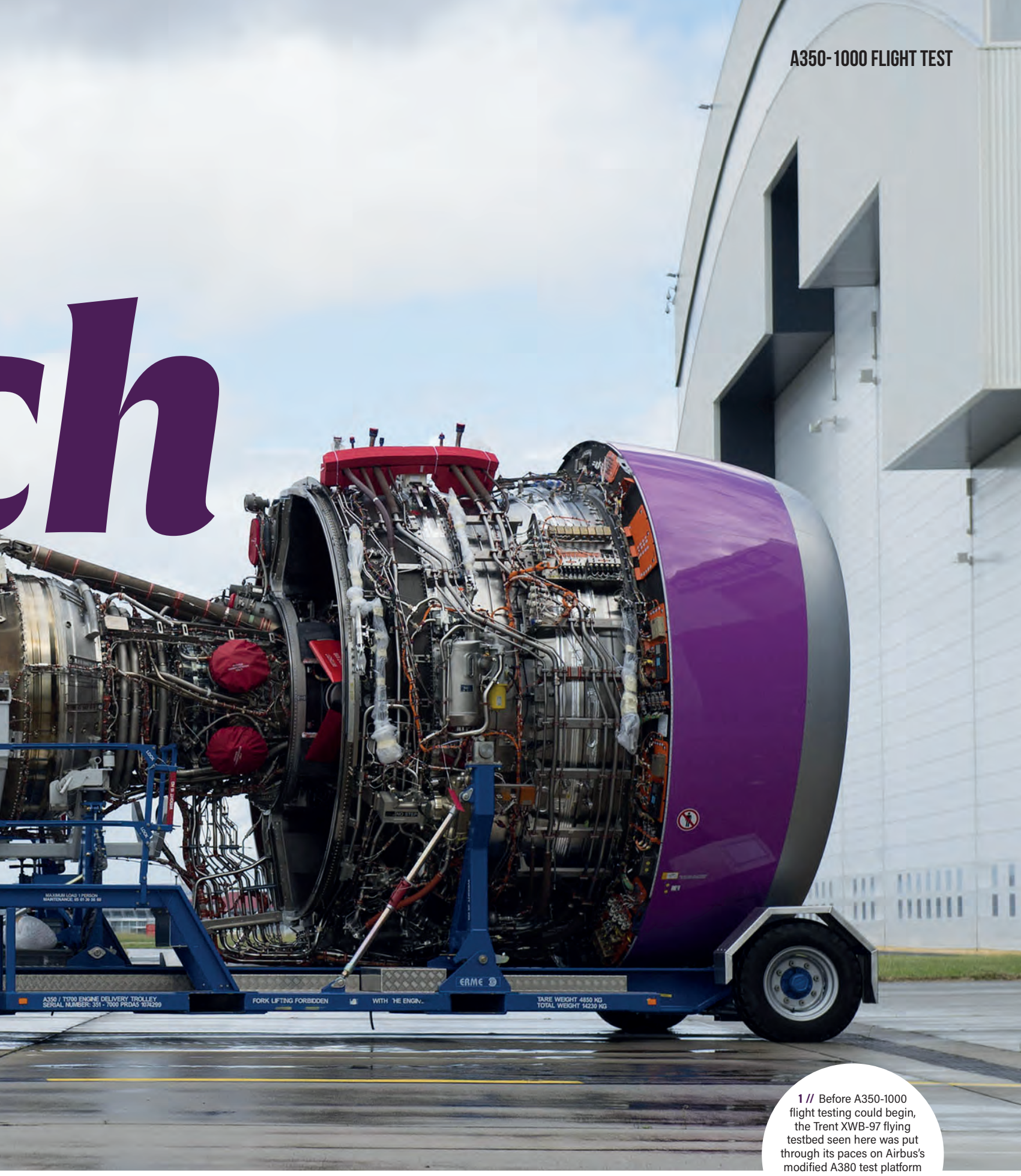

1 // Before A350-1000 flight testing could begin, the Trent XWB-97 flying testbed seen here was put through its paces on Airbus's modified A380 test platform

2

2 // The first of three A350-1000 flight test vehicles – MSN059 – lands at Toulouse-Blagnac Airport following its four-hour and 18-minute maiden flight in November 2016

STEP BY STEP

The Airbus A350-1000 flight test campaign comprises five phases. The first initial development phase sees all three aircraft enter the program and by this month [March] may have seen Airbus freeze the variant's aerodynamic configuration. Further development flying and the beginning of airworthiness certification work will involve MSN071 conducting performance tests in both cold- and hot-weather conditions and at high-altitude airports. MSN065 will be engaged in external noise measurement.

After a period devoted to finalizing certification, the three machines will continue test flying in preparation for entry into service (EIS). Airbus hopes to receive full type certification ahead of EIS, at the end of this fourth phase, which will be followed by the manufacturer establishing its support for customers introducing the new variant into their scheduled operations.

After a maiden take-off at Toulouse in southwest France in late November, the Airbus A350-1000 twin-aisle twinjet very quickly started flying with Airline1. This is not a previously unknown carrier launched to provide the new 366-seater's initial commercial services, but rather an Airbus in-house operation.

In Airline1, the manufacturer has resurrected the simulated airline 'experience', focusing on aircraft maturity and operability that it set up for certification (or airworthiness approval) of the 325-passenger A350-900. Coordinating flights with the Airbus Flight and Integration Test Center (FITC), Airline1 comprises dedicated staff who manage a hangar and A350-1000 daily maintenance, support and repairs in an operating environment intended to replicate commercial service.

"We're reinforcing Airline1 to improve the way we manage potential failures and increase our understanding not just of the aircraft, but of our customers' world," says A350 maturity and operability head Philippe Garnier. "This is about improving maintenance efficiency, developing effective health-monitoring, and delivering machines that have the highest-possible levels of maturity."

With A350-1000 flight tests continuing into mid-2017, Airbus is focusing more sharply on visual inspections of the airframe and cabin. It says the exercise includes an 'operability test card' boosted by standard procedures for preflight and cockpit preparation and with airline-style technical documents for troubleshooting. The health of the flight test fleet is being tracked using real-time monitoring and predictive monitoring.

By January, two years after entry into service (EIS), 62 A350-900s had been delivered, with major customers, including Cathay Pacific, Finnair, Lufthansa, Qatar Airways, Singapore Airlines and Thai Airways having performed 25,000+ flights.

A350-1000 CHANGES

The A350-1000's increased capacity arises from the addition of 11 extra fuselage frames to lengthen the cabin; two 97,000 lb-thrust Rolls-Royce Trent XWB-97 engines each generate 13,000lb more thrust than the A350-s900's Trent XWB-84 engine. The stretched variant sports new six-wheel landing-gear bogies (to reduce airport pavement loading by spreading the increased weight), while an improved wing with extended trailing edges provides a low approach speed for landing, according to Airbus senior marketing vice president François Caudron. The A350-1000 will have a range of about 7,950 nautical miles, slightly less than its smaller, lighter sibling's 8,100 nautical miles.

The A350-1000 changes are sufficient to necessitate a separate flight test campaign, but chief test pilot Capt. Christophe Cail emphasizes that the -900's "high level of

3

3 // MSN059's duties for performance testing will include exploration of the flight envelope, handling qualities, loads and braking

maturity" has enabled Airbus to restrict the program to "less than one year with just three prototypes".

Rolls-Royce claims that 1,600+ orders make the Trent XWB design, which grew out of the late-1980s' RB.211-524L project, the fastest-selling engine ever for a twin-aisle (or wide-body) jetliner. The Trent XWB-97 achieves its higher thrust from new high-temperature turbine technology, a larger engine core, and advanced high-bypass fan aerodynamics.

Trent XWB-97 trials on the Airbus A380 flying testbed continued after November's A350-1000 first flight. Cail said that the initial 165 flight-hour campaign between November 2015 and April 2016 had been devoted mainly to operability, including some tests related to engine-specification certification. A second round of tests was expected to see a similar time devoted to "de-risking, maturity and specification certification for engine integration items (hot weather, natural icing, drainage and fire extinguishing)" by the end of 2016.

PREFLIGHT TESTING

Cail notes that Airbus had completed many hours of 'system-by-system' preflight A350-1000 bench and laboratory work, including ground vibration tests and trials of the landing gear and electrical and flight control equipment. "We put all these things together on Aircraft Zero, which is a simulator on which we have all the real databuses and computers.

"Everything is put together to make sure it works and we have done a lot of simulated flight hours. The flight test crew was very highly involved. For instance, we have done the rehearsal for the first flight on the simulator. We switched on electrical power for the aircraft and the onboard flight test installation, which is a huge step."

600,000+
Flight data parameters

120,000
Flight test equipment electrical connections

3,300
Measurements (by 220 types of sensors)

Once the A350-1000 was operating independently under the power of its Trent XWB-97 engines, Airbus performed two lots of rejected take-off (RTO) runway tests, according to Cail. "First, the low-speed RTOs at up to 100kts [115mph]. The very last test was the high-speed RTO at 140kts. We took the aircraft up to take-off speed and performed another RTO to make sure the engine and systems

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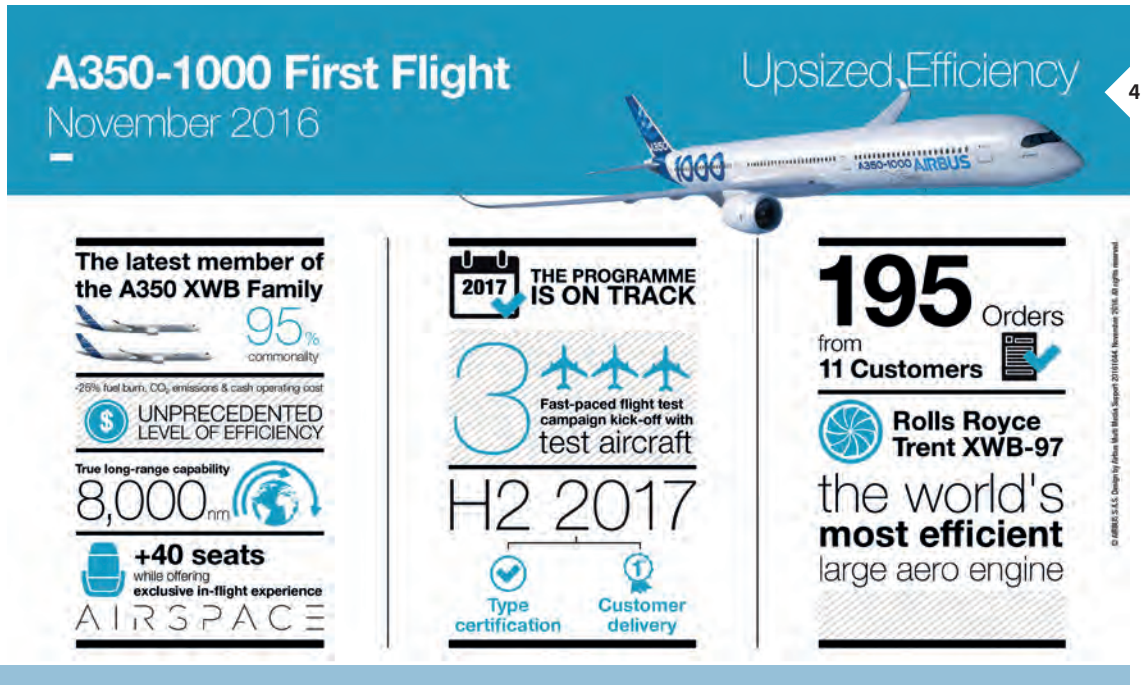

4 // A350-1000 infographic released at the time of the first flight

worked well. Then we inspected the aircraft to prepare for the first flight."

GROUND TELEMETRY

For real-time analysis and systems monitoring, Airbus transmits aircraft flight test parameters to a ground-based telemetry room manned by more than 100 specialists. For the A350-1000's first flight, the manufacturer used two telemetry rooms in Toulouse, and three more at Airbus sites at Bremen and Hamburg in Germany and in Bristol in the UK.

The FITC supplements test observations aboard the prototype with those from an accompanying Dassault Falcon 20 business-jet chase plane. The Falcon 20's crew includes an Airbus test pilot to "monitor and if necessary help a flight test aircraft", says Cail. Flying around and alongside the prototype, the Falcon crew are able to provide an external view.

A350 FLIGHT TEST PROTOTYPES

The A350-1000's 1,600 flight-hour test program is being shared among three prototypes, which Airbus identifies very simply by their manufacturer's serial numbers (MSNs). It comprises five phases of testing, although Airbus has not indicated how much flying time is budgeted for each phase.

The first aircraft – MSN059 – is scheduled to complete 600 flight hours of testing, with the remaining 1,000 hours split evenly between the second and third machines, MSNs 065 and 071. As planned, the latter became the second to fly, on January 10 this year.

MSN059 and MSN071 are equipped with a 'heavy' flight test installation; MSN065 is to have a 'light' FTI and will fly only after being fitted with an airline cabin interior. Each prototype will be fitted with equipment for a range of specific flight test duties.

MSN059 is opening the flight envelope as much as possible, establishing handling qualities, and completing engine and systems tests. MSN071 will complement the first aircraft's systems and engine testing, and carry out environmental tests covering cold- and hot-weather trials and high-altitude airport performance.

MSN065, the cabin development and certification prototype, will be used to evaluate passenger air systems. Cail points out that, unlike the first two units, it will be used mainly for cabin development and certification and extended-range operations. It will then be used for route-proving flights to conclude the flight test campaign.

FIRST FLIGHT PROFILE

The A350-1000 first-flight crew comprised experimental test pilots Hugues van der Stichel and Frank Chapman, test flight engineer Gérard Maisonneuve, and flight test engineers Patrick du Ché, Emanuele Costanzo and Stéphane Vaux.

"For take-off, the trailing-edge flaps were in Flaps 3 configuration and remained so while the crew checked aircraft systems including pressurization," says chief test pilot Capt. Christophe Cail. The aircraft climbed to an altitude of between FL100 (nominally 10,000ft above sea level) and FL150. Initially the A350-1000 flew in direct control law – a "very simple way to make sure everything works", says Cail.

Airbus aircraft employ sidesticks mounted outboard of each pilot near the flight-deck sidewall. Under direct law, unmodified pilot inputs provide a direct relationship between the sidestick and the flight-control surfaces, with control sensitivity depending on airspeed. No auto-trimming is available, but the crew receives over-speed and stall warnings.

During the first 2.5-hour phase of flight, the crew explored the flight envelope at speeds of 145kts (167mph) to 206kts, the maximum for the selected flap configuration. The landing gear was raised after about an hour's flight. Reporting a "very comfortable" flight, the crew confirmed that they could engage normal law, the flight-control system's usual operating configuration.

Normal law covers three-axes control, flight-envelope protection and wing-load alleviation. It prevents the aircraft being overstressed, even with full sidestick deflection, and limits attitude to 30° nose-up/15° nose-down pitch and to 67° of roll.

During a 30-minute mid-phase of flight, the A350-1000 was taken to FL250, again being flown in direct and normal law and at speeds up to VMO (or maximum operating velocity for the configuration). Finally, descending to between FL150 and FL100, the crew tested landing-gear operation and checked aircraft behavior in full-flap landing configuration.

5 // Airbus introduced three new 'stations' in its Toulouse, France, A350 XWB final assembly line to facilitate concurrent A350-900 and A350-1000 production

5

Meanwhile the manufacturer has revealed details of the 'heavy' test equipment fit on MSN059. The installation permits Airbus to gather more than 600,000 parameters of flight test data. Some 220 types of sensor collect 2,850 analog and 150 discrete measurements, with 300 databus 'tappings' throughout the aircraft able to handle the transmission of 100Mbps of information between the aircraft and the ground.

The equipment includes 140 remote acquisition units and 120,000 electrical connections linked via 120,000km of cabling, which according to Cail is "about half that used for previous aircraft". Fifteen internal and external video cameras are available.

Three flight test engineer (FTE) stations monitor aircraft data, while two engine specialists gather powerplant information. In addition, a 51-seat "flight test cabin" can be installed on MSN059 to carry specialist ground-support personnel and mechanics when the aircraft is operating away from its French base.

MSN071, the other heavily equipped A350-1000, has identical FTE stations, although its FTI architecture is a subset of that on the first aircraft. It also has some specific equipment, since each aircraft has instruments linked its specific flight test role.

MSN059 is equipped to carry 10 metric tons of water and glycol liquid ballast that can be transferred between tanks in its forward and aft cargo holds in just four minutes to vary the position of the aircraft's center of gravity. This enables the manufacturer to avoid the need for separate flights for each center of gravity position.

FLIGHT TEST ENGINEERING

Each FTE station replicates the flight-deck situation and provides dedicated external views of engines, flaps and slats, and landing gear by video. Real-time monitoring covers eight cockpit displays on dedicated configurable screens, including "many parameters that the pilots cannot see and access", according to Cail.

The main FTE station permits three engineers to manage and monitor all test parameters, many of which cannot be seen and accessed by the test pilots. Indeed, Cail is at pains to point out that the aircraft "is not configured by the pilots but by the FT engineers".

"It is very important that the FTE feels as if he is in the cockpit. To do so, we have some cameras in the cockpit so he can see what is going on also to get copies of the pilot's screens in the cockpit."

Accordingly, the principal station offers the possibility to modify the aircraft configuration.

"We are able to intervene directly. For the flight-control unit we can access the flight-control system computers and we are able to change parameters. That allows us to make a lot of changes in flight, so that saves a lot of time," explains Cail. Meanwhile, Airline1 stands by to maintain and support the first A350-1000 fleet until the new variant enters service. \\

140
The number of remote data acquisition units

120KM
Length of equipment cable routed all over the aircraft

6

6 // Japan Airlines (JAL) will fly both variants of the A350 XWB, having signed a purchase agreement for 18 A350-900s and 13 A350-1000s, plus options for a further 25 aircraft

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HH-60

SIKORSKY HH-60W

W advances

Before the first engineering manufacturing and development Sikorsky HH-60W helicopter takes to the air in 2018, infrastructure and test facility developments on the ground are being completed

Sikorsky reached a milestone in the development of the next combat rescue helicopter (CRH) for the US Air Force in early February, with the award of a US$203.4m contract to build five system demonstration test articles (SDTA). The five helicopters will be completed to production standard and are in addition to the four engineering manufacturing and development (EMD) aircraft already under development under a US$1.2bn contract. The first of these EMD helicopters is due to fly for the first time in 2018.

Ahead of flight testing, Sikorsky has also recently commissioned a 2,500ft² (762m²) systems integration laboratory (SIL) at its primary manufacturing facility in Stratford, Connecticut, to test key avionics and missions systems for the new helicopter.

The SIL was formally opened in December 2016 and has already begun test and development work for the CRH, which is designated the HH-60W. The USAF has a requirement for 112 HH-60Ws to replace its aging HH-60G Pave Hawk fleet.

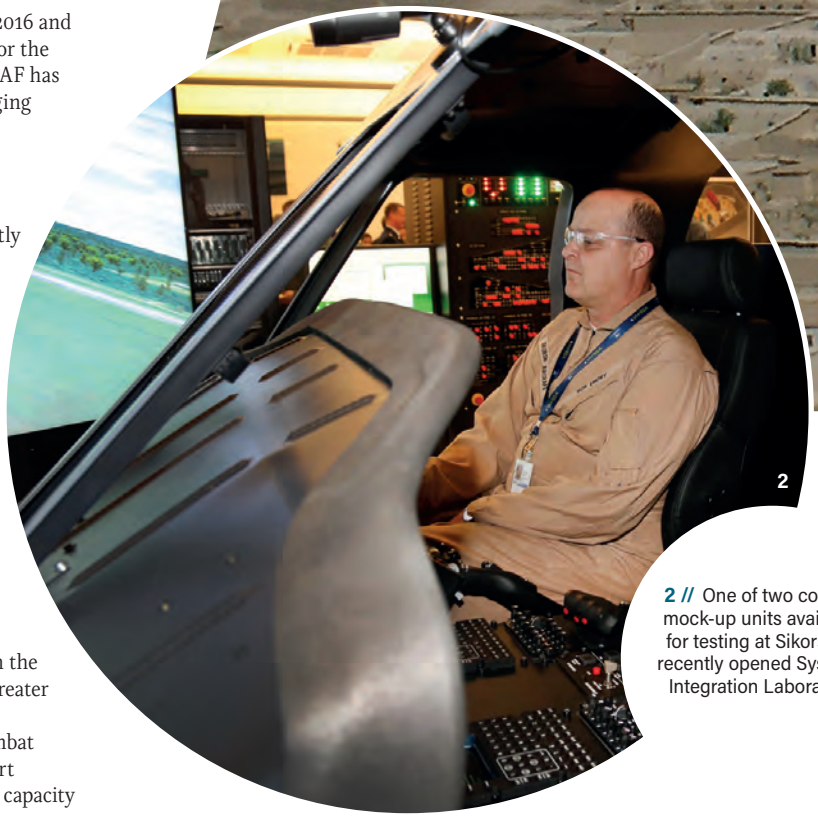
COMBAT RESCUE

Sikorsky is using the tried and tested UH-60M Black Hawk battlefield utility helicopter currently in production for the US Army as the baseline for its HH-60W development, but the new helicopter is not merely a modification of the older design. The USAF program of record is for a total of 112 HH-60W helicopters.

Sikorsky says the HH-60W is built from the 'ground up' as a CRH, with a comprehensive avionics and mission systems suite, additional internal fuel capacity and enhanced weapons carriage capability. Gross weight is increased to 22,500 lb (10,206kg) but the HH-60W utilizes the same General Electric T700-GE-701D engines, composite rotor blades and drive train as the UH-60M. This commonality of parts will reduce lifetime costs despite differing mission requirements between the USAF and the US Army (which needs to lift a greater number of troops over shorter distances).

The HH-60W is designed for long-range combat search and rescue and special operations support missions and has almost twice the internal fuel capacity

1 // Artist's rendering of the Sikorsky HH-60W Combat Rescue Helicopter



2 // One of two cockpit mock-up units available for testing at Sikorsky's recently opened Systems Integration Laboratory

2
Cockpit mock-up units in the Systems Integration Laboratory

4
Engineering manufacturing and development aircraft

5
System demonstration and test articles

as the baseline US Army UH-60M – 660 US gallons (2,500 liters), as opposed to 360 US gallons (1,360 liters). Sikorsky says this is sufficient to meet the USAF requirement for a 195 nautical mile (361km) combat radius.

A flexible external weapons system supports both 7.62mm and .50 caliber fixed forward and crew-served weapons. The cabin, cockpit floor and walls have improved armor protection against small arms fire.

The heart of the avionics and missions systems is the Lockheed Martin (now Sikorsky Missions Systems) Tactical Mission Kit (TMK), which integrates a number of largely off-the-shelf systems, including an AAR-57 missile and hostile-fire warning system, AVR-28 laser warning system, ALQ-210 digital radar warning receiver (DRWR), integrated chaff and flare defensive system, Link 15 tactical datalink (TDL), radar and a forward looking infrared (FLIR) system. The exception to the off-the-shelf philosophy in the TMK is the advanced mission systems computer, which is the only item being developed from the outset.

SYSTEMS INTEGRATION LAB

The major CRH program testing activity at the present time is the recently opened SIL, which includes four laboratories for testing the avionics, electrical power, electronic flight controls and integrated vehicle diagnostics systems. Sikorsky says that each system is due to be tested independently before it progresses to aircraft representative (fully integrated) testing.

"The SIL is unique only in that it is tailored directly to the requirements of the CRH program. We don't have to add all the dynamic components, engine controls and flight controls of the air vehicle," explains Tim Healy, director of Sikorsky's CRH program. "We do have some work that we have to do in that regard, but predominantly our SIL is to take the UH-60M 'backbone' avionics and modify them to meet CRH needs. A significant amount of that testing work is supporting the integration of the Lockheed Martin TMK."

Healy is a former USAF test pilot, with both operational and flight test experience on the HH-60G (including commanding a USAF Reserve Pave Hawk squadron in Afghanistan) and he also led the USAF's Bell-Boeing CV-22 Osprey development test team. He has

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COMBAT RESCUE HELICOPTER PROGRAM

The US Air Force Combat Rescue Helicopter (CRH) program seeks to acquire 112 long-range helicopters to replace the existing primary rescue helicopter fleet of Sikorsky HH-60G Pave Hawk helicopters, which entered service in the early 1980s.

The CRH will be required to perform demanding personnel recovery missions, including combat search and rescue, casualty evacuation and support for US Special Forces.

Sikorsky was teamed with Lockheed Martin for the bid, with a proposal based on the UH-60M Black Hawk in production for the US Army, but significantly enhanced to meet CRH mission requirements and internally designated the CRH-60. The team was announced the winner of the competition on June 26, 2014, with the award of the US$1.2bn engineering manufacturing and development (EMD) contract for an initial four helicopters.

The EMD contract also includes six aircrew and maintenance training systems, ranging from full motion simulators to discrete systems trainers such as the rescue hoist and landing gear.

The USAF officially bestowed the HH-60W designation on the helicopter in November 2014 and a year later, Lockheed Martin acquired Sikorsky in a US$9bn deal.

The HH-60W design features increased internal fuel capability, allowing greater range, and an increase in cabin space over the HH-60G. The helicopter is equipped with General Electric T700-701D engines, composite wide-cord main rotor blades and a fatigue and corrosion-resistant machined airframe, which includes improved armor protection, including against armor-piercing projectiles. It is also capable of air-to-air refueling using the probe-and-drogue method, to increase combat radius over the 195 nautical mile (361km) USAF requirement.

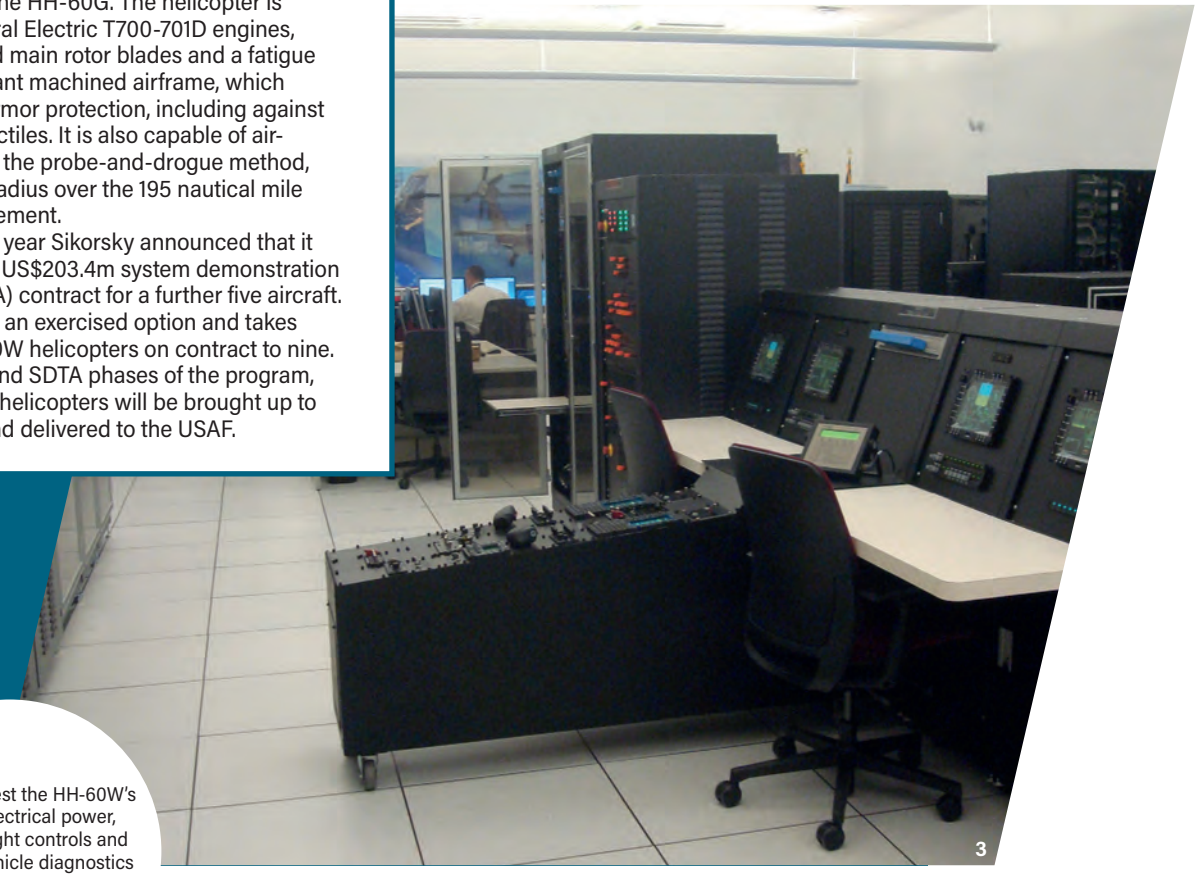
On February 2 this year Sikorsky announced that it had been awarded a US$203.4m system demonstration and test article (SDTA) contract for a further five aircraft. The SDTA contract is an exercised option and takes the number of HH-60W helicopters on contract to nine. Following the EMD and SDTA phases of the program, eight of the nine test helicopters will be brought up to final configuration and delivered to the USAF.

approximately 4,000 flying hours, accumulated in 41 types of helicopter, fighter and transport aircraft.

The SIL consists of two cockpit mock-up units, which allows two helicopters to be 'flown' simultaneously and places humans in the loop; a TMK integration bench; a software development bench; and a number of smaller software development benches that focus on the individual line-replaceable units in the HH-60W systems.

"The facility provides a simulated flight environment, allowing us to test key subsystems individually and then fully integrated. This will identify any issues before advancing to test flights and will help reduce the number of required flight test hours, resulting in time and cost savings for the customer," Healy adds. "The SIL is testing the helicopter systems; we're not developing new 'development tools'. The facility became operational in phases; it is fully operational now and that was achieved just after our ribbon-cutting ceremony on December 7 last year, with the delivery of the TMK in January. But we've been doing development and testing in there since last summer."

Under the CRH contract, Sikorsky is developing a second SIL that will be installed at the USAF's sustainment facility at Warner-Robins Air Logistics Center in Georgia. This second laboratory is already in production and will be delivered in the middle of 2018.



3 // SIL will test the HH-60W's avionics, electrical power, electronic flight controls and integrated vehicle diagnostics

4 // The Sikorsky CRH team and USAF representatives at the newly opened Systems Integration Lab

SOFTWARE TESTING

The Tactical Mission Kit is being developed by Sikorsky Mission Systems (Lockheed Martin prior to the recent merger of the two defence giants) and the software is initially being tested in a dedicated SIL in the company's facility in Owego, New York.

"They then deliver it to us here in Connecticut in blocks, or software releases, and we feed it in to our SIL to continue with the integration of the overall system," Healy continues. "The culminating milestone is in what we call our flight-worthy air release, so all the software will culminate with a single flight-worthy release software drop, which we call system configuration seven. We'll go through several system configurations and will have an airworthy release in mid-2018."

Testing in the SIL is overseen by USAF representatives, who visit regularly and continuously review the test results. "The USAF will also oversee the overall test program, not just the SIL, and we're operating in an integrated test team environment where the Air Force and Sikorsky will both participate side by side," Healy adds. "We will share all the data openly with each other, because that has been proved on many programs to be the most efficient way to do developmental testing."

The release of the flight-worthy software is timed to support the beginning of the flight test campaign, which is also due to get underway in 2018. Following this, Sikorsky's SIL will be used for continual development work and the testing of future software upgrades, as well as activity to support foreign military sales of the HH-60W, should customers emerge.

WORKING TOWARD FLIGHT TEST

Because the HH-60W will be operating at higher gross weights than the baseline UH-60M, consideration is being given to structural fatigue cracking from the outset – a lesson learned from the HH-60G and similar variants, which operated at weights higher than they were initially designed for.

"There is a lot of analysis that supports the planned life of the airframe, defining the usage spectrum, loads and criteria analysis, for example, and that is all underway right now," Healy says. "We also have a full program of instrumentation and flight load survey, which will begin after the first flight in 2018."

112
HH-60Ws included in the US program of record (orders)

2,500FT²
Total area of the Systems Integration Laboratory

The additional five helicopters awarded under the February 2 SDTA contract will support the development test program and also provide initial flight training for USAF experimental test and instructor pilots. Sikorsky says these aircraft will follow on from the four EMD aircraft, with deliveries to begin in early 2019 and, once they have been delivered, they will allow the USAF to conduct initial operational test and evaluation activities.

Assembly of the four EMD helicopters will begin early this year, with delivery in 2018. The overall program is running ahead of the contracted schedule, with SDTA deliveries set to begin in 2020, following the EMD phase and some six months early.

"The program baseline is 75 months in total, from contract award to the end of the SDTA phase, a point which known as RAA – required assets available," Healy concludes. "We are executing to a schedule that will get us to that RAA in 69 months, on March 26, 2020." \\

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// ROB COPPINGER

Ice in fuel pipes, pitot tubes, across wing surfaces and inside engines has been the cause of many aviation accidents, with researchers still struggling to crack the fundamental processes of icing

cryst

1 // The Global Aerospace Centre for Icing and Environmental Research (GLACIER) in Manitoba, Canada, is used to certify large turbine engines *(Photo: Pratt & Whitney Canada)*

dldear?

Despite the decades-long history of aircraft encountering ice and airline and government fleets employing de-icing equipment and drawing up policies on how to avoid icy weather, fundamental research into ice particles is still needed and is now being undertaken in North America and Europe.

"As of 2015, both the [US government's] Federal Aviation Administration and the European Aviation Safety Agency require the engine manufacturers to address the issue of ice crystals," Canada's National Research Council (NRC) aerospace research council officer, Jim MacLeod, tells *Aerospace Testing International*.

Icing in the engine can shut it down and pipes can be blocked from supplying fuel. Elsewhere, the build-up of ice on a wing will affect its aerodynamic properties leading to a potential stall. All these icing and flight stability phenomena have been the cause of many fatal and non-fatal crashes (see *Ice crashes*, p40). However, there is not only one kind of ice particle, there are three types classified by scientists (see *What is ice?*, p39). MacLeod explains that because of the changing requirements for engine certification, the manufacturers need to understand more than just the basic effects of these classified super-cooled liquid droplets, known as ice.

It may seem strange after 100 years of flight, but the properties of atmospheric ice particles and how they accrete on aircraft is not fully understood. "It's not an exact art at the moment," comments Cranfield University senior lecturer Dr David Hammond, on the modeling of ice particle accretion.

Cranfield, in the UK, has its own icing tunnel to conduct experiments that contribute to ice accretion modeling tools. An aircraft component can be placed in this tunnel with the temperature as low as -30°C and airspeeds of up to Mach 0.5 (383mph) accelerating mists with a density as low as 0.0134 oz/yd^3 (0.5g/m^3) at the model, delivering droplets of water as small as 15µm or up to 300µm, to simulate flying through a cloud. The tunnel has a mass flow rate of 176.4 lb/sec (80kg/sec). The tunnel has space for components up to 29.9in (761mm) by 29.9in.

3,000RPM
Jet engine low pressure fan speed during GLACIER tests

150,000
The power of future gas turbine engines GLACIER will be able to test (lb force)

0.5
The density of a mist in Cranfield's icing tunnel (grams per cubic meter)

1,000
Size of a natural ice particle (micrometers)

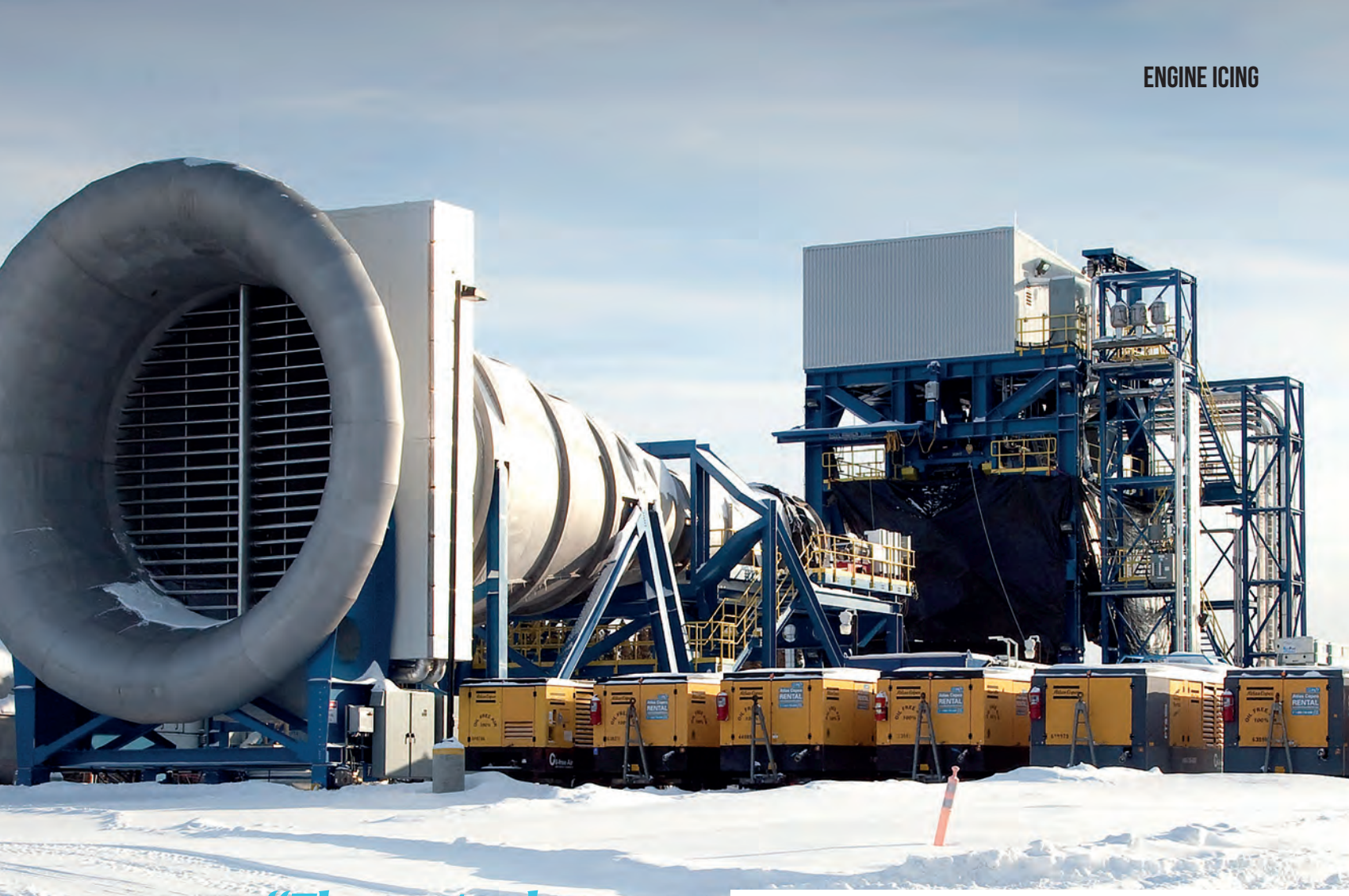
INTERNATIONAL EFFORTS

Hammond has worked on a range of European Union-funded (EU) projects about ice including its formation within fuel pipes, and its impact on engines and probes, such as pitot tubes, and protection systems. Since mid-2016 he has been involved in a £17.6m (US$22.2m) UK government project managed by its Aerospace Technology Institute. Called Wing Design Methodology Validation (WINDY), the project, led by Airbus, lasts until October 31, 2019.

WINDY's scope extends beyond just icing. Hammond says that

2 // Note the large horizontal array of spray bars of NASA's icing research tunnel, at its Glenn Research Center *(Photo: NASA/Marvin Smith)*

2



"The center has an icing research tunnel, which can produce airspeeds up to 350kts and temperatures as low as -25°C"

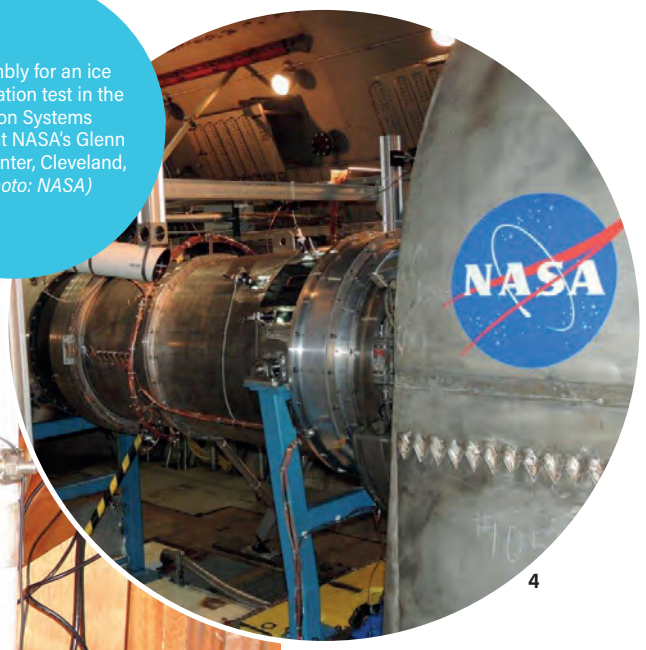
3 // The GLACIER facility is a specialized 9m-diameter wind tunnel that sprays super-cooled water mist into the world's largest aircraft turbines (*Photo: Rolls-Royce*)

the European aircraft manufacturer is interested in the impact of ice on the airframe. "We capture the [droplet] shape in some detail, we try to get some heat transfer information about the growing ice shapes, and with that we can verify or illustrate any problems in the [software] icing codes we're using and also suggest leads into how the codes can be refined in the future," he continues.

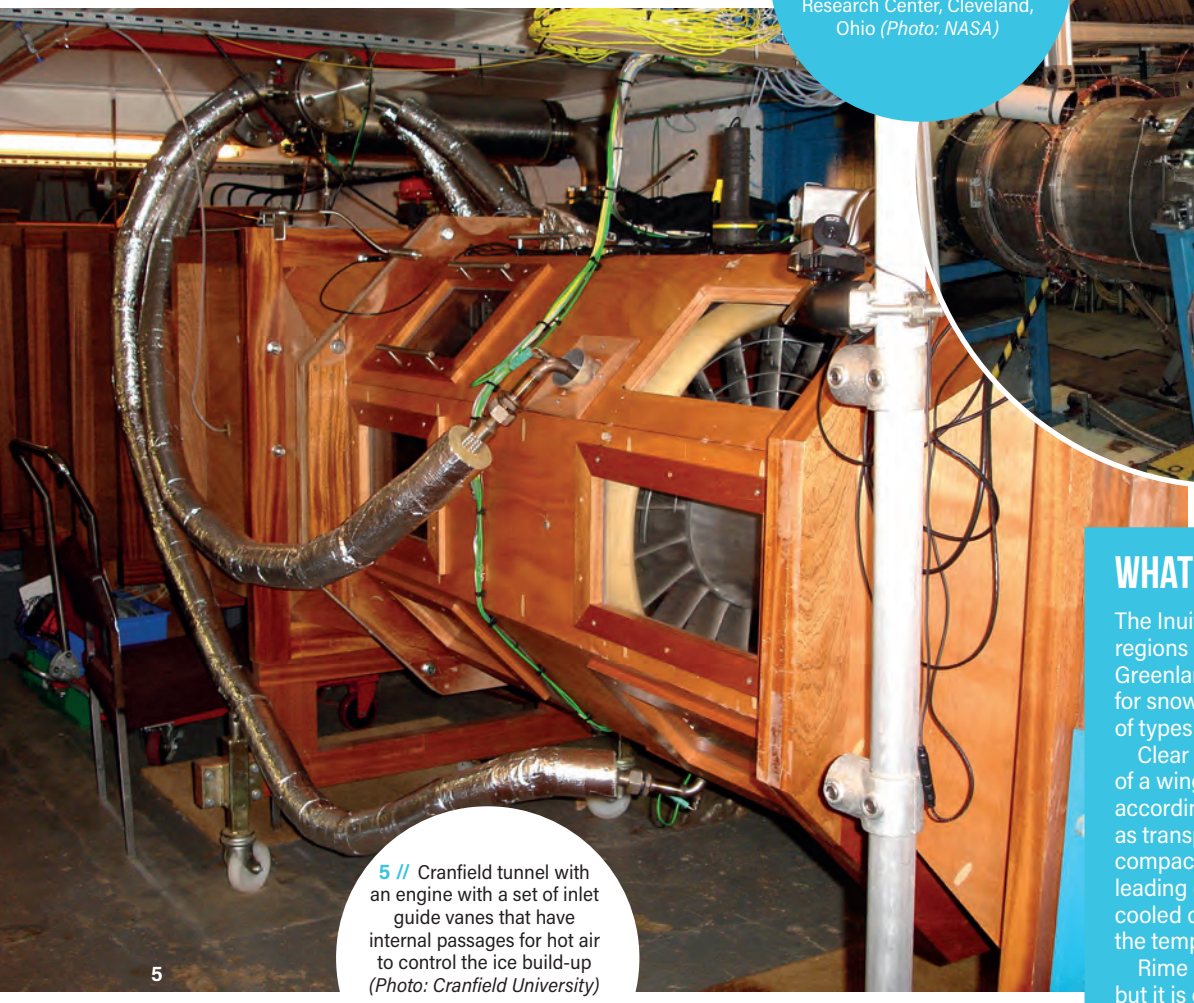
Hammond has also carried out work for NASA. The US space agency's John H Glenn Research Center in Ohio has been installing new ice-related equipment in the past few years to study super-cooled droplets that become ice crystals. The center has an icing research tunnel, which can produce airspeeds up to 350kts and temperatures as low as -25°C. Its super-cooled water droplets can be as small as 49.78µm and mists can be produced for cloud effects. It can test an artefact 6ft high, 9ft wide and 20ft long.

Like Hammond, the Glenn researchers are looking at the physics of water at low temperatures, how it crystallizes as ice, how that freezing water behaves as it encounters surfaces, how it sticks to aircraft components and also how ice particles, which typically occur naturally at 1,000µm in size, break into smaller pieces and reach the engine core.

"All of our tests so far have been to provide databases [of data] to use to modify our existing tools," explains Ashlie Flegel, icing branch-engine technical lead at



4 // Assembly for an ice crystal formation test in the Propulsion Systems Laboratory at NASA's Glenn Research Center, Cleveland, Ohio *(Photo: NASA)*



5 // Cranfield tunnel with an engine with a set of inlet guide vanes that have internal passages for hot air to control the ice build-up *(Photo: Cranfield University)*

Glenn. Those tools are computational fluid dynamic (CFD) software, using a computer to model airflow around an aircraft. "We have legacy CFD software and we're trying to modify it to accept ice crystal icing events. It's mainly been developed for traditional airframe super-cooled liquid water icing events," adds Flegel. However, pollution – particles of industrial emissions contaminating the atmospheric moisture – is not being considered in the fundamental calculations.

RISKY SCIENCE

Those databases and CFD software were to recreate, in Glenn's facilities, the experience of a test aircraft, a BAE Systems BAe 146, and one of its Textron Lycoming ALF502R-5 turbofans. A fully instrumented BAe 146 has been flown by NASA through clouds to study the effects of ice crystal formation on the aircraft and in its engines. One of that BAe 146's four engines, provided by Honeywell (which bought Textron Lycoming), was placed inside a recently modified altitude test chamber at Glenn.

"We did duplicate an event on an engine that experienced a flight test," Glenn research test engineer Dr Michael Oliver explains. "The engine that we tested for the first time was the exact engine NASA had put in an aircraft and flown around. It had an ice crystal icing event on and they recorded all that information while flying."

By 2013, spray bars had been installed at Glenn's altitude chamber. With the information from the BAe 146 flight, the same sort of ice crystal cloud could be produced using the spray bars with the same engine in the chamber. "A 36,000ft altitude ice crystal cloud – we can make it and test your engine," says Oliver. He and his colleagues stress that this altitude test chamber with an ice crystal cloud capability is the only one in the world.

WHAT IS ICE?

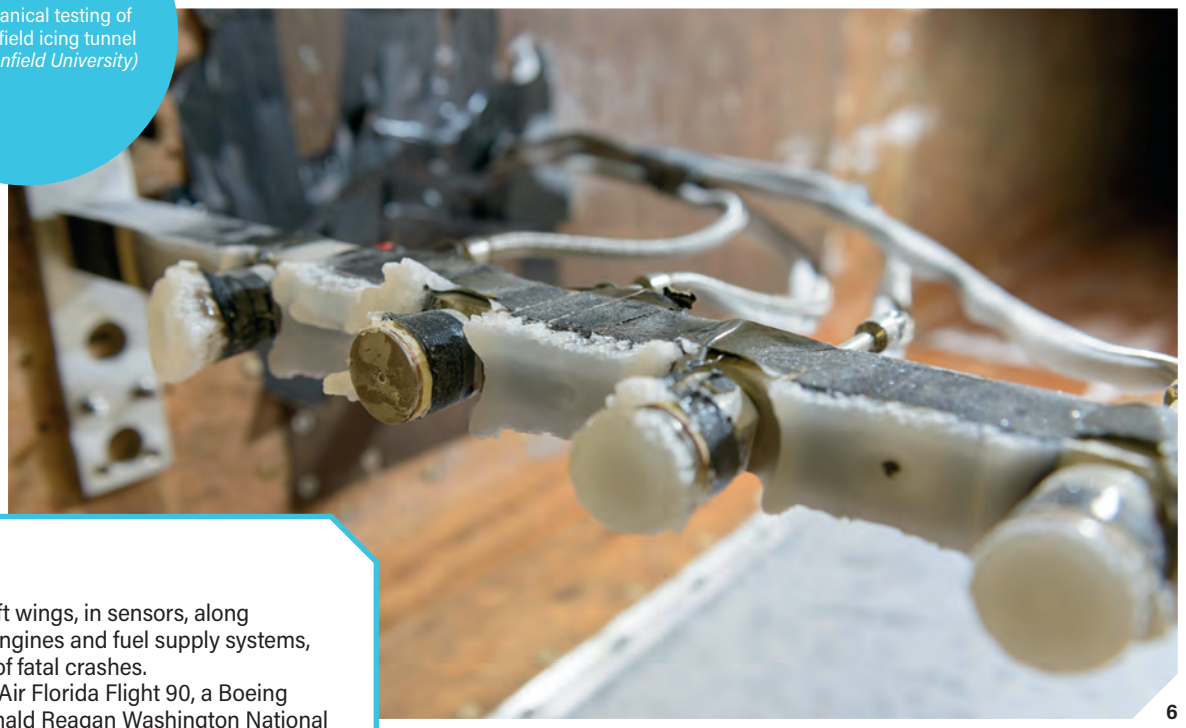
The Inuit people, who inhabit the Arctic regions of Canada, Alaska, Siberia and Greenland, are known to have many words for snow and for scientists there is a variety of types of ice when dealing with aircraft.

Clear ice that forms on the leading edge of a wing must be prevented from forming, according to aviation authorities. Described as transparent, homogeneous, smooth and compact, it forms as cones on the wing leading edge. But it begins life as a super-cooled droplet that is found in a cloud where the temperature is close to 0°C.

Rime ice also forms on a leading edge, but it is opaque and white and can be brittle. Formed from super-cooled cloud droplets frozen rapidly in bubbles of air, its home is a cloud at a temperature below 0°C.

Not all ice particles need a cloud. Hoar frost forms from the sublimation of water vapor into ice. In its crystalline form, it looks like needles or feathers and can be seen across the wing surface.

Finally, there is mixed ice. As the name suggests, this is a mix of the above three forms of ice. It is described as whitish and brittle and forms in clouds where the temperature fluctuates. It is like rime ice in its formation.



6 // Mechanical testing of ice in Cranfield icing tunnel *(Photo: Cranfield University)*

ICE CRASHES

Ice accretion on aircraft wings, in sensors, along fuselages, and inside engines and fuel supply systems, has caused a number of fatal crashes.

On January 13, 1982, Air Florida Flight 90, a Boeing 737, was to fly from Ronald Reagan Washington National Airport, Washington DC, to Fort Lauderdale, Florida. Ice on the aircraft led to it crashing just after take-off killing 74 of the 79 passengers and crew on board.

Air France flight 447 crashed into the Atlantic Ocean in June 2009 because ice had blocked the pitot tube sensor, switching off the autopilot. This led the aircraft into stall, from which the pilots could not recover.

Loss of both engines due to ice ingestion brought Scandinavian Airlines Flight 751's flight to an end on December 27, 1991. The airline's McDonnell Douglas MD-81 took off from Stockholm Arlanda airport and crashed in a field shortly afterward. Eight of the 129 passengers and crew were seriously injured.

Ice in the fuel system was the problem for a British Airways Boeing 777-200, which landed just over a 1,000ft short of the runway at Heathrow Airport on January 17, 2008. Both engines had failed, but this time the cause was ice blocking fuel pipes. There were no fatalities, but 47 were injured including one seriously.

The Glenn researchers added that another reason for the research, beyond safety, is that aircraft normally descend to a lower altitude to avoid icy clouds, but at the lower altitude the atmosphere is thicker. The aircraft must burn more fuel to reach its destination. As well as safety, airlines would save fuel costs if they were able to fly at a consistent cruise altitude, typically 38,000ft.

So, part of the ongoing work is to understand the processes to be able to provide data for engine manufacturers to recreate conditions on their own test stands. Oliver explains that Glenn's altitude chamber is not able to test an airliner's engine because it cannot produce enough airflow, no more than 330 lb/s (149.7kg/s). To test full-scale airliner engines from the likes of General Electric, Pratt & Whitney and Rolls-Royce, the chamber would have to produce a lot more airflow.

To test full-scale airliner engines, Pratt & Whitney (P&W) uses the NRC, P&W Canada (PWC), and Rolls-Royce joint venture, the Global Aerospace Centre for Icing and Environmental Research (GLACIER) in Manitoba, Canada.

"The center can accommodate the largest aircraft engines in use today and will support the future growth of gas turbine engines of up to 150,000 lbf with fan diameters of up to 140in," PWC tells *Aerospace Testing International*. The GLACIER test stand is equipped with an icing system that has been designed and supplied by the NRC.

When Rolls-Royce uses GLACIER, it "operates the engine at several different conditions, from just above freezing, but mainly 0°C to -25°C or -40°C, and see how the engine reacts", says Rolls-Royce test support center chief Paul Mason. He explains how GLACIER has strobe lighting so the ice growth can be photographed in detail. "We have a strobe light and high-speed cameras that mean, though the engine is running at 3,000rpm on the fan, we can see the ice build-up from the cone of the engine down to the spinner at the front and forming on the blades themselves."

The Glenn researchers say there are no answers at present to the question of ice crystals. In time, between Ohio, Manitoba and Cranfield, a theory might emerge that can deliver a solution, but, until then, the research will continue, to try to validate the data models, so scientists and engineers can fully understand this slippery natural phenomenon at work. \\

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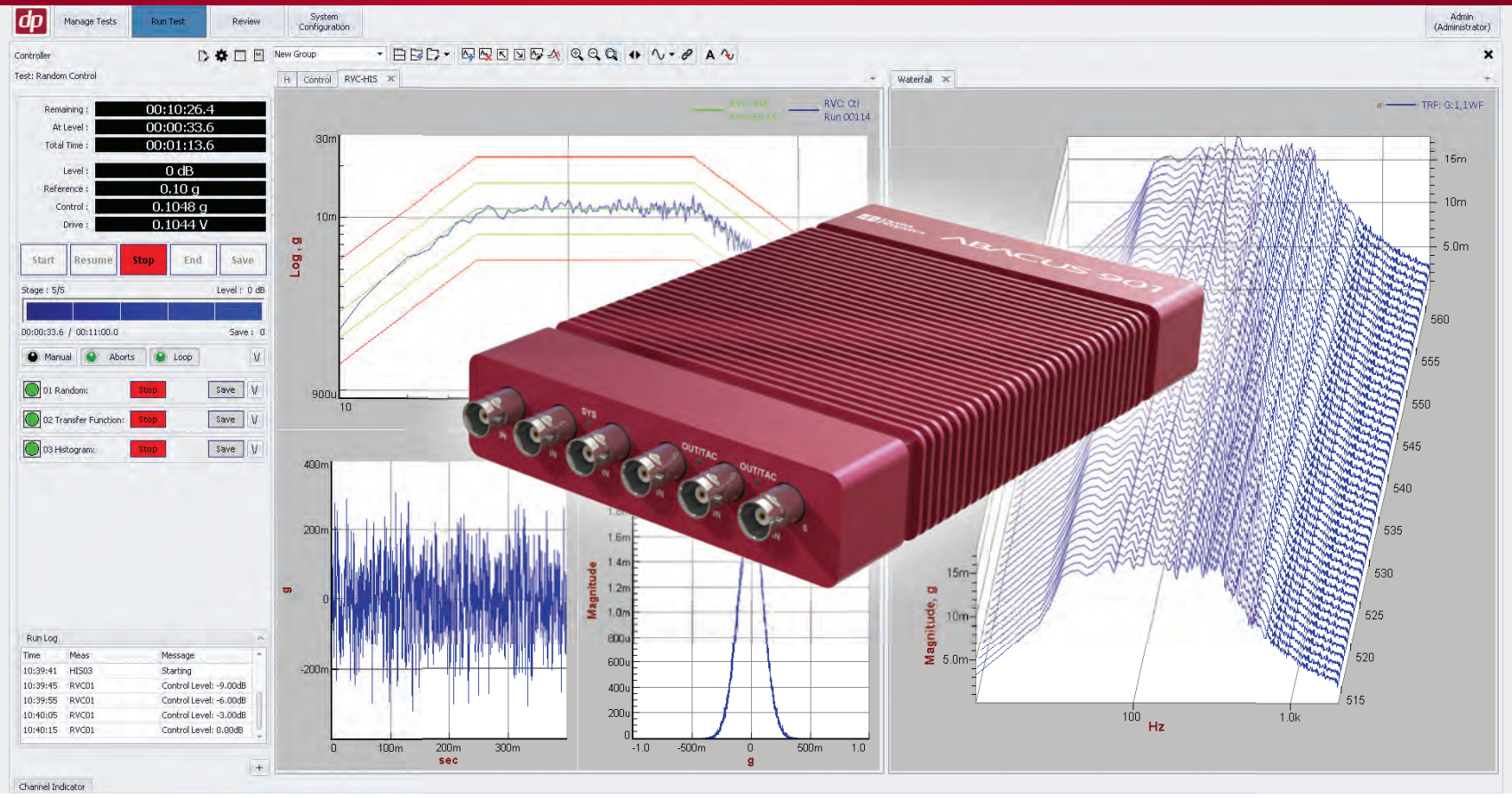

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Global outlook

The latest in Bombardier's line of Global business aircraft, the Global 7000 achieved first flight in November 2016. Steve Patrick, director, flight test operations and safety, Global 7000 Flight Test Team, discusses the type's busy, five-aircraft flight test program

1 // Bombardier had accomplished 18 flights and more than 54 hours of flight testing of the Global 7000 by mid-January 2017

2

2 // The Global 7000 completed its first test flight over Toronto on November 7, 2016, flying for 2 hours and 27 minutes

3 // A test pilot boards a flight test vehicle from the Global 7000 program

3

TEST FLEET

A five-strong fleet of Global 7000 FTVs will "ensure the appropriate certification for entry-in-service", according to Patrick. He describes their individual roles:

FTV1, or 'The Performer', completed the first flight and will be used to thoroughly test flight characteristics and performance.

FTV2, 'The Powerhouse', will test the complete envelope.

FTV3, 'The Navigator', will evaluate the avionics and electrical systems.

FTV4, 'The Architect', will have a purpose-built interior to validate the features of the aircraft's state-of-the-art cabin interior and technologies.

FTV5, 'The Masterpiece', will serve as the entry-into-service validation aircraft. It will pave the way for the first production Global 7000's entry into service in the second half of 2018.

Bombardier's specification for the Global 7000 must be among the most ambitious yet attempted in business aircraft design. The Canadian airframer is creating an aircraft capable of carrying eight passengers and four crew 7,400 nautical miles at Mach 0.85, yet certified as standard for steep approaches into airports exemplified by London City.

At the top end of its performance range, Bombardier says the Global 7000 will reach Mach 0.925, although operators will be more interested in its typical Mach 0.9 cruise at an initial 43,000ft cruising altitude, rising toward the 51,000ft maximum operating altitude.

New-generation General Electric Passport engines and an advanced transonic wing are major factors helping Bombardier achieve this rare combination of range, speed and airfield performance. Global 7000 pilots will also appreciate the aircraft's extensive avionics fit, integrated under Bombardier's Vision system, along with fly-by-wire controls and "the security of the industry's most complete flight envelope protection". Meanwhile, passengers will relax or work efficiently using the aircraft's standard Ka-band connectivity, while streaming high-definition content onto the Global's large screen TV system.

It's a configuration the related Global 8000 will share. Shorter by 9ft, the Global 8000 promises the longest range of any business aircraft ever, but although it appears to have survived rumors of cancellation, it is not yet subject to a published development timeline.

Steve Patrick, director, flight test operations and safety, Global 7000 Flight Test Team at the Bombardier Flight Test Center (BFTC), is taking on the challenge of preparing the extraordinary Global 7000 for service.

FLYING START

The first Flight Test Vehicle (FTV1), manufacturer's serial number 70001, registered C-GLBO, completed the type's maiden flight, from Toronto's Downsview airport, on November 4 last year. Describing the sortie, Patrick says, "The flight was dedicated to testing basic system functionality and assessing handling and flying qualities. It lasted approximately 2 hours 27 minutes, during which all flight controls were exercised. The pilots reported that the systems and aircraft performed as expected. The flight crew conducted a climb to 20,000ft and the aircraft reached a planned test speed of 240kts."

A Global 5000 business jet flew 'chase' on the maiden sortie, capturing air-to-air photography and video. It also enabled visual inspection of the Global 7000 in flight, a vital function checking for lose panels or other structural irregularities.

PREPARATION

First flight was the culmination of a long process of definition, design and ground test. The Global 7000 program's primary driver is the requirements of its customers, as Patrick explains: "Customer feedback throughout the Global 7000's development is important to Bombardier. Even before putting pen to paper, our industrial design team worked closely with our engineers and customer representatives to understand what defines a truly exceptional cabin experience."

Subsequent testing included a plethora of techniques. "Computer modeling and simulation are used in many areas of aircraft design. Aerodynamic modeling is the basis for developing the flight control laws, which are further tuned on test rigs prior to flight."

"Computer models also allow us to assess the vibration characteristics of the structure in order to avoid flutter. Noise is predicted using acoustics models to assess the aircraft noise footprint. Thermodynamic modeling is extensively used to predict temperature in enclosed spaces and assess potential failures, such as duct ruptures. Ice accretion models are used to predict the size of ice build-up on unprotected surfaces. System simulation models are used extensively to assess behaviors in failure conditions.

"We used a series of wind tunnel tests to validate the Global 7000's aerodynamic configuration. These included low-speed, high-speed and high-lift testing, as well as icing tunnel tests. The trials allow us to fine-tune the key aerodynamic parameters of lift and drag. They also provide valuable loads information that's used to design the structure."

Ground-based rigs were used in an extensive trials campaign that informed aircraft configuration development, validation and optimization in the years preceding first flight and, according to Patrick, will support subsequent certification flight tests.

He notes, "Ground-based testing is aligned with modeling and simulation of components, and embedded within the product design and development processes at Bombardier. It ranges all the way from details at structural component level to highly integrated rigs that accurately represent the entirety of multiple aircraft systems, including avionics, systems such as electrical and hydraulic power, primary and secondary flight controls, and many others.

"Ground-based trials on the FTVs, for example, include high-intensity radiated field/electromagnetic interference, fuel system calibration, and cold and hot weather testing. In addition, ground-based testing is an important part of the certification program, with many of the ground rig tests contributing information used to certify the product."

0.925
Mach maximum speed

0.9
Mach typical cruise speed

0.85
Mach long-range cruise speed

17
Global 7000 passengers in standard configuration

Patrick says the Global 7000 test rigs and simulators played a crucial role in crew preparations for first flight: "Bombardier Flight Test Center crews make extensive use of simulators and test rigs prior to flight testing. The Reconfigurable Engineering Flight Simulator [REFS] allows for development and preflight validation of control laws. The System Integrated Test Simulator [SITS] enables more specific testing of individual systems and their compatibility with other systems; for instance avionics, powerplant and fuel can be assessed simultaneously. Finally, the Engineering Simulator (ESIM) is a fixed-base platform combining a fully representative aircraft cockpit, actual aircraft components and software, and aerodynamic flight models with a state-of-the-art visual system. It allows every mission to be pre-flown, if required, with the aircrew completing the premier mission on the ESIM prior to actual first flight."

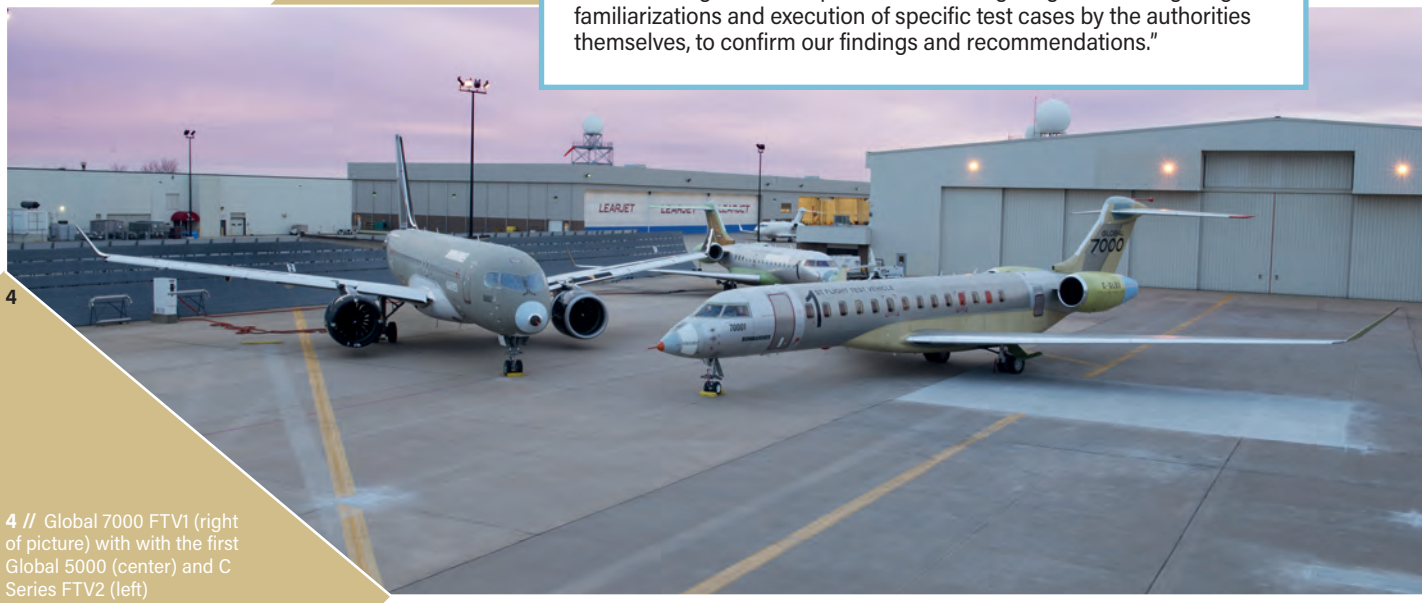
Each of the five FTVs is being configured to suit its primary mission. "This includes operation stations,

WORKING WITH THE REGULATOR

As part of the close working relationship between the product development team and the certification authorities, the BFTC team works directly with the flight test groups at Transport Canada Civil Aviation, the Federal Aviation Administration and European Aviation Safety Agency.

Patrick notes, "These groups actively participate in the flight test program to confirm the findings of our own test crews. Most of our test pilots, in addition to having extensive careers and being graduates of the world's best test pilot schools, are also Design Approval Delegates.

"In this capacity, Transport Canada has delegated much of its approval activity to these crews. This delegation depends on continued close working relationships achieved through regular meetings, flight familiarizations and execution of specific test cases by the authorities themselves, to confirm our findings and recommendations."



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4 // Global 7000 FTV1 (right of picture) with with the first Global 5000 (center) and C Series FTV2 (left)

equipment racks, fixed and transferrable ballast, and controls for external measurement devices –trailing static cones, liquid water content icing probes, and so on," Patrick says. "Every test aircraft has extensive instrumentation configured to suit its primary mission. This will involve analog and digital parameter measures on airframe, engines, systems, electrical, avionics, air systems, pneumatics, hydraulics, fuel and any other system under test. Digital video cameras are used to oversee cockpit activity, with a series of external cameras used to view landing gear, wing leading edges, engine inlets, tail, etc."

111FT 2IN
Global 7000 fuselage length

104FT
Global 7000-8000 common wingspan

27FT
Global 7000-8000 common height

16,500 LB
Flat-rated thrust per engine for both models at ISA +20°C

5

6

5 // The Global Vision Flight Deck features four LCD screens, a head-up display system, an enhanced vision system and a synthetic vision system

6 // The cabin seats 17 passengers in standard configuration

GLOBAL PASSPORT

Global 7000 power comes from the General Electric Passport turbofan, installed as an integrated propulsion system in a Nexelle nacelle. Although designed to suit the particular range and speed requirements of the Global 7000 and 8000 models, the Passport also leverages technologies proven in the manufacturer's own GE90 and GEnx commercial engines, and the LEAP turbofan created with Safran.

GE announced the Passport's FAA certification on May 23 last year, after an extensive test program that began in November 2013 with its ground running of what it calls the 'First Engine to Test'. April 2014 saw icing certification testing before flight trials on the port inner-engine pylon of GE's Boeing 747-100 testbed, between December 2014 and April 2015.

At the time of the certification announcement, GE said the engine had "accumulated more than 2,400 hours and 2,800 cycles in ground and flight testing. By the time the Passport enters into service, it will have accumulated the equivalent of 10 years of flying for a Global 7000 or Global 8000 aircraft operator with more than 4,000 hours and 8,000 cycles."

MOVING ON

On November 21, 2016, FTV1 flew to the Bombardier Flight Test Center in Wichita, Kansas. Patrick confirms the move was ahead of schedule, but declines to comment on the subsequent test timeline: "For competitive reasons, we are not disclosing further milestones in the flight testing program. We'll communicate all relevant milestones upon their completion."

Bombardier will achieve those milestones through a program of carefully designed and performed individual flight tests, explains Patrick: "Each flight follows the 'recipe' developed over the years by BFTC personnel and includes lessons learned from the recent testing and certification of the C Series airliner. Early on the morning of the test, the team assembles for a short 'configuration briefing' to confirm that the aircraft is set up as requested and no new items need to be considered. The crew then steps to the aircraft and the engineers go to telemetry if the flight is being monitored in real time. Mission durations vary based on operational requirements.

"With the flight completed, data is passed to the maintenance and engineering teams; they discuss the test results and complete their initial data review. Some data is analyzed in real time via telemetry or onboard test personnel. On completion of the debrief session, the teams move on to preparations for the next flight, including reviewing the test card. Each aircraft has multiple crew members who stagger their activities such that testing can be supported every day if required."

Patrick is also happy to reveal details of trials planned to take the Global 7000 FTVs away from Wichita: "The test aircraft will deploy for several reasons, including hot and cold environmental testing, runway performance, natural icing, high-altitude airport compatibility, and 'route proving', which we refer to as 'function and reliability' testing. Many of the deployments are in the USA and Canada, but international deployments can also be expected."

Speaking in mid-January, he added, "We won't disclose the length of the flight test program, but it's progressing very well and we have a robust schedule planned. We've accomplished 18 flights and more than 54 hours of flight time. We remain focused on meeting the program's development and certification schedule and the aircraft's entry-into-service in the second half of 2018." \\

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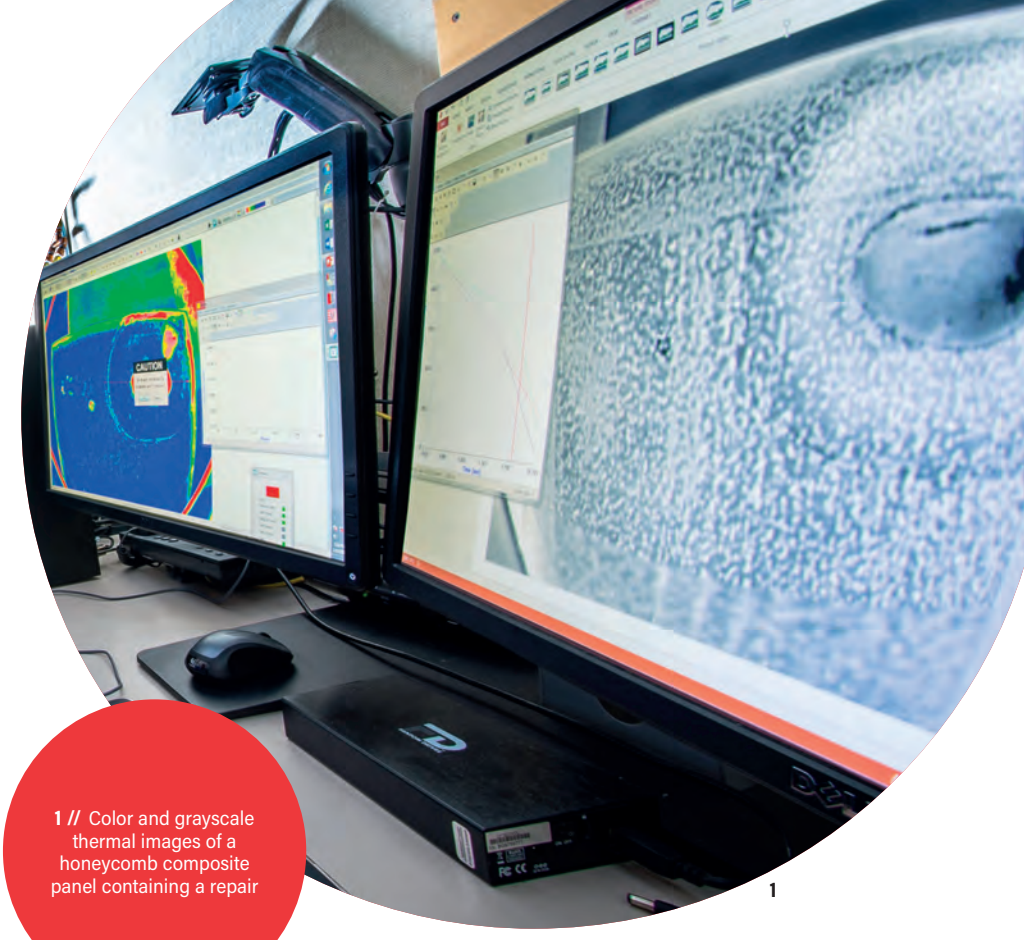
The flaw

MEET JEFF THOMPSON, TECHNICAL FELLOW AND LEAD ENGINEER OF THE BOEING RESEARCH & TECHNOLOGY IN-SERVICE NON-DESTRUCTIVE INSPECTION GROUP



1 // Color and grayscale thermal images of a honeycomb composite panel containing a repair

1

// HOW DID YOU BECOME A TEST ENGINEER?

My path to non-destructive testing (NDT) actually started with 'destructive' testing. I was hired into Boeing directly from college back in 1984, when I joined the shock physics lab and performed both basic research and testing using a railgun [electromagnetic launcher] to impact materials and determine how they reacted under high stress conditions by smashing things together at high speed. The railgun was funded through the strategic defense initiative (known as the Star Wars program). After four years of railgun testing, 'peace broke out' and funding for railgun research and testing was terminated. I received a patent for a railgun concept. Since that time, railguns have made a big comeback for military applications. The tools necessary to characterize railgun performance and material evaluation involved electromagnetic, optical and ultrasonic sensors, which later enabled me to get the job I have now in non-destructive testing. My physics and astronomy degree enabled me to land a job in the signature technology organization within Boeing, where I helped to develop infrared sensors for the F22 and methods to test the sensors. When work was completed on the F22 demonstration/validation phase, I wanted a new challenge, so I applied for my current job.

// IS TESTING A RAILGUN AS MUCH FUN AS IT SOUNDS?

The railgun was used as a tool to launch projectiles into materials to identify how they responded to high stress. We also tested components that would be part of a 'smart projectile' that would be launched from a railgun. At that time no one knew how the electronic and other components that would make up the smart projectile would react to extremely high acceleration and magnetic field effects. Much of the testing relied on cathode ray tube oscilloscopes, whose data was recorded by means of a Polaroid camera. There was not digital data capture back then. It was all analog and there was one opportunity to get the settings correct to capture the required data when the railgun was fired. But yes, it was a lot of fun!

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

Estimating results or order of magnitude calculations is an art form. Back-of-the-envelope calculations are very useful when planning for a test, or determining whether new information or results make sense. It is a skill that most of the old engineers had when I started my career, but far fewer of today's possess the same capability. The information necessary to perform the calculations at that time primarily came from books and published papers. Without such knowledge, calculations could not be made. Now, information is widely available on the web. Since we are all now managers of information, there is less need to memorize values, mechanical properties, or other information useful for an occasional sanity check. However, without a feeling for what should be a reasonable result, gained through the basic understanding of some key values, it is much more difficult for new engineers to question unreasonable results. Having a basic understanding of what a reasonable answer should be, prior to performing a test, is essential to understanding whether the results make sense.

"Back-of-the-envelope calculations are very useful when planning a test"

// TELL US ABOUT YOUR CURRENT JOB.

I am a technical fellow in the in-service NDT group. I lead a team responsible for developing and implementing NDT procedures that airlines and maintenance facilities use to inspect their aircraft. My team is funded by the Commercial Aviation Services organization to support airlines around the world, providing technical assistance, training and NDT procedures for fleet use. I have been on 135 trips for Boeing to 28 different countries. In addition to my in-service support, I am the Boeing Enterprise Level 3 in Thermography [infrared testing] responsible for training and qualification of personnel within Boeing and approval of thermography systems

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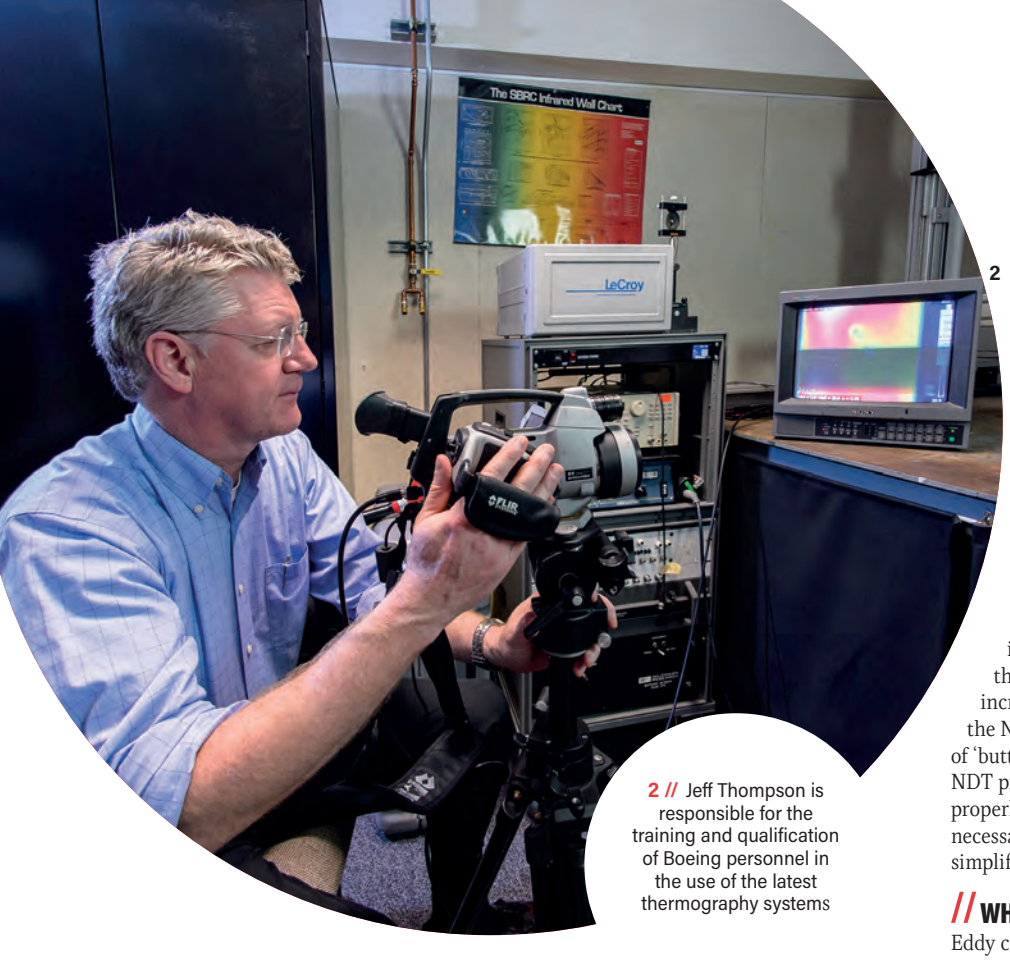

2 // Jeff Thompson is responsible for the training and qualification of Boeing personnel in the use of the latest thermography systems

at supplier facilities. Thermography is as close as you can get to applying an astronomy degree to industrial applications.

// DESCRIBE A TYPICAL DAY.

Aircraft must be periodically inspected to ensure they are free of defects that could affect their performance. The ability to examine the airplane must be considered in the design phase to ensure easy inspection is designed into the structure and our airline customers can perform the necessary tasks. This requires that in-service inspection be considered for the entire lifetime of the airplane, so my team is involved from the cradle to the grave of an aircraft. I routinely interact with design/stress engineers to ensure appropriate inspection methods are applied using reliable detection criteria for future inspection tasks. Providing an answer can involve designing and fabricating reference standards that replicate the key features of the structure to be examined to assure inspection reliability. Fielding NDI questions; directing the inspection effort of my crew who support long-term, scheduled inspections; solving critical emergent inspection problems; reviewing and approving all NDT procedures; and working on a variety of thermography inspection applications all help to fill my day.

// WHAT ARE YOU WORKING ON RIGHT NOW AND WHAT ARE THE CHALLENGES?

I'm currently focused on the in-service inspection of metallic and composite structures for Boeing aircraft already in the fleet, as well as inspection concerns for new models and advanced structures. Regarding the challenges, new multisensor inspection equipment available for in-service inspection has much greater capability than equipment available only a few years ago. With increased capability comes increased complexity of the NDT procedures. In many cases the exact sequence of 'buttons that must be pushed' must be specified in an NDT procedure in order to calibrate the equipment properly. Future reduction in calibration complexity is necessary to reduce the calibration burden through simplification of the operator interface.

// WHAT NDT METHODS ARE AT YOUR DISPOSAL?

Eddy current, ultrasound, x-ray, fluorescent penetrant, magnetic particle, thermography, and remote visual inspection are all commonly used methods, listed in order of most to least common use for in-service inspection.

// WHAT IS THE LATEST METHOD YOU HAVE STARTED TO USE?

Many new applications continue to be explored and implemented both in the factory and for in-service airplanes, however thermography in particular has improved rapidly over the past 20 years. Inspection applications that were once out of reach of thermography are becoming possible due to improvements in low-cost infrared cameras and improved image acquisition/processing techniques that provide defect quantification. Detection of smaller and deeper defects has improved significantly in the past few years. In some cases, thermography is now a viable non-contact alternative to conventional ultrasonic inspection methods.

My group follows development of new inspection technology and we routinely employ new methods when capability and commercial availability warrant implementation. Typically, only larger airlines can make a business case for expensive equipment, so new methods will always be alternatives to traditional methods, to ensure that all Boeing customers can reliably inspect their airplanes. Over the years, we have introduced dual-frequency eddy current, thermography, magneto-optic imaging, ultrasonic phased arrays and eddy current arrays. Our approach is always to evaluate

"For metal airplanes, eddy current inspection is the method of choice"

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new technology, define the inspection limits, and then put the capability in the 'inspection toolbox' until a cost-effective application is identified.

// WHAT IS THE ONE NDT TASK THAT YOU PERFORM MORE THAN ANY OTHER?

Eddy current inspection accounts for the majority of our in-service inspection procedures for metal airplanes. It is a versatile inspection method that is universally employed for airplane inspection. It is our first choice for an inspection solution for metallic structure. Ultrasonic inspection is the next most common method. It is the primary inspection method for composite structures. X-ray and thermography procedures are only infrequently used.

// HOW HAS NDT HELPED IMPROVE TESTING EFFICIENCY?

If you were to look at the original 707 NDT manual, you would find that x-ray inspection was used for most inspection applications. It was the best inspection option at that time. It was expensive and time-consuming, but it was the only viable option available. Since the mid-1960s, NDT equipment for industrial applications has increased tremendously along with the associated inspection methods. Low-frequency eddy current and ultrasound take the place of x-ray for almost all current inspection applications. These inspection methods are reliable, easy to implement and avoid the inconvenience of safety issues associated with ionizing radiation. We only develop an x-ray procedure every couple of years, but with the advent of new and lower-cost digital detectors, there may be opportunities to implement new x-ray techniques in the near future.

"New materials containing embedded sensors may provide the structure with a means of inspecting itself"

3 // Boeing's latest commercial aircraft models, such as the 787-9, feature composite structures that require new NDT methods for inspection

3

// WHAT HAS BEEN THE MOST RADICAL CHANGE IN RECENT YEARS?

For in-service airplane inspection, the conversion from analog to digital equipment has provided the biggest increase in inspection capability. Variable frequency instruments with high dynamic range improve detection capability and ease of use, especially since the size and weight of the equipment has decreased over the years.

// HOW IMPORTANT IS TRAINING?

Initial training is required. Recurring training is essential. Almost all members of my crew have American Society of Nondestructive Testing (ASNT) certification. I have ASNT Level 3 professional certification in eddy current, ultrasonics and thermography. Recurring training is a requirement for re-certification that is required every five years. The last course I attended was a Level 3 ultrasonics course. I routinely provide NDT training to groups within Boeing whose job function requires NDT knowledge.

// WHAT IMPACT HAVE NEW MATERIALS HAD ON YOUR WORK?

For metal airplanes, eddy current inspection is the method of choice. For composite aircraft structures [which are fabricated from essentially non-conductive carbon fibers] eddy current inspection is not possible. We rely on ultrasound as the primary inspection method for composite structure. The use of composite inspection methods required the development of a variety of ultrasonic techniques to detect disbonds, delaminations and porosity, using portable equipment that can be used easily in an in-service airplane environment. In-service inspection usually must be performed with only single-side access, while production inspections using 'through transmission' ultrasonic testing, with access to both sides of the part, is commonly used.

// ANY PARTICULAR TEST OR MOMENT STICK IN THE MEMORY?

Developing and implementing liquid crystal thermography – using low-cost temperature-sensitive sheets – to detect moisture ingression in composite honeycomb parts was very satisfying. The method permits a thermography type inspection to be performed

4

4 // Jeff Thompson early in his career, performing a field test to identify moisture ingression in 767 flap wedges using an infrared camera with a head-up display

5

5 // An in-service NDT technician at work today

using sheets of cholesteric liquid crystals that change color with temperature. Since water has a high heat capacity, honeycomb panels containing absorbed water can be detected after the heat is applied through a vacuum-attached liquid crystal sheet. Areas of water ingression remain cold while the skin warms up. The temperature difference is made visually apparent by the colors on the liquid crystal sheet enabling moisture to be identified and the panel to be repaired. The method was very successful. At the time the method was implemented, infrared cameras cost more than US$50,000 and the reusable liquid crystal sheets cost US$20. Being involved in new inspection issues and having the ability to explore and implement new inspection options has resulted in some 16 patents for me and my team, with another dozen pending.

// HOW DO YOU SOURCE NDT EQUIPMENT?

Since Boeing NDT procedures affect airlines worldwide, many NDT vendors seek our advice when new equipment is under development. The interaction helps to drive improvements that are beneficial to in-service airplane inspection. Since Boeing aircraft are sold to a global customer base, we purposely do not specify specific equipment or vendors, but rather provide drawings in the NDT procedures for reference standards that the airlines must fabricate to ensure that their choice of inspection instrument is appropriate, meets the inspection requirements, and can be calibrated reliably prior to inspection. The airlines are permitted to use any NDT equipment for the specific NDT method specified, as long as it meets the calibration requirements of the procedure.

// HOW DO YOU SEE NDT CHANGING IN THE FUTURE?

The ultimate goal of all in-service inspections is the so-called car wash system, in which an airplane drives through a series of sensors to automatically inspect the entire airplane in real time. However, it is not likely that such a sensor suite will ever be implemented, since most of the inspection tasks are performed on discrete structure [attachment lugs, clevis joints, various fittings, etc] buried deep inside the airplane. Inspection requires the inspector to access these structural components and manually manipulate the transducer/probe to fully examine the part. Smart sensors or embedded sensors applied to key structure that is difficult to access may permit a remote inspection to be performed. While large areas are not routinely examined, it is possible that robots, crawlers, drones, or automatic scanning systems may be implemented in future inspections or surveys.

// HOW FAR AWAY IS STRUCTURAL HEALTH MONITORING FOR IN-SERVICE NDT?

New materials containing embedded sensors may provide the structure with a means of inspecting itself, or identify specific area of structure that warrant a more-detailed, manual inspection. Structural health monitoring for in-service NDT is in its infancy right now. Structural health monitoring coupled with future capability yet to be realized for quantification of material state could lead to reduced inspections by autonomously monitoring structure and performing inspections only when detected damage approaches a threshold of interest, but still well below a threshold of concern. \\

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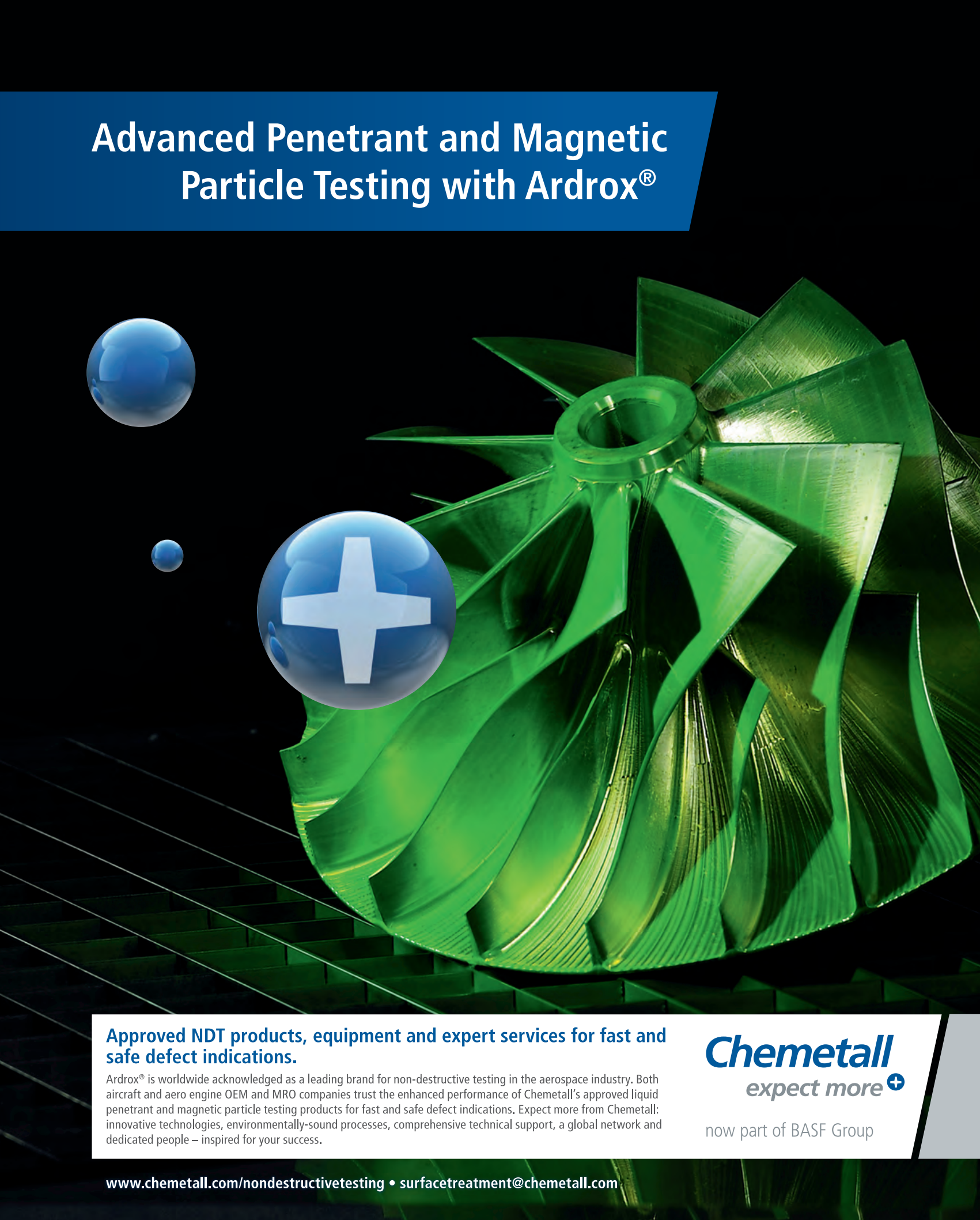

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EMBRAER KC-390

// PAUL E EDEN

Embraer is making rapid progress through the test campaign for its advanced KC-390 multirole airlifter as it heads toward IOC with the Brazilian Air Force later this year

1 // The second KC-390 prototype flew for the first time in April 2016, and is seen here engaged in paratroop trials from the ramp

2 // The KC-390 final assembly line

On November 18, 2016, Embraer's radical KC-390 jet airlifter received its IFI Provisional Type Certificate. The company was clearly delighted to prove the type's early maturity in a program that continues to progress smoothly toward a planned 2018 full-service date. "The Instituto de Fomento e Coordenação Industrial (IFI) is the Brazilian Air Force branch responsible for military certification," explains Paulo Gastão Silva, VP, KC-390 Program, Embraer. "Its Provisional Type Certificate for the KC-390 Basic Vehicle confirms that the aircraft in its basic configuration complies with the certification requirements."

The manufacturer and regulator are working closely together on the program, enhancing the validation processes and improving processes and procedures. "This progress is making an important contribution toward ensuring initial operational capability is reached in the second half of 2017 and final operational capability in the second half of 2018," the spokesperson says.

Although it benefits from Embraer's recent experience with the E-Jet commercial airliner and fly-by-wire flight control systems for its Legacy 450/500 business jets, the KC-390 is a clean-sheet design and the airframer will remain engaged in its test program until the declaration of final operational capability.

Coming less than two years after test pilots Mozart Louzada and Marcos Salgado de Oliveira, and flight test engineers Raphael Lima and Roberto Becker, lifted the prototype KC-390 off for its one-hour 25-minute maiden flight on February 3, 2015, the IFI certification is even more remarkable considering the program's 265-day grounding soon after that first sortie. Brazil's parlous economic state saw the Força Aerea Brasilira (FAB) temporarily unable to fund KC-390 development.

26
Metric tons maximum payload

0.80
Mach maximum cruising speed

36,000FT
Maximum ceiling

3 // Known within the company as Aircraft 801, this is the KC-390 structural test airframe

Embraer continued work on the ground, but the aircraft only returned to flight on October 26, 2016.

Soon after the return to full testing, KC-390 senior program manager Alexandre De Pol Fernandes reported high availability, noting, "We're logging an unprecedented flight rate for a prototype." The jet logged 50 hours in January 2016 alone. By then, the airlifter had been cleared out to Mach 0.8 and up to 36,000ft, figures the flight test crew at last year's Farnborough International Airshow were delighted to share with *Aerospace Testing International*, emphasizing they were numbers C-130J pilots could only dream of.

"We're logging an unprecedented flight rate for a prototype"

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A second prototype joined the test effort when it flew for the first time on April 28, 2016. Embraer is working the prototypes hard, since only the two are being built. Interchangeability between tasks in the event of unserviceability is therefore critical and, according to Silva, "Both are fully equipped with flight test instrumentation and presenting high availability, logging an unprecedented flight rate." Static test and fatigue test airframes are also supporting the trials effort, and Embraer has built a forward fuselage section for bird strike testing.

1,520NM
Overall range with 23 metric ton payload

35.05M
KC-390 wingspan

35.20M
Overall length

Typical of a modern test campaign, much of the KC-390's flying is for validation purposes, as Silva confirms: "Embraer makes extensive use of state-of-the-art tools, including simulation, modeling and laboratory testing to develop its products and the KC-390 flight test campaign is confirming results obtained by these tools.

"It is being certified through a dual approach with the Agência Nacional de Aviação Civil, Brazil's National Civil Aviation Agency, and by Desenvolvimento Comando-Geral de Tecnologia Aeroespacial IFI, the military certification authority. Specific customer requirements going beyond the original certification and requiring a dedicated solution will be the subject of ad hoc discussions and addressed through case-by-case agreements."

REFUELING TRIALS

Potential customer requirements include inflight refueling clearance against receivers others than those approved for the FAB and while Silva says, "Embraer does not comment on test details," it seems likely the manufacturer would support such activity.

Working closely with the FAB has facilitated progress in inflight refueling trials and benefitted other specific mission requirements, with military assets available as required. By spring 2016, the aircraft's rear ramp had been operated in flight, as had its side paratroop doors. The latter are removed inward, a retractable baffle

KC-390 DEFINED

Argentina, the Czech Republic and Portugal are industrial partners in the KC-390 program and performing ground tests on indigenous components for the aircraft, while Embraer oversees the entirety of the flight test campaign in Brazil.

Between them, Argentina, the Czech Republic and Portugal, Chile and Colombia have signed declarations of intent covering 32 KC-390s in addition to the 28 ordered for the FAB. At least six of the Brazilian aircraft will be permanently configured as tankers with underwing pods, although a purchase of 14 air-refueling kits is planned, and all KC-390s are easily equipped as tankers as required.

New Zealand has requested information on the aircraft as a potential C-130 replacement, and Embraer says export aircraft will be available from 2019.

Designed from the outset as a multirole tactical transport and tanker, the KC-390 is powered by a pair of V2500-E5 turbofans, carefully positioned underwing to avoid debris thrown up by the nose undercarriage during rough landings. Proven in decades of powering A320-family aircraft, the V2500 represents a cost effective, rugged and easily supportable powerplant solution.

The KC-390's advanced wing design is key to its short-field and slow-speed capabilities, incorporating slats and an unusual continuous double-flap arrangement capable of 40° deflection in discrete 1° increments.

Interestingly, while the KC-390 is a military design to its core, Embraer's regional airliner capabilities become glaringly obvious in the forward cabin, where a full airline-style lavatory and galley are installed. Personnel traveling in the cabin will no doubt appreciate the convenience, while loadmasters will appreciate the dedicated station designed to offer control and oversight of the advanced cargo handling system.

4 // Registered PT-ZNF, the first prototype lifts off from Gavião Peixoto for the type's maiden flight on February 3, 2015

5 // PT-ZNF during its first flight

extending forward of the door aperture to protect exiting paratroopers from the airstream.

Embraer has followed classic military airlifter design theory by installing a rear ramp, albeit choosing a unit somewhat longer than usual to reduce the loading angle for cargo, personnel and vehicles. It is also opened for gravity airdropping. Thanks to its advanced flap design, the KC-390 can adopt the slow-speed, nose-high configuration for such work, where palletized freight falls from the hold under the influence of gravity.

Airdropping and many other flight test aspects require photography and observation from chase aircraft and Silva says, "Embraer uses its own prototypes, with a Legacy 650, Legacy 500 and Phenom 300 currently available. A two-seat Hawker Hunter is used for specific high-speed testing."

TEST SITE

The trials campaign has centered on Embraer's Gavião Peixoto, São Paulo site, although Silva notes, "Tests requiring specific conditions, including natural icing and crosswinds, will be performed outside Brazil."

Artificial icing trials are planned for the McKinley Climatic Laboratory at Eglin AFB, Florida, later this year and a visit to Punta Arenas, southern Chile, will enable crosswind tests.

In choosing to debut the prototype at the Farnborough International Airshow in July 2016, Embraer took advantage of its rapid progress on the program and the availability of the second aircraft to showcase the new machine to at least 20 military delegations.

MILITARY HERITAGE

Perhaps more immediately familiar from its regional jet and burgeoning business aircraft lines, Embraer began its defense program proper in the 1970s, against a Brazilian government request for manufacture of the EMB-326 Xavante. An advanced jet trainer and ground-attack aircraft, the Xavante was a license-built Aermacchi MB.326 variant.

Later in the decade, the company began work on the EMB-312 Tucano turboprop trainer, until the AMX program, with Aermacchi, moved it onto a new technological and industrial plane. Subsequent work for the FAB, including a comprehensive F-5 upgrade, prepared Embraer for the KC-390, working directly with Brazil's air force and international companies, including a marketing agreement with Boeing.

2
Number of V2500-E5 turbofan engines

169M³
Cargo hold volume

2,500
Planned total of test program hours

"The transport's extraordinary slow-speed performance will enable it to refuel helicopters"

The jet arrived at Farnborough via Portugal, and departed on a 'tour' that included the Czech Republic, Egypt and the United Arab Emirates. But this was more than a demonstrator trip, since the transatlantic flying satisfied a number of test requirements and high-temperature trials were completed in the Middle East. Likewise, when a pair of FAB F-5 fighters joined the KC-390 for an independence day flypast on September 7, 2016, they assumed pre-contact receiver positions behind the transport so their pilots could report on turbulence – there was none.

On February 20 this year, Embraer announced that a sortie the previous day had seen an F-5 achieve dry contacts with the KC-390's underwing Cobham 912E refueling pods for the first time. The transport's extraordinary slow-speed performance has already been cleared and will enable it to refuel helicopters as well as fast jets. Dedicated helicopter inflight refueling trials are scheduled for 2018.

By the beginning of 2017, live paratroop drops from the side doors and ramp, and airdrops had been successfully trialled as Embraer worked to prove the KC-390's tactical capabilities. The jet's tactical prowess will increase further, with trials planned for 2018 covering operations from snow and ice runways, demonstrating an important capability to support Brazil's Antarctic activities.

Working in the face of customer-generated problems, Embraer is making rapid progress on the multi-role KC-390 tanker/transport. It promises to deliver a modern twinjet that comes close to the C-130J in many areas of its performance and soundly beats the venerable turboprop in others. Embraer plans to bring the aircraft back to Europe for this year's Paris Air Show, before embarking on a tour of other potential customer nations. No doubt it will settle a number of test points on the way. \\

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// THOMAS NEWDICK

Age conc

Non-destructive testing has a critical role to play in maintaining the USAF's venerable fleet of B-52 bombers

ern

1 // A magnifying glass is used to inspect a section of x-ray film at Minot AFB. X-rays are used for inspecting welds on the B-52H Stratofortress *(Photo: USAF/Airman 1st Class J T Armstrong)*

2 // B-52H Stratofortress, Serial 61-0007, nicknamed Ghost Rider, takes to the skies for a functional test flight in August 2016, at Tinker AFB, Oklahoma

3 // Ghost Rider spent three days in paint before getting its signature nose art and returning to the active fleet

Visit one of the two US Air Force bases that are still home to frontline B-52 strategic bombers, and you'll often hear from aircrew and maintainers whose fathers or grandfathers have taken the Stratofortress into battle. The B-52H model is still in combat today, and flew its first sorties in support of Operation Inherent Resolve (Iraq/Syria) on April 18, 2016.

"The B-52 has a very respectable role and status," says Capt. Jon Birmingham, an aircraft commander from the 23rd Bomb Squadron at Minot Air Force Base. "Not only because of how old it is, but how reliable it is."

Continued reliability will be paramount if the B-52 is to reach its out-of-service date, currently slated for somewhere between 2040 and 2050.

"These things are so well built and so well preserved that you can go and just bring one back out of storage and have our incredible people at the System Program Office fix it up and it's back in service within a matter of months," explains Col. Kieran Denehan, 5th Operations Group commander at Minot.

"Pilots of the 10th Flight Test Squadron flew six times ... to ensure Ghost Rider was safe"

Col. Denehan, responsible for overseeing the operational B-52s of the 5th Bomb Wing at the North Dakota base, was referring to serial 61-0007, nicknamed Ghost Rider, the first B-52H to be taken from long-term storage at the Aerospace Maintenance and Regeneration Group (AMARG) in the Arizona desert and returned to the active strategic bomber fleet.

The first two digits in the aircraft's serial indicate that Ghost Rider was built in 1961.

It took 19 months to return Ghost Rider from mothballs to the frontline B-52 fleet, where it joined Denehan's 5th Bomb Wing. With its reinduction, the fleet was brought back to its 76 treaty-sanctioned aircraft, replacing a B-52H lost in an accident at Barksdale Air Force Base, Louisiana in 2014.

Responsible for returning 61-0007 to flying condition and to the same avionics and weapons configuration as the current fleet was the Oklahoma City Air Logistics Complex at Tinker Air Force Base. "This is really a testament to accomplishing the art of the possible," says Brig.-Gen. Mark Johnson, commander of the complex. "It shows that when there is a common goal, team members from across multiple organizations can rally behind the objective and deliver their team's full impact to the project."

Pilots of the Tinker-based 10th Flight Test Squadron flew six times to verify

system functionality and ensure Ghost Rider was safe and reliable prior to delivery to the Air Force on September 27, 2016.

Non-destructive testing is playing an increasing role in maintaining the B-52 fleet, ensuring structural integrity. Inspection of critical components is a key requirement for these aging bombers, whether for one taken out of the desert 'boneyard' after seven years spent in storage, or the in-service aircraft that now averages 18,000 flying hours.

NDT TOOLBOX

Among the non-destructive tools available to help B-52H maintainers test for surface and subsurface defects are liquid penetrant, magnetic particle, eddy current, ultrasonic and x-ray technologies. Once these tests have been run on a component, specialists record its status and discard it if too badly damaged or send it to the appropriate shop for repair. A final inspection then takes place before returning it to operational status.

"If we find a crack in the wing before it grows too large we can save the engine from falling off the aircraft," explains Airman 1st Class Danielle Harrington, an apprentice with the 2nd Maintenance Squadron (MXS) at Barksdale Air Force Base, Louisiana. A recent incident illustrated exactly the kind of risks Harrington is talking about. On January 4 this year, a B-52H on a training flight from Minot lost an engine as the result of an in-flight mishap. The bomber landed safely and the engine was later found in an unpopulated area. The USAF has launched an initial safety investigation into the incident.

Fatigue cracks are the major concern for the non-destructive testers. As well as the aircraft themselves, inspection also includes ground equipment — much of which is as old as the bombers.

"The way we inspect does not affect the use of the part by tearing it apart or breaking it," says SSgt Joshua Martinez of the 2nd MXS. "Our methods keep parts intact for future use, which saves money on replacements." In the case of the B-52, the only way to furnish a replacement part might be to build it from scratch.

"Just because an item has been on the aircraft for a while doesn't mean it needs to be replaced," continues Martinez. "By inspecting a part and verifying that it is defect-free, we can extend the longevity of the B-52 by ensuring vital aircraft parts are mission ready."

The B-52's eight Pratt & Whitney TF33-P-3/103 turbofans are particularly sensitive, being one of the company's earliest turbofan designs. What looks like a scratch on an aging component might be a more serious defect. Fortunately, x-ray inspection can provide the answer. As a result of the development of mobile x-ray test kits, inspections can be run on B-52s on the flight line, as well as during depot inspection, saving money in the process."Whenever we find a defect or a crack on a part we call the non-destructive inspection team for support," says TSgt Lawrence Scruggs, the NCO responsible for the 2nd MXS propulsion section. "We call them because they see defects better with their machines than we can. It ensures we are keeping a serviceable part in the inventory, rather than having to discard it and buy another."

4 // A member of the 2nd Maintenance Squadron non-destructive inspection team uses a USN60 ultrasonic unit to inspect a B-52H's 694 bulkhead

5 // A USN60 ultrasonic unit is used to detect cracks on the 694 bulkhead located in a crawl space above the B-52H bomb bay

4

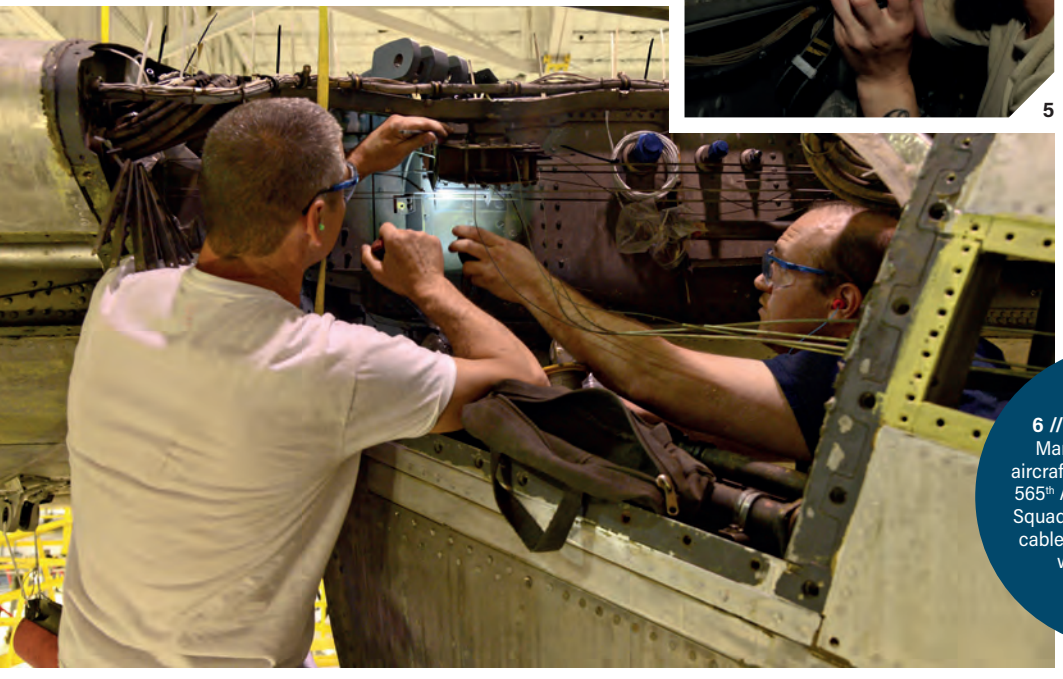
5

45,000

Number of man-hours required to bring B-52H serial 61-0007 back into service, a process completed in 272 days

15

B-52Hs had been fitted with Combat Network Communications Technology (CONECT), the latest avionics standard, by the end of 2016. The entire fleet will be operational with the upgrade by 2020



6

6 // Chris Carson and Martin Harpster, both aircraft mechanics with the 565th Aircraft Maintenance Squadron, work on throttle cable pulleys on the right wing of a B-52H

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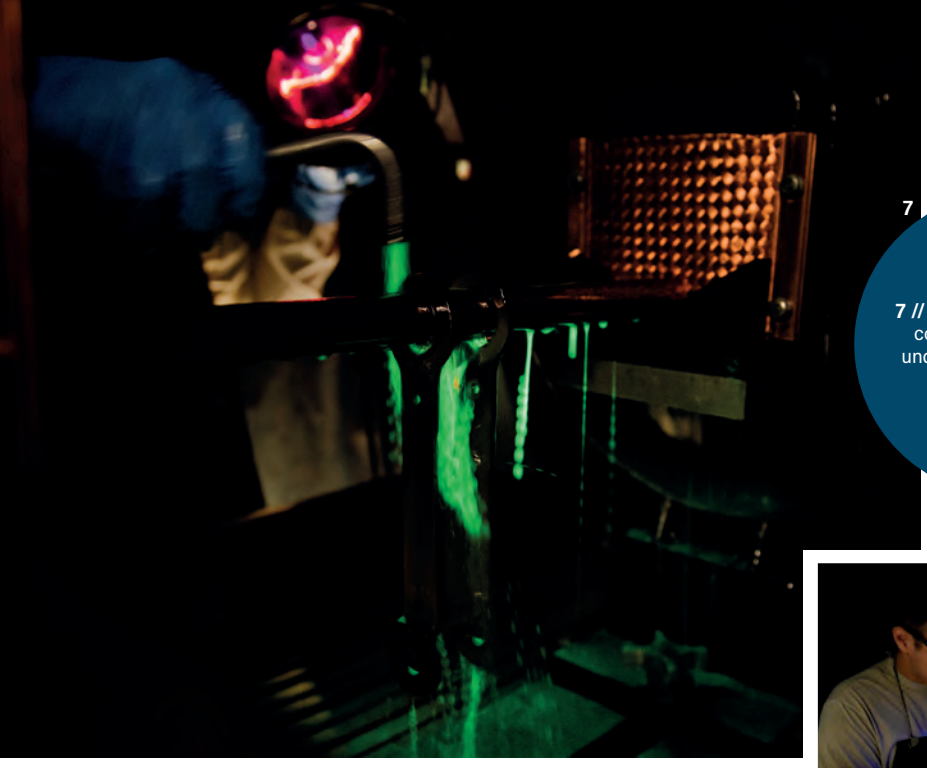
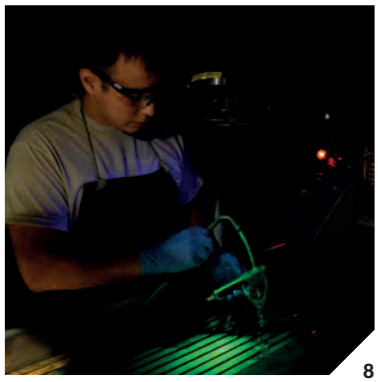


7 // A magnetized aircraft component is viewed under an ultraviolet light at Minot AFB

Eddy current testing can find cracks in aluminum, steel and titanium, using electromagnetic sound waves to pass through electrically conductive components. This method is useful for larger, flat areas of the aircraft, uncovering cracks and measuring their length.

For smaller components, including bolts and brakes, magnetic particle inspection is used. "The particles we use on these smaller parts are fluorescent," Martinez continues. "If there is a defect, the particles will attach to it, and together with a blacklight [UV light] in a dark environment, those defects become visible."



8 // SSgt Joshua Martinez, 2nd Maintenance Squadron assistant NCO in-charge of nondestructive inspections, examines a part

UNDER THE MICROSCOPE

With a focus on engine inspections, the B-52 community is developing improved non-destructive testing. At the Oklahoma City Air Logistics Complex, the 548th Propulsion Maintenance Squadron (PMXS) is refining its methods of uncovering cracks in turbofan components. The goal is to discover microscopic fractures that current test methods might miss.

"There's always new technology coming," says Scott Sawyer, 548th PMXS flight chief. "We've always got to be looking to the future to figure out if there is a better, cheaper, more effective and faster way of doing this that will achieve the same or a better result."

The latest addition to the non-destructive inventory is the use of ultrasonic waves. These waves are used to bombard the component under test, forcing the faces of a crack to rub against each other, producing heat. A highly sensitive infrared sensor is used to detect the difference in temperature at a fracture.

Existing test methods are also being refined. Using eddy-current sensors to discover cracks traditionally involves running a handheld device with a narrow

B-52 HERO TESTING

At the start of 2017, the US Air Force conducted Hazards of Electromagnetic Radiation to Ordnance (HERO) testing on a B-52H at Edwards Air Force Base, California. The test made use of the Benefield Anechoic Facility (BAF) at Edwards — the world's largest anechoic chamber — and a B-52 from the 96th Bomb Squadron at Barksdale Air Force Base, Louisiana.

The test was conducted on behalf of the B-52 Program Office at Tinker AFB, Oklahoma, and complies with an Air Force Safety Office mandate that calls for electromagnetic environmental effects evaluations on all weapons-carrying USAF aircraft types. The HERO test ensures that any equipment containing electro-explosive devices functions properly in the type of electromagnetic environment likely to be encountered in operational service. At the most critical level, ordnance can detonate unexpectedly if these requirements are not met. Using the criteria HERO Safe, HERO Susceptible, and HERO Unsafe, the test program ensures that ordnance is not susceptible to radiated or conducted electromagnetic energy.

"The advantage of using the BAF chamber is that it enables more sensitive measurements with low background noise levels, compared with testing on the flight line where there are numerous interfering radio frequency sources," explains Hannah Dahlgren, project lead engineer with the 772nd Test Squadron at Edwards AFB. "Since no signals escape the chamber, the customer does not have to deal with regulatory clearances to radiate from the aircraft, which typically results in transmitting late at night to avoid interfering with flight line and commercial operations."

Used for electronic warfare testing, the BAF is coated with radiation-absorbent material (RAM) to ensure that the subject under test is not exposed to radio frequency interference from outside. Different-sized RAM is used in the chamber according to the particular frequency and test procedure being conducted. Pallets of ferrite tiles were also used to absorb the various emitting frequencies from the aircraft.

Four days were required to maneuver the B-52 into position for the HERO tests, with the bomber raised on jacks and then rotated 180° using the BAT turntable. The aircraft's landing gear was retracted to simulate inflight conditions. The tests were the first time that a B-52 had been jacked up in the BAF. No real ordnance was employed during testing. Instead, on-site equipment simulated radio frequency and electromagnetic conditions. Data was gathered using sensors mounted in areas where the B-52 would normally carry weapons.

coil sensor probe across a large area, with readings taken in multiple areas. A new version of the device employs multiple sensors in the form of a flexible ribbon that tests a wider area simultaneously. While the previous method required up to 60 hours for certain parts, "with this new technology you can contour the ribbon in a dovetail inspection, for example, and perform the inspection in three or four swipes as opposed to several dozen," as 548th PMXS process engineer Ernesto Nieto explains.

As well as aircraft components, lubricants also require regular testing. A spectrometer is used to monitor 19 elements present in oil samples. "If the numbers don't match the recommended values we can provide maintenance with repair suggestions," says Martinez. The Joint Oil Analysis Program will uncover signs of metal breakdown in the engine oil, helping prevent catastrophic failure.

9

9 // Non-destructive testers performing an inspection to ensure aircraft parts are safe to return into circulation and to be used on the B-52H

10 // Magnetic particle inspection uses fluorescent particles to attach to cracks and defects, which become visible to the naked eye under 'black' UV light

10

Most of the component testing takes place during the B-52's regular inspection, a two-week procedure carried out after every 450 hours of flight time. On arrival, the non-destructive test teams are assigned different areas of the bomber — and support equipment — to work on. Once testing reveals a damaged part, specialists are brought in from either the metal technician or aircraft structural maintenance teams. Since the B-52 is a complex assignment, certain inspections will involve all three teams working together.

"Without non-destructive inspections there would be no fast and cost-effective way to inspect parts for damage," concludes Martinez. "Items would have to be replaced more often, costing the Air Force money, in addition to an increase in man-hours to keep up with the additional maintenance requests."

"Non-destructive methods in the hands of a trained and experienced technician are capable of detecting flaws or defects with a high degree of accuracy and reliability," confirms SSgt Zachary Pierce of the 2nd PMXS. "The defects we find during our inspections are repaired and allow the B-52H to continue flying and performing the Barksdale mission."

Without non-destructive testing, certain critical components of the B-52 simply could not be inspected. And in a time of fiscal constraint, demand for inspection is only going to increase. Soon after Ghost Rider returned to service, the USAF once again turned to the issue of re-engining the B-52 fleet. Outgoing commander of the 'Mighty Eighth' Air Force, Maj.-Gen. Richard Clark, backs a re-engining of the fleet. Should that happen, the Stratofortress might yet see a full century in service. \\

150

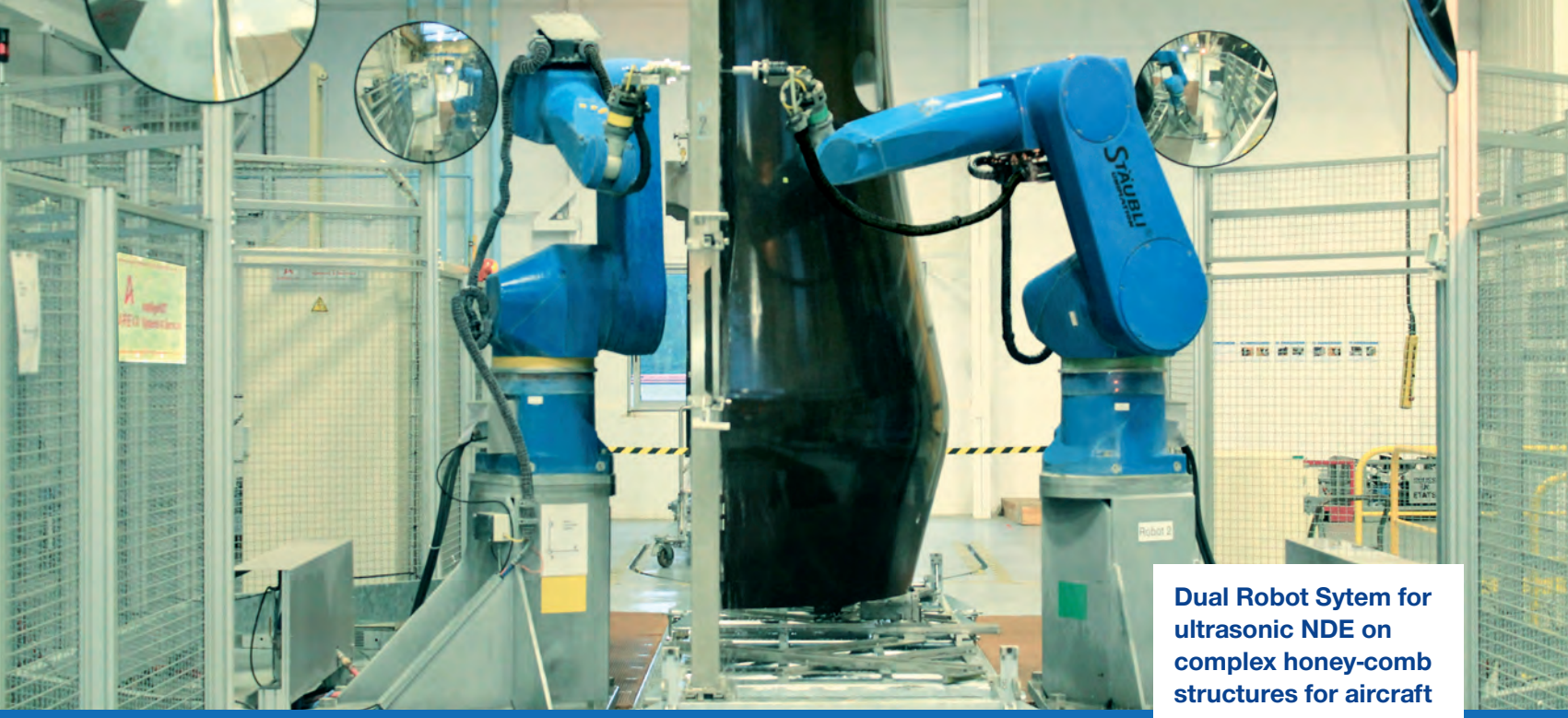
Flight hours before the B-52's engine oil requires testing

US$1.6M

The cost of rebuilding a single engine for a B-52H

200,000

Number of jet engine parts (all aircraft types) inspected by the Oklahoma City Air Logistics Complex each year



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Shaker restyled

NASA needed very different shaker tables for vibration testing part of the space agency's most advanced and sensitive orbital observatory, the James Webb Space Telescope

Conducting vibration tests on the James Webb Space Telescope (JWST) has been challenging from the start. To begin with, a survey of existing shaker facilities throughout the US, "found there were no systems to which we could transport the hardware that could handle the testing," – the words of Jon Lawrence, mechanical systems lead, launch vehicle liaison with NASA's Goddard Space Flight Center.

Although NASA has the world's most powerful spacecraft shaker system, it was not sufficiently powerful, nor large enough for what the JWST's telescope and instrument portion of the spacecraft needed. Rocket launches create high levels of vibration in spacecraft and equipment. Shaker testing is done to simulate launch-induced vibrations. In this case, Goddard was planning not to test the entire JWST spacecraft, but only the combined optical telescope element/integrated science instrument module (OTIS).

However, in the words of NASA, the telescope is the "most dynamically complex test article ever tested at Goddard". The OTIS is designed to have unprecedented infrared sensitivity to detect the faintest, earliest galaxies, but that sensitive equipment must cope with the tough launch environment and the launch-like testing at the Goddard center.

The OTIS, which has a mass of about 3,950kg, is being put through sine vibration testing, which means it experiences a range of frequencies along

1 // A mirror section from the James Webb Space Telescope (Photo: Northrup Grumman)

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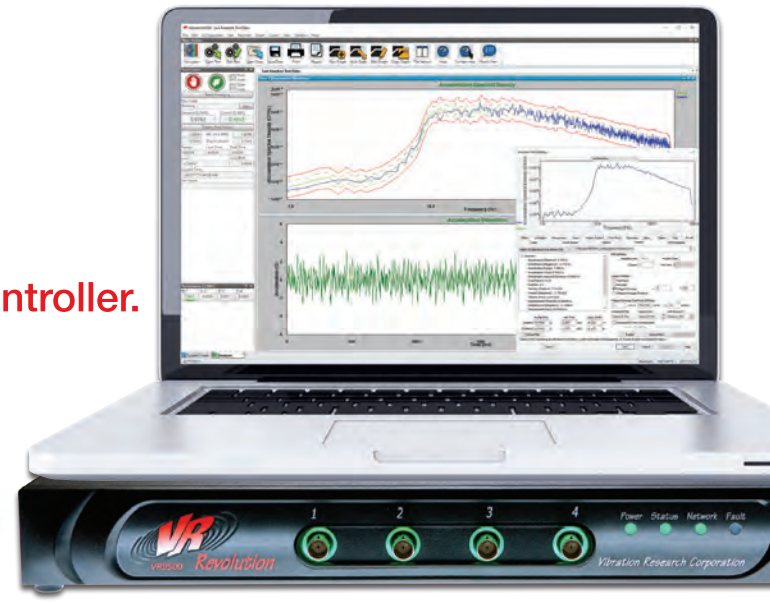

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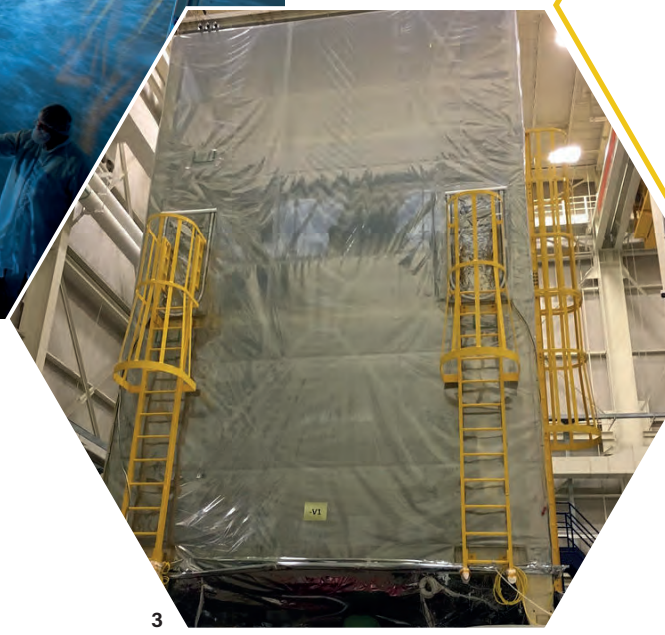
2 // JWST has a five-layer, tennis court-sized sunshield that will act like a parasol to provide shade when in orbit

3 // A 'clean tent' protects JWST from dust and dirt when moving between the relatively dust-free cleanroom and the vibration and acoustics test zones



"A new facility at Goddard provided the best schedule, cost, safety and benefit"

with discrete amplitudes. The test rig had to be able to impart a lot of force for this, more than any system available to NASA. The agency therefore had to build from scratch two shaker systems for horizontal and vertical applications. With these, the OTIS is vibrated in three axes.

Another challenge was the JWST itself. The OTIS has a large footprint at 131in by 131in (333cm by 333cm), has an asymmetric profile and an offset center of gravity in its stowed-for-launch configuration. When placed on top of the test equipment, the vibrations this would generate would cause a large dynamic overturning moment.

"There were no systems identified to which we could transport the hardware that could handle the large dynamic overturning moment of the payload under test," explains Lawrence. "A trade study determined that a new facility at Goddard provided the best schedule, cost, safety and benefit."

8.6M
Height of the optical telescope and integrated science instruments (OTIS)

1.5G
The OTIS test article will experience up to 1.5 times its own weight (1.5*g*)

352,000
Particles per cubic meter of 0.5µm size within the clean room tent

EARLY TEST DATA

While testing the JWST's OTIS on the NASA Goddard Space Flight Center vibration test system (VTS) on December 3, 2016, accelerometers detected an unexpected response from the OTIS structure while it was on the horizontal shaker.

The unexpected response triggered an immediate automatic shutdown of the test. All the engineers' subsequent visual and ultrasonic examinations of the OTIS structure have shown it to be sound. Three low-level vibrations of the telescope were undertaken in December after the anomalous readings. Further testing was carried out in January to try to determine the cause of the unexpected response.

The JWST team concluded that the testing anomaly was caused by what they call "gapping", or extremely small motions, in one primary mirror wing launch restraint mechanism. The science payload was visually and ultrasonically inspected and no damage was found. After approval from an internal independent review team, which concurred with the root cause assessment, OTIS testing has resumed.

Another change for a NASA vibroacoustic test campaign is that the rocket launch being simulated is not a US launcher, but a European one. Arianespace's Ariane 5 will launch the JWST in 2018. The vibroacoustics data from the rocket was easily available, but to adequately recreate the maximum dynamic inputs of the launch environment, the test rigs will induce in the OTIS three separate sinusoidal sweeps. This means it will sweep between a low and high frequency during vibration – in this case 5-100Hz. The *g* levels in sinusoidal sweeps can be constant or variable. With OTIS testing, they will be variable.

For each rocket payload, additional customized dynamic environment modeling is also done. This is where the payload's dynamic analysis model is coupled to the launch vehicle's dynamics model to see how they respond to vibration and acoustics. By varying the loads applied to these joint payload rocket models, a coupled loads analysis (CLA) is produced, giving more specific load data. The results of JWST CLAs were provided to NASA and its contractors to help them define the new shaker system.

HIGH G
DYNAMICS TESTING

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

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#2	13,000 lbf	2" Stroke

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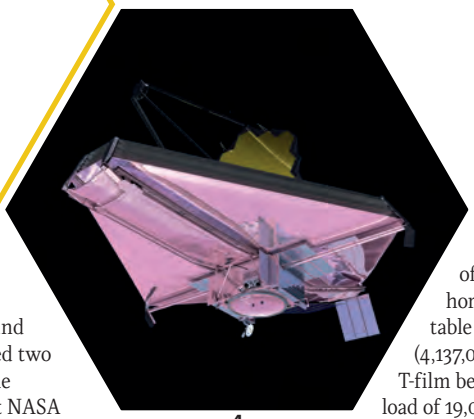

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4 // Artist conception of JWST (right bottom front side view)

Taking all these factors into account, NASA and its industrial partners, Qinetiq North America, Data Physics and iTeam Corporation, constructed two test rigs – collectively called the Vibration Test System (VTS) at NASA Goddard Space Flight Center. The horizontal and vertical shakers were designed to replicate how the OTIS is ultimately attached to the rocket. The vibration test fixture, which bolts to the VTS, replicates the interfaces between the OTIS and the JWST's own spacecraft bus (see JWST – Beyond Hubble).

SUCCESSFUL INSTALLATION

With the VTS contract awarded in December 2013, meetings began in the following February. In 2014 the critical design reviews were held in April for the horizontal system and in October for the vertical one. A year later the VTS check-out was complete and Goddard took ownership.

Installing the VTS did not require any great changes to Goddard's infrastructure other than some rerouting of power cables. However, it did require airbags, to insulate the rest of the Goddard building from the shakers' own vibrations.

On the horizontal system, the x-axis vibrates at frequencies from 5-100Hz with a force of 1-1.25*g*. The y-axis can be excited to 1.5*g* at 50-60Hz.

The horizontal shaker uses a single shaker from Data Physics that is capable of 50,000 lbf (222kN). The vertical shaker similarly uses a Data Physics 50,000 lbf shaker. Because of the overturning moments, the horizontal shaker system uses a slip table with low-pressure, 600 lb/in^2 (4,137,000N/m^2), oil T-film bearings. Each T-film bearing can withstand a dynamic load of 19,000 lbf (84kN).

The overturning moment the slip table and its bearings must counter is up to 1,300,000in-lbf (147,000Nm). These T-film bearings react to roll and pitch moments with a maximum stroke of 2.5in (6.35cm), according to Team Corporation's website. The horizontal system's T-film bearings give it a turning moment capacity of 13.0 million in-lbf in pitch and 10.7 million in-lbf for roll. The horizontal system also uses yaw bearings that can cope with 16,000 lbf each, with a moment capacity of 189.0 million in-lbf for yaw.

While the vertical system has one Data Physics 50,000 lb shaker, the peak force used by this system is 35,000 lbf. The z-axis will be shaken at 20-40Hz with a force as low as 0.75*g* and as high as 1.5*g* at 5-20Hz. The vertical system has far more overturning moment capacity than it needs. Its overturning moment capacity for pitch is 2.9 million in-lbf whereas what is required is only 400,000in-lbf. For roll,

JWST – BEYOND HUBBLE

To be launched late next year, the James Webb Space Telescope (JWST), which is named after a NASA administrator that ran the agency from February 1961 to October 1968, is the successor to the Hubble Space Telescope. The JWST will orbit the sun, 1,500,000km from our planet. In contrast, the Hubble telescope is 'just' 570km out in space.

The JWST consists of its spacecraft bus, which contains the propulsion and control systems for attitude, communication, and data handling; the combined OTIS module; and the sun shield. The telescope's spacecraft element will have its vibration test later this year at Northrop Grumman, JWST's prime contractor, in Redondo Beach, California.

The JWST is an infrared telescope that uses a 6.5m beryllium mirror that consists of 18 segments that unfold after launch. The instruments are located directly behind the mirror. The telescope uses a cryo-cooler to cool the detectors of one of the instruments, the mid-infrared instrument, to 7K so that it can detect the universe's earliest heat sources.

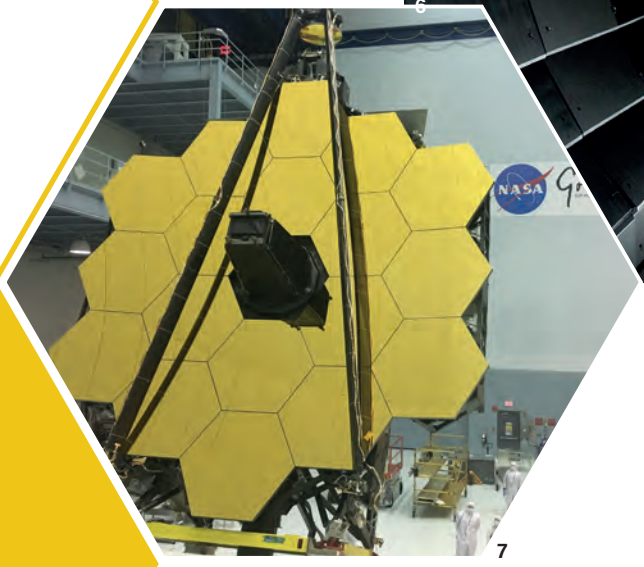
The telescope will allow scientists to study every phase in the history of the universe, from events immediately after the big bang, to the formation of solar systems and the atmospheres of exo-planets. The JWST is an international collaboration between NASA, the European Space Agency and the Canadian Space Agency.

Once the JWST is in service it will be operated by the Space Telescope Science Institute, which also operates the science program for the Hubble telescope.

5

5 // The horizontal shaker table is shown during its construction before installation of the vertical shaker

6 / 7 // The primary mirror of NASA's James Webb Space Telescope will consist of 18 hexagonal mirrors



7

"On December 3, there was an unexpected response in the horizontal shaker"

its capacity is 2.9 million in-lbf whereas it requires 1.3 million in-lbf, and for yaw it has 3.17 million in-lbf whereas it only needs 300,000in-lbf.

To help with the overturning moment, the vertical shaker is equipped with a large guided head expander – a table that is larger in area than the area of the shaker beneath – which is attached to the test object. (A guided head is a larger area table that is supported by linear bearings or shear mounts that provide guidance, limiting the table's range of movement.)

The VTS is not housed in a clean room. Instead, a custom clean tent with a built-in HEPA air-cleaning system was designed, constructed and tested. To meet the needs of the OTIS, the tent provides a cleanliness of class 10,000 (ISO class 7) or better. This tent encloses the OTIS during vibration testing. It will also be used during acoustic testing in the acoustic test chamber.

Another key new aspect of the VTS is that it has been designed as a system to provide safety to the OTIS hardware under all foreseen possibilities of facility anomalies. No matter what facility issue might be experienced during testing, such as loss of power or loss of coolant, the VTS is designed to shut down softly to avoid imparting detrimental loads to the OTIS.

TEST ANOMALY

Testing began in late 2016. On December 3, there was an unexpected response in the horizontal shaker and the test was immediately shut down. Despite the problems, the assessment of the test data so far does not indicate that there is a need for any design changes to the JWST hardware or its attachments to the spacecraft bus or rocket. The VTS will be used for all future large Goddard payloads once JWST testing has been completed. However, there are no specific plans for other NASA or commercial payloads of such a size.

After OTIS completes the sine vibration and acoustic testing at Goddard, it will go to NASA's Johnson Space Center in Texas for cryogenic optical testing. After that it will be shipped to prime contractor Northrop Grumman for integration to the spacecraft bus to become the JWST observatory. "The observatory will undergo deployment testing, sine vibration and acoustic testing along with functional testing prior to shipment to the launch site in French Guiana," Lawrence concludes. \\

18
JWST's primary mirror is made of 18 separate segments that unfold and adjust to shape after launch

6.5M²
The area of the JWST's beryllium mirror

7
The temperature (Kelvin) at which the JWST's mid-infrared instrument (MIRI) is maintained

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// ANTHONY JAMES

Killer

Supercomputers can help model and simulate extremely complex aerodynamic data, and may one day spell the end for physical wind tunnel testing

bytes

From supplying mind-numbingly complex aerodynamic data to NASA engineers designing the next Space Launch Vehicle, through to the simulation of the sound produced by contra-rotating blades in future propulsion systems, supercomputers have an increasingly vital and fascinating role to play in aerospace development and testing.

Just as consumer technology seems to double in its performance on an almost daily basis, aerospace manufacturers must continue to invest in their number-crunching capabilities and review their relationships with specialist partners to ensure they glean the most from today's state-of-the-art supercomputer science.

One such partner is the UK's Centre for Modelling and Simulation (CFMS), a specialist in high-value design capability, which has been offering clients in the aerospace, defense, automotive, civil engineering and renewable energy sectors access to its new supercomputer since October 2016. Based in Bristol, CFMS is ideally placed to work with both Airbus and Rolls-Royce on aerospace assignments.

"Airbus uses the computing power at CFMS for research and development of new simulation-based methods and design processes, then testing of these new approaches ahead of application in our more production-type environment," explains Behrooz Barzegar, vice president of flight physics integration, policy and development at Airbus.

CLUSTER LUST

CFMS recently refreshed its supercomputer offer, installing a new Cray CS400 cluster, featuring an Intel Xeon processor from the E5-2600v4 product family alongside an ArcaStream parallel storage system. NVIDIA Tesla graphical processing unit (GPU) accelerators further speed applications, providing CFMS customers with faster response times and enhanced performance levels for demanding computational tasks.

"With an evolution in engineering design taking place, we are welcoming a new era where advanced simulation takes center stage, accelerating product development and differentiation while enabling technological advantages and business growth," explains Sam Paice, chief operating officer, CFMS. "Up to five times more powerful than the previous system, industry organizations, including Rolls-Royce and Airbus, use the CFMS High Performance Computing (HPC) cluster for research and methods development, which underpins simulation-based design activities."

137
Teraflops of peak performance provided by CFMS's new cluster

161
NASA Pleiades racks (11,472 nodes)

7.25
Peak performance of Pleiades (petaflops/second)

938TB
Pleiades total memory

Dominik Ulmer, VP business operations (EMEA) at Cray, explains how the new cluster has improved things. "The Cray CS400 system at CFMS has 137 teraflops of peak performance," he says. "That means the system can process 137 trillion floating-point operations per second, which is a measure of compute performance.

"This raw power of the system is equivalent to almost 14 trillion pocket calculators. But just as important is the infrastructure around the compute power. For example, the communication network to allow all the processors to work in parallel, the input/output system to efficiently get data into the system, and the packaging that allows the system to be cooled and maintained."

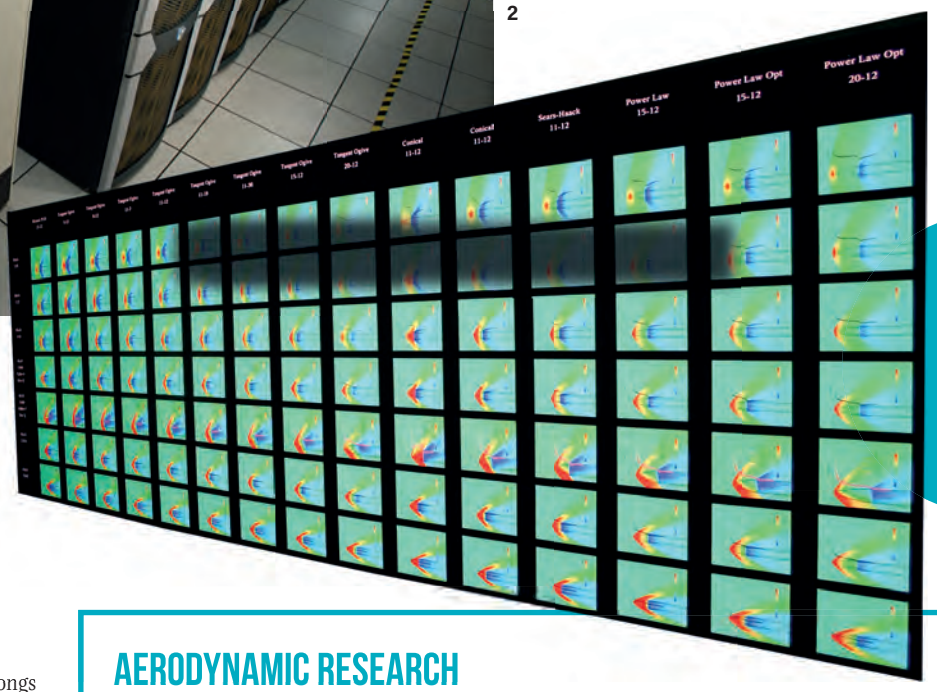
Fortunately a supercomputer doesn't cost a trillion times more than a pocket calculator: "A major feature of the CS400 design is the ability to scale the system up as the workload demands," explains Ulmer. "Hence, the prices of a Cray CS400 ranges from the hundreds of thousands to the millions of dollars."

Ulmer confirms that Cray has many aerospace customers around the world on its books: "Some of the largest systems Cray has installed are in the aerospace field, for example the US Air Force Research Lab," he says. "Our commercial customers typically see their Cray as a competitive resource and do not want us to mention their environment. But we have systems in commercial aerospace companies in the USA and Europe, and this is one of our fastest-growing industries."

1

1 // A new Cray CS400 cluster supercomputer is now available at the UK's Center for Modelling and Simulation (CFMS)

2 // Pleiades, one of the world's most powerful supercomputers, enables NASA scientists and engineers to conduct modeling and simulation for a variety of missions



3 // NASA uses a dedicated hyperwall to display, analyze, and study ultra-large high-dimensional data sets in meaningful ways

MEET PLEIADES

When it comes to the daddy of all supercomputers, it figures that it belongs to NASA, one of the world's largest and most advanced aerospace organizations. Named Pleiades, it received a substantial upgrade at the start of 2016, with the installation of 1,008 Intel Xeon E5-2680v4 nodes, which boosted the system's theoretical peak performance to 6.28 petaflops (quadrillion floating-point operations per second).

The remaining racks of Intel Xeon X5670 processors were subsequently removed from Pleiades in July 2016 to make room for an additional 14 Intel Xeon E5-2680v4 racks, doubling the number of E5-2680v4 nodes to 2,016 and increasing the system's theoretical peak performance to 7.25 petaflops. As a result, Pleiades now has a total of 246,048 CPU cores across 161 racks containing four Intel Xeon processor types, and packs more than 900TB of memory.

And if one supercomputer isn't enough, NASA can call on another, dubbed Endeavour – a shared-memory system based on an Intel Xeon Sandy Bridge processor. Installed in 2013 to replace its previous Columbia supercomputer, it boasts a theoretical peak performance of 32 teraflops, with a six terabyte memory.

Both supercomputers are at NASA's Ames Research Center and are key in the development of space exploration vehicles, aircraft and rotorcraft, and for understanding complex aeronautical phenomena: "NASA's aerospace engineering and design efforts rely on a combination of experimental data, flight tests, and computational modeling and simulation to provide extensive design and analysis data more efficiently," explains a spokesperson for the NASA Advanced Supercomputing (NAS) Division. "Experimental tests, such as wind tunnel tests for aerospace vehicles, are expensive and time-consuming, requiring maintenance of large, highly specialized testing facilities and construction of precisely instrumented test models to make the needed measurements. They are also limited in the scale and range of conditions that they can reproduce. While flight tests can better cover the relevant scales and conditions for a particular design, they are even more difficult and costly, and are only practical once a design is almost fully developed."

In contrast, computational models run on NASA supercomputers like Pleiades can be generated within

AERODYNAMIC RESEARCH

What if an aircraft's wings could be actively reshaped during flight to adapt to changing conditions? This was the focus for a recent NASA project modeled with the help of its Endeavour supercomputer.

"We set out to examine the potential benefits of a distributed flap system – placing flaps down the length of the wingspan that can be moved independently to adaptively reshape the wings for varying flight conditions," explains David L Rodriguez, senior research scientist and engineer at NASA's Ames Research Center. "This would keep the wings operating near peak efficiency throughout the flight."

Endeavour was used to simulate such a flap system on a standard NASA aircraft model, running multiple scenarios with the flaps in different positions to determine which shapes would work best in various flight conditions. The goal was not only to find the optimal shape for each condition, but to determine how much better the reshaped wing would perform at each condition than the baseline wing design.

"Better aerodynamic performance leads to higher fuel efficiency, which in turn leads to new, lighter aircraft designs," adds Rodriguez.

The project required about two dozen full aerostructural optimizations to be run on Endeavour, which equates to thousands of individual CFD simulations, despite the team developing an approach that was roughly five times more computationally efficient than typical analysis methods.

The results showed improvements in aerodynamic performance and potential fuel savings in all the simulation scenarios. Extending a distributed flap system across an entire wingspan using existing technology would add weight and increase complexity, but as the technology evolves, distributed flap systems could become commonplace within the next few decades.

(Information provided by Michelle Moyer at NASA Ames)

4

a matter of days and can provide the needed design and analysis data at a fraction of the cost. This modeling and simulation provides scientists and engineers with predictive analysis capabilities, enabling them to proactively examine a much broader range of potential conditions and design variations than would be possible through testing alone.

Supercomputers are particularly helpful in ensuring the rapid and inexpensive prototyping and testing of novel aerospace designs combined with optimizations of shape and operation, and the design and support of wind tunnel and flight tests during final stages.

"The reduction of uncertainties due to wind tunnel background turbulence and noise is obtainable with high-fidelity, large-eddy simulations on supercomputers," explains Dr Cetin Kiris, computational aerosciences branch chief, NASA Advanced Supercomputing Division. "The next generation of low-dissipation, high-performance algorithms running on massively parallel supercomputers are poised to tackle unprecedented flow and geometric complexities presented by future vehicles. For example, unsteady buffet analysis of booster separation, including fluid structure interaction."

However, there are still some problems beyond even a supercomputer's reach: "Only qubit-based quantum computing can address optimization problems of large dimensionality," asserts Kiris. "Even massively parallel qubit-based computing has made very limited progress on this front. For the foreseeable future, simulations of flow past aerospace vehicles at full-scale Reynolds numbers are bound to rely on imperfect turbulence closure models, limiting their predictive capability even on state-of-the-art supercomputers. Similarly, due to the prohibitive computational cost of microscopic-scale simulations for multiphase, chemically reacting, non-Newtonian fluids, significant modeling assumptions are required."

MELTDOWN PREVENTION

NASA's Pleiades supercomputer, while undoubtedly sophisticated, is still very maintainable, says Bill Thipgen, NASA's Advanced Computing Branch chief. "With over 11,400 nodes, the failure of any single node has minimal impact on the system overall," he says. "Even the failure of a switch only impacts nine nodes. With the dual-plane hypercube architecture, Pleiades provides a stable environment through failures. When failures occur, we have on-site staff that either repair or replace the problem component. All our purchases include three years of maintenance and for components that fall outside the maintenance window, particularly in the case of nodes, we move to a cannibalization mode where we take out a small portion of the older components to maintain a larger pool."

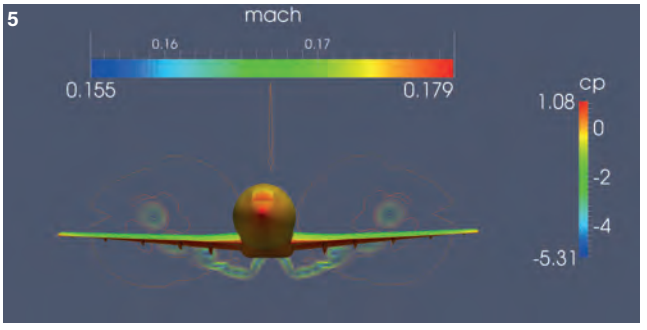
CLOUD AHEAD?

Investing in your own supercomputer still makes more sense than using the combined computing power of the cloud. "The cloud is getting a lot of attention, but it is not really a new concept in high-performance computing [HPC]," says Cray's Ulmer. "Some workloads are good for the cloud but many are not. Also, most HPC systems are loaded 24/7, so it is more expensive to rent time on the cloud full time versus owning the system. You do not rent a car when you use it all day, every day. Also, there are significant data movement and security challenges with cloud computing. Most companies therefore augment their on-site HPC environment with the cloud, instead of replacing it."

This view is shared by NASA's Advanced Computing Branch chief, Bill Thigpen. "Pleiades is a secure, private cloud for NASA's users, providing an on-demand service that is expandable as their needs increase," he says. "As a fully subscribed asset, we are able to provide computing capabilities to our HPC user community at a lower price than is currently available in cloud offerings. In addition our studies have shown that the HPC cloud offerings have a significantly lower performance profile than our HPC systems for most of the large-scale, tightly coupled simulations typical of NASA science and engineering codes."

The industry will continue to monitor the cloud's capabilities, but supercomputers look set to have a fundamental role to play going forward. Big data analysis tools combined with high-fidelity numerical simulation databases can provide the detail necessary to make design improvements from first principles. A numerical approach to design and testing enables the rapid assessment of designs spanning a large parameter space, especially for hard/expensive-to-build geometries and complex physics such as a launch pad.

Ultimately, actual wind tunnel testing could be made redundant. Computer simulations combined with rigorous quantification of uncertainties will pave the way toward the aerospace industry's overarching goal of design by simulation using a numerical wind tunnel. However, in the near future, NASA believes testing will still be necessary to validate highly complex flow physics – flutter, dynamic stall, reacting, multiphase, etc – where large modeling uncertainties remain. \\



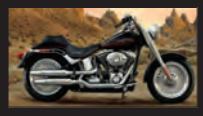
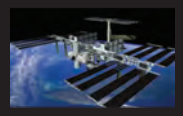
4 // A NASA passive particle visualization of a pylon-installed, contra-rotating, open-rotor simulation created using the Launch Ascent and Vehicle Aerodynamics (LAVA) code's Cartesian higher-order accurate CFD solver

5 // Simulation from a recent CFMS project

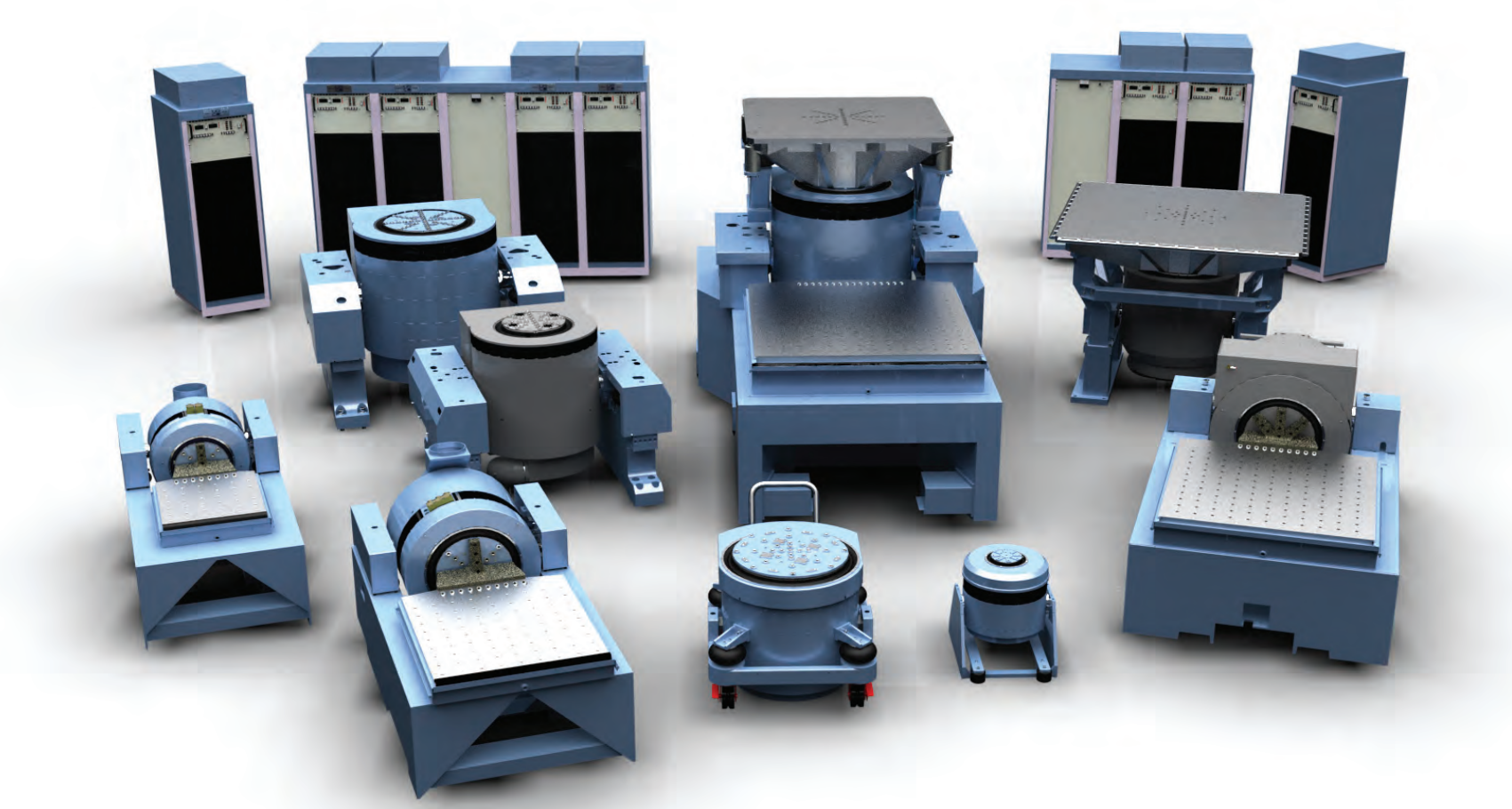
UNHOLTZ-DICKIE CORP.





Vibration Test Solutions...



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A TASTE OF SPACE

In its sixth year, Space Tech Expo & Conference 2017 continues to grow in its new venue in Pasadena, California

May 23-25, 2017

VENUE DETAILS

Pasadena Convention Center, 300 East Green Street, Pasadena, California 91101.

Space Tech Expo is a global event, and returns to Europe (Bremen, Germany) October 24-26, 2017. Find out more about Space Tech Expo Europe at **www.spacetechexpo.eu**

OPENING HOURS

Tuesday, May 23
12:00–18:00
(Includes a welcome reception, 16:00–18:00)

Wednesday, May 24
09:00–17:00

Thursday, May 25
09:00–15:00

This year's Space Tech Expo is all set to be bigger and better than ever before, with more on offer to both exhibitors and attendees. As is the case every year, testing plays a major role in the show, and this year sees a focus on environmental testing – with visitors able to see firsthand how equipment reacts to harsh environments. Key exhibitors will demonstrate how parts perform in extreme heat or freezing temperatures, how they counter vibration or shock, radiation, electromagnetic effects and altitude. There will also be leak-detection demonstrations that will be carried out at different temperatures.

As America's engineering meeting place for space and defense technology, the exhibition is attended by thousands of industry leaders, decision makers, engineers, specifiers and buyers wanting to meet manufacturers and the supply chain for civil, military and commercial space. More than 170 exhibitors have already booked to join the show, including JPL, Dayton T Brown, Jacobs, NRO, Space and Missile Systems Center, Q-Plus Labs, General Dynamics, DIT-MCO, Zygo Corp, Experior Labs, and Cascade Tek. \\

SPACE TECH CONFERENCE

Space Tech Conference returns to Pasadena in 2017 with an insight-packed three-day agenda that will help commercial, military, government and academic organizations navigate the opportunities and challenges of doing business in an increasingly complex landscape. Through keynotes, panels and audience-interactive discussion sessions, the conference will examine questions and issues including:

Key themes:

- Implementing 'Space Enterprise Vision': Adapting to a new era in Air Force space requirements.
- New space and old space: How will incumbents and startups work together?
- Commercial, government and military collaboration in future space.
- Space funding and new space finance.
- How do you accelerate from being a startup to a real market player?
- Improving US commercial space competitiveness: Increasing space exports.
- Small launch vehicles: Addressing the bottleneck of getting into space.
- Scaling operations and manufacturing capabilities to support growth of mega constellations.

New for 2017: Focus day on: Space services – New markets and business operations (May 24) Led by Dave Barnhart, CEO, Arkisys, and director, USC Space Engineering Research Center at University of Southern California (formerly program manager at DARPA).

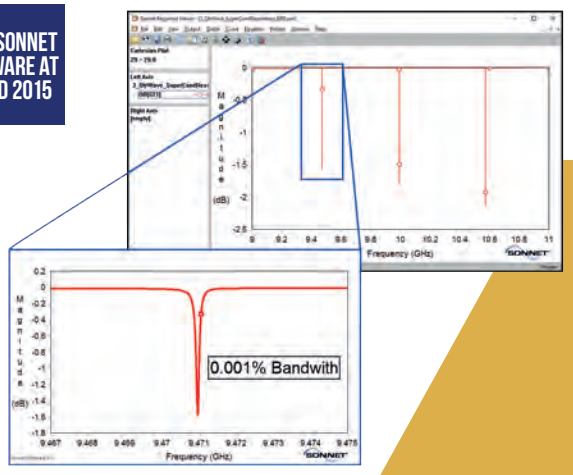
Sessions include:

- Show me the (new) money: Generating the capital to create new space-to-space operations markets.
- Show us the market: Building the business case.
- Managing the traffic: Balancing the need to track and mitigate debris with new business operations in space.
- Tech demo panels: Technologies that enable space-to-space services.

Confirmed speakers include: Aaron Parness, robotics group leader, NASA JPL; Jason Herman, director, Robotics & Automation Technology Group, Honeybee Robotics; Andrew Rush, president & CEO, Made in Space; and Aurelien Pisseloup, space logistics & on-orbit services business development, Airbus Defence & Space.

Planar circuit analysis like no other

VISIT SONNET SOFTWARE AT STAND 2015

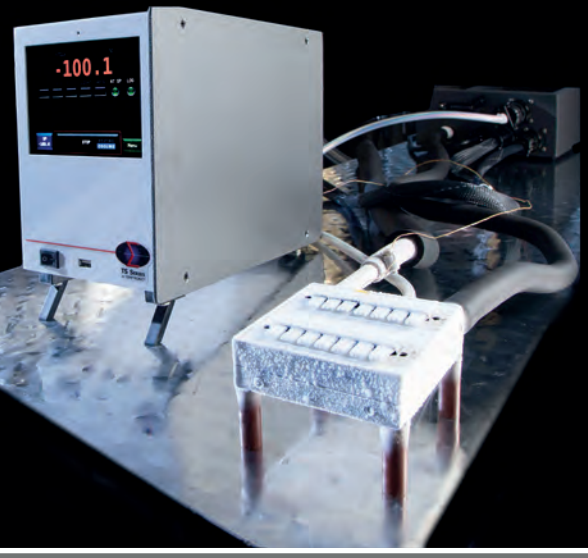


Visit Sonnet Software at stand 2015 to see a demo of the company's Sonnet Suites Version 16, which introduces the Enhanced Resonance Detection feature, engineered to detect and resolve extremely narrowband resonances.

Sonnet will show how this algorithm significantly increases the accuracy of modeling very fine frequency resolution filters, particularly superconductor resonators, which use many of the traditional RF resonator structures, such as half-wavelength or open circuit transmission lines.

With over 30 years of experience in electromagnetic software, Sonnet Software provides the industry's most accurate and reliable EM software tool for planar circuit analysis.

Sonnet has a long-standing relationship with the space industry, particularly in the development of the electronics for spacecraft design. The high accuracy of Sonnet Suites, along with access to Sonnet's world-class support team, allows engineers to build flight hardware with confidence, while staying on schedule and under budget.



Simulate space temperatures with inTest Thermal Solutions

VISIT INTEST THERMAL SOLUTIONS AT STAND 3006

inTEST Thermal Solutions will be exhibiting thermal management systems for precise and extreme temperature conditioning of Mil-Aero components during product development and production testing.

Exhibitors can experience the harsh temperatures of space-borne environments, and manage the high-heat dissipation of powerful electronics. Visitors will see thermal systems that deliver precise, extreme temperature conditioning for the design and manufacture of avionics and Mil-Aero components. With proprietary cooling technologies, inTEST Thermal Solutions' conduction and convection systems are capable of -185°C to +500°C with ±1.0°C accuracy and up to 100°C per minute transition rates.

Each thermal system is configured to meet an application, be it rapid, precise, thermal cycling or long-dwell temperature exposure. A myriad of options are available to access, view, connect and monitor the unit under test (UUT).

Shake it up with IMV

VISIT IMV AT STAND 5031

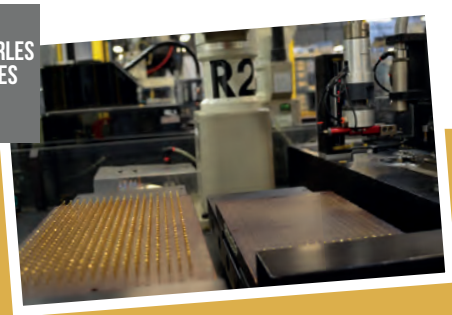
IMV Corp is one of the few multi-axis shaker manufacturers in the world and has three sets of three-axis shaker systems operating in the USA. Visit IMV at stand 5031, where it will be showcasing its systems.

The systems are able to test with simultaneous excitation across all three axes even at 2,000Hz. Each of the shaker systems combines three electrodynamic (ED) shakers assembled at right angles to each other and interconnected by an Integrated Cross Coupling Bearing Unit (ICCU), to support a vibration table. The ICCU provides a precise excitation at a high frequency – up to 2,000Hz, compared with hydraulic systems which are generally up to 150Hz.

Although headquartered in Japan, IMV Corp is a global company offering vibration test systems and has its subsidiary, IMV America, Inc. in Anaheim, California. The company, which is publicly traded, has nearly 60 years of experience in vibration test systems, and specifically 30 years of experience in multi-axis shaker solutions.

Its customers include major manufacturers and test labs in the USA; JAXA (The Japan Aerospace Exploration Agency); and Airbus Defense and Space in the UK.

VISIT EVERETT CHARLES TECHNOLOGIES AT STAND 8015



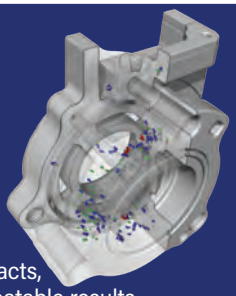
Fast and reliable prototyping for best time-to-market

Everett Charles Technologies (ECT) will showcase its leading portfolio of probes for RF and high-current applications, a comprehensive offering of battery probes that feature highly consistent electromechanical characteristics, and the most flexible and reliable compliant connector solutions.

Prototype projects at ECT start with understanding requirements and direct engineer-to-engineer dialog with the customer to ensure the solution aligns with their needs. Electrical and mechanical analysis prior to hardware build increases design integrity. High-precision machining of plastics and metals utilizes CNC and Swiss screw machining centers. 3D printers and spring winding machines are deployed to guarantee best quality and accuracy. All related internal processes are controlled for high-quality and fast turn times. In the final phase, the customer can rely on ECT's experience in managing the project into high volume manufacturing. ECT's multi-site, ISO-certified, US-based manufacturing capabilities ensure product development from prototype phase to volume production within the customer's launch schedule.

Get results at the Jesse Garant Metrology Center

VISIT JESSE GARANT METROLOGY CENTER AT STAND 2017



Jesse Garant Metrology Center allows manufacturers to make a qualified decision regarding their parts at key stages throughout a product's lifetime, which includes pre-production, production, failure investigation, sorting, and reverse engineering. It does this via industrial CT scanning, industrial x-ray, and 3D scanning services.

The company is a globally recognized part inspection service company, providing NDT and metrology solutions using advanced imaging equipment, which is consistently monitored to provide NIST traceable artifacts, to ensure accurate and repeatable results.

Depending on the dimensional inspection project, the company's metrology services are an ideal fit for first article inspection AS9102 Form 3 reporting requirements. Inspection results are analyzed by experienced in-house staff, ensuring customers' requirements are met and relayed in an easy-to-read format.

Meet the trailblazers in leak testing

Since its founding in 1960, Helium Leak Testing (HLT) has excelled in leak testing services for research, industrial, commercial and production operations in all aspects of industry. Moreover, HLT actually introduced many advances to the helium leak detection industry. Most notable among these are the dual high-speed test station (QC-DC), the absolute static pressure analyzer, and the adjustable helium leak standard (AHLS). Its customers can be found in aerospace, automotive, environmental, food processing, medical devices, military applications, packaging, petrochemical, power generation and semiconductor disciplines.

With more than 50 years in operation, HLT continuously contributes technical expertise and reliable service to the highly specialized and demanding field of industrial helium leak testing, calibration and related vacuum equipment.

VISIT HELIUM LEAK TESTING AT STAND 8024

FREE SESSIONS

Last year's event saw the introduction of the government, military and prime contractor organizations day, which drew in great crowds from the floor.

This is held on the last day of the expo, and will once again see a series of free-to-attend requirements presentations being held in the exhibition hall, as part of three days of free sessions content, enabling all attendees to benefit from an invaluable learning opportunity.

Last year, speakers outlined their current and future projects, highlighting opportunities for the space supply chain, while also sharing details tailored for small businesses.

Feedback last year centered on this fantastic opportunity for companies to find out how to work with the government and military sector, as well as being given the invaluable chance to network with organizations that are usually off the radar.

This year, attendees will hear from JPL, Lockheed Martin NASA, Air Force Space Command, SMC, NASA, JPL, Northrop Grumman, Boeing and Orbital ATK.

This popular day is free to attend and absolutely not to be missed! For more information and to register for your free hall pass visit www.spacetechexpo.com. \\

CVLD vs CCLD

Superior immunity to EMI, EMP and magnetic field interference are just some of the benefits of CVLD

Constant voltage line drive (CVLD) and constant current line drive (CCLD) have a lot in common. They share the benefits and drawbacks that are common to all line-drive preamplifiers, but there are some substantial differences. The shared benefits and drawbacks are derived from the similarity of the overall anatomy of CVLD and CCLD accelerometer systems. The fundamental differences between the two derive from the input – whether it is constant voltage or constant current. The constant voltage input gives CVLD superior immunity to EMI, EMP and magnetic field interference.

Piezoelectric accelerometers require preamplifiers to convert the high-impedance output into a low-impedance signal that is suitable for transmission to measurement and analysis instruments. These preamplifiers can be standalone units that are able to perform multiple roles, they can be integrated into the input circuitry of vibration meters or input modules such as the LAN-XI charge front end, or they can be line-drive preamplifiers.

Line-drive preamplifiers are considerably different from both standalone and instrument-integrated preamps. They are miniature devices that essentially contain the front-end aspect of a conventional preamplifier in a miniaturized form that can be built into or placed near the accelerometer. This limits line-drive preamplifiers to functioning as fixed gain devices with no controls, but makes them particularly beneficial in potentially 'noisy' industrial environments where they have the advantage of driving low-impedance signals along extraordinarily long and inexpensive cables. The sensitivity of such a system to a combination of ground-loop voltages and cable noise is lower than in any other configuration of vibration preamplifier.

There are two basic types of preamplifiers that may be used with piezoelectric accelerometers: charge and voltage. Voltage preamplifiers treat the accelerometer as a voltage source and produce an output voltage proportional to the input voltage. Charge preamplifiers treat the accelerometer as a charge source and produce an output voltage proportional to the input charge. They do not amplify charge. Brüel & Kjær CVLD and CCLD preamplifiers are charge preamplifiers.

Since their introduction in 1968, several line-drive designs have been used, but almost all current systems use a two-conductor cable that links the preamplifier to the power supply and carries both the power and the vibration signal. The power supply can be either a constant current or a constant voltage, which is the primary difference between the two preamplifiers.

CCLD configurations receive power from a constant current and output a signal represented by voltage. The output voltage from CCLD charge amplifiers goes straight to the instrument input, giving rise to one of the drawbacks of the CCLD system. Interference comes in as induced voltage, so because impedance for CCLDs should be as low as possible, ground-loop and induced voltage is added direct to the output signal.

CVLD configurations, on the other hand, receive power from constant voltage and output modulated current, which is measured by the instrument input. Because impedance should be as high as possible (an ideal source would have infinitely high input impedance), ground-loop and induced voltage do not change the current and therefore give no input.

// Brüel & Kjær CVLD accelerometer Type 5985 (left) provides correct results, even in the most demanding environments full of EMI, EMP and magnetic field interference. It connects to input modules such as LAN-XI CVLD Front Panel UA-3111 (right)

CVLD setups result in several benefits over CCLD configurations. CVLD preamplifiers have superior immunity to EMI, EMP and magnetic field interference, which is particularly attractive to the defense industry. Ground-loop sensitivity is 26dB lower in line-drive preamplifiers than in standalone and instrument-integrated preamplifiers, and CVLD sensitivity is 44dB lower still than in CCLD preamplifiers. Rather than the typical maximum cable length of 30m for CCLD, CVLD cable lengths can exceed 1,000m. \\

ONE-STOP UN38.3 TESTING

Safely transporting Li-ion batteries requires completion of advanced testing and IMV can handle all aspects of the tasks needed

Vibration tests for lithium-ion batteries are critical and all manufacturers should check that the air carrier they choose has been properly certified to the UN38.3 safety standards for these components during their transportation.

IMV has a newly launched one-stop testing service for the UN38.3 Li-ion battery transportation safety testing requirement. It has a capability for all tests from T1 to T8 with its safeguarded equipment including explosion-proof rooms, scrubbers and environmental monitoring. With high-quality tests, IMV's highly skilled testing engineers help customers develop new battery models.

Vibration testing is critical for aircraft equipment, and responding to special demands such as for large specimens or using multishaker methods (multiple-input multiple-output – MIMO) is becoming important for the test industry. IMV has opened the Advanced Technology Centre for Environmental Testing, which is located 45 minutes by car from central Tokyo.

IMV is well known for electrodynamic vibration test systems and has a long history of providing testing and consultancy services to major automotive customers. Japanese automotive manufacturers' vehicles have received high quality ratings in market studies and IMV has been an important partner in achieving this success.

The company offers high-level technical capabilities and services, which have been developed through years of experience.

Japan's first vibration and shock test laboratory was established by IMV in Kanagawa in 1998. Since then, the company has been expanding its test laboratory business, with the establishment of advanced centers in Osaka and Nagoya, Japan, and Thailand, and for all of IMV's customers, providing a wealth of experience and technical capability.

The Advanced Technology Centre for Environmental Testing also includes facilities for vibration, shock, temperature, drop and impact tests for lithium-ion batteries to the international standard UN ECE-R100. Additionally, there is a large vibration test system, which includes a 2,000kg testing specimen capacity.

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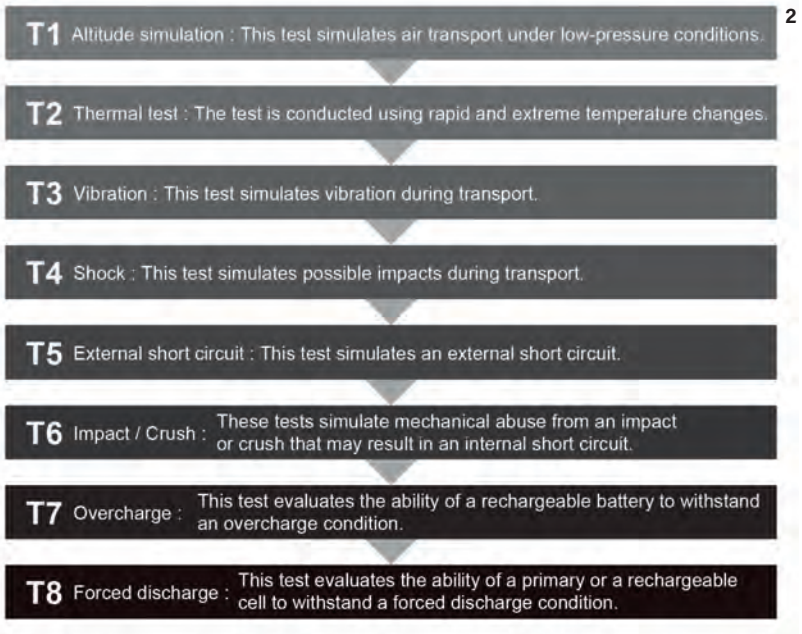

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1 // Climatic chamber combined with a 65kN air-cooled shaker

2 // Flow chart of IMV battery shake testing

The new IMV facility has full capability for mechanical shock and charge/discharge testing of Li-ion batteries. The center has separate battery and vibration testing zones. Battery testing includes charge-discharge systems, which enable center users to perform complete battery pack evaluation with ease. Shock velocities more than 3.5m/s can be replicated using IMV's recently installed A-class shaker series (65kN air-cooled systems).

A variety of fire-prevention measures and explosion-proof systems are installed including: carbon monoxide concentration meters, temperature sensors, pressure relief dampers, anti-flammable vents, twin fireproof doors with thicknesses of 150mm and 300mm, an exhaust gas treatment scrubber, and cameras with monitoring screens.

The vibration testing zone is equipped with an ultra-large vibration test system, which can be configured for long specimens and has a force rating of up to 200kN, using a push-pull method. To support the various needs of the test center users, the zone is also equipped with horizontal and vertical vibration test systems (30-65kN) combined with climatic chambers.

IMV is accredited to ISO/IEC 17025 (JIS Q 17025) – systems for quality, administration and technical operations. Employee training follows ISO 27001 so no critical or sensitive information will leave the IMV test center. \\

SPACE TECH EXPO USA

May 23 - 25, 2017
Pasadena, CA, USA

America's meeting place for space engineering and technology

Don't miss

The free-to-attend Open Technical Forum includes 30+ presentations exploring aerospace manufacturing and design, thermal management, electronics and testing innovations. The three-day program will feature the following:

- Gov/mil/prime requirements day – working with the supply chain
- The challenges and successes of qualification testing using independent test labs
- Using fatigue damage spectrum to correlate validation tests to end-use environment
- Applying modular avionics architecture for next-generation exploration missions

exhibiting companies include:

Top show features:

- **Space Tech Conference 2017**
- **A three-day free-to-attend program**
- **250+ specialist suppliers**
- **Exclusive networking receptions**

Register for a free expo pass - www.spacetechexpo.com

DIRECT FIELD ACOUSTIC EXCITATION

A direct acoustic field for testing noise levels as an alternative to reverberant rooms has been successfully controlled using technology from Siemens PLM Software

Acoustic testing is a milestone in the qualification process of space hardware. Subjecting an item to intense noise levels while measuring its vibration levels is a test performed on component (reflectors, solar panels, etc) and system (satellite) levels. In Europe, the acoustic tests of satellite subsystems such as antenna reflectors are often performed in large (or medium) reverberant rooms, the same ones used for testing a satellite. Over the past 15 years the US space industry has been seeking alternatives for reverberant rooms. The main drivers are the need for a less costly test facility, and a portable test that can come on-site instead of having to ship the article and the engineers to a distant location (at best), or, worse, to a competitor's facility.

This effort has yielded the definition of a new test setup that uses commercially available professional audio equipment (loudspeakers and power amplifiers). NASA Handbook 7010 (2016) is the first and only standard that sets out the guidelines for those companies which want to use this new methodology. The differences between the two setups are many in terms of equipment, needed space and safety. Importantly, to the engineering community it is the acoustic field to which the item is subjected that sets the two methods apart. When placed in the middle of a loudspeaker circle, the test item is excited by a direct acoustic field, hence the name Direct Field Acoustic eXcitation (DFAX) or DFAT in the USA. This is very different to the Reverberant Field Acoustic eXcitation (RFAX) to which the same article would be subjected in a standard acoustic test facility.

Understanding these differences was the objective of a recent study funded by the European Space Agency (ESA) and carried out by Thales Alenia Space (TAS) – one of the world's leading satellite and electronic payload manufacturers – and Siemens PLM Software, which provides data acquisition and control systems for dynamic and acoustic environmental tests. The questions asked at the start were fundamental.

// Siemens PLM Software provided data acquisition and control systems for acoustic tests using an array of 66 loudspeakers (and a 350kW peak-power amplification system) set up in a hangar in Toulouse *(Photo: Thales Alenia Space)*

A large reflector test article was tested in a reverberant room, the Large European Acoustic Facility (LEAF) at the ESA site in Noordwijk in the Netherlands, and with an array of 66 loudspeakers (and a 350kW peak-power amplification system) in a hangar in Toulouse, France. The results confirmed the differing nature of the acoustic fields. Although the multi-input/multi-output (MIMO) controller ensures a minimal dispersion between the pressure levels at the 12 control locations, the noise field in the whole test volume was not homogenous: using a series of measurement points (not for control), the pressure levels between center and periphery were measured to be up to 2dB different. Other issues related to the acoustic field (e.g. potential standing waves between loudspeakers and specimen) deserve more attention but these can be mitigated using simulation tools.

Important progress in commercial loudspeaker technology has allowed for something approaching a typical qualification level, i.e. 145dB Overall Sound Pressure Level (OASPL), and most importantly the vibration levels measured on the specimen during the DFAX test were comparable with those measured with RFAX. A decision should balance the pros and cons of DFAX versus standard RFAX. DFAX has clear lower running costs and initial investment, but also brings benefits from an engineering standpoint (e.g. ramp-up time to level is considerably shorter than in a reverberant room, and many tests can be performed during a test campaign).

At the same time, the data shows that there are still some questions to answer before adopting such a method on a program (at least in Europe, since in the US DFAX has been used to qualify entire satellites for a few years already). But it is clear that agencies and industries are all interested in this technique, so progress can be expected. \\

AN NDT INSPECTOR CALLS


2

Automated and connected devices are providing breakthroughs for aerospace in-service NDT, and more than ever it requires skilled and adaptable specialists

Non-destructive testing (NDT) processes play a major role in maintaining airworthiness during the whole life of aircraft, from design to maintenance. To cope with increasing air traffic and the need for NDT for normal inspections, new solutions are being developed. They can be easily used by non-specialist personnel, sometimes remotely supported by an expert. However, despite their increasing capabilities, these tools cannot always replace a human expert, but are complementary: as the devices become smarter, there is an increasing need for more skilled and adaptable experts to overcome unusual or unexpected cases.


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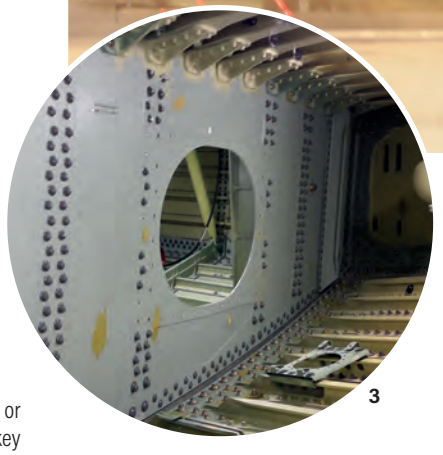
3

Large range of skills

The worldwide fleet contains more than 20,000 aircraft, which have more than 40 years of design evolution that incorporates changing materials and structure. NDT techniques must evolve to ensure the continued safety of 1970s structures (B747, A300) as well as composite aircraft (A350, C-Series, B787). In-service NDT activity needs experts to manage a wide range of techniques, procedures and equipment, combined with a extensive knowledge of aircraft structures and materials.

In exceptional cases such as collisions or strong impacts, the NDT specialist is the key stakeholder to assess the damage and to release the aircraft after repair. Recently, a highly experienced NDT technician from Testia was requested by a company after an on-ground collision between an A319 and an A320, in Myanmar. Supported by a structural engineer, he successfully assessed the damages, even on a non-impacted zone on the opposite side of the fuselage. He participated in the repair campaign, leading to the release of one aircraft. The second one was converted into a restaurant room.

Worldwide mobility

A real case Testia handled was a phone call on Friday at noon to the head of the department requesting four technicians in Singapore and two in Dubai starting from Sunday for an indefinite period.

This illustrates the regular requests that follow a service bulletin or some airworthiness directive. The involvement and the mobility of the team are necessary conditions to an efficient organization. An Aircraft on Ground situation requires an experienced and autonomous team on-site – just providing a specific tool or a procedure would lead to unacceptable delays.

Open-mindedness for adaptability

Despite the best efforts to anticipate and automate procedures and tools, things do not always go as planned. Therefore, NDT teams must be highly skilled to react to unforeseen issues, without jeopardizing safety or increasing inspection times. On a recent A320 elevator infrared testing inspection, for a major Central American MRO, the expert discovered that Testia's heating-qualified device had failed. As there was no way to supply a new one in time, it was suggested to cool the part instead. Discussions with Level 3 experts in Testia's office ensured compatibility with qualified infrared OEM procedures. Inspection was carried out on-site and the aircraft was released on time.

NDT in-service activity is introducing automated and digitized systems, opening amazing opportunities of connectivity and productivity enhancement, always with the same level of safety. More than ever, NDT relies on the mastery of its specialists to cope with the unexpected. \\

1 // Most advanced NDT tools still need experts to assess the results

2 // Inspectors cannot suffer from vertigo

3 // Narrow tanks bring their own challenges with claustrophobia!

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M+P INTERNATIONAL CODA SOFTWARE MONITORS LIFTING OF JSWT

Real-time monitoring of forces with m+p Coda software made possible the safe lifting and mating of components for NASA's large James Webb Space Telescope

NASA recently used an m+p international's Continuous Online Data Acquisition (m+p Coda) software system to monitor the critical lifting and mating of the Optical Telescope Element and Integrated Science Instrument Module (OTIS) for the James Webb Space Telescope (JWST) to its vibration test fixture. Typically engineers would monitor all the signals during the loading and verbally relay the current load values. With the OTIS system there are just too many critical load points to monitor effectively without confusion.

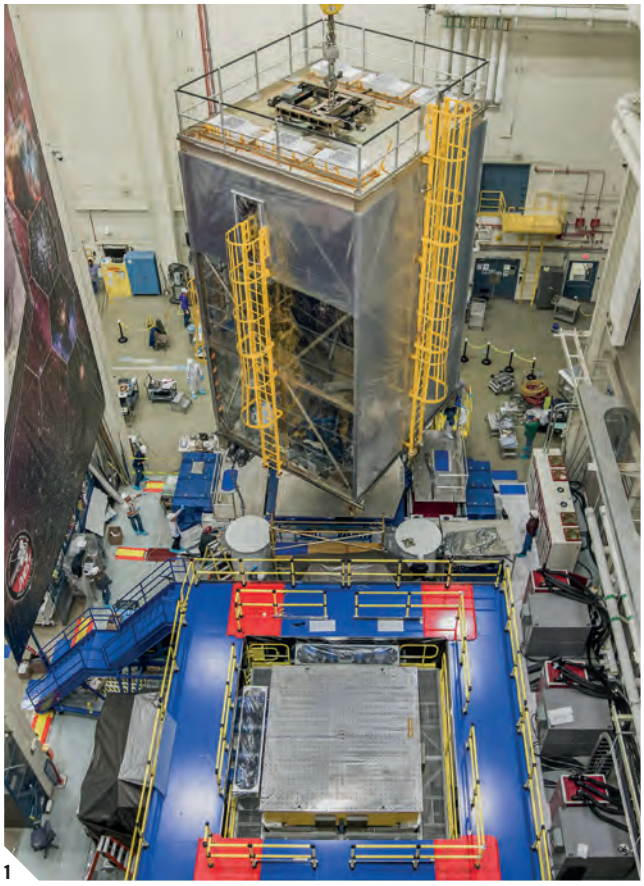
The monitoring system was based on 20-channel analog/digital converter m+p VibRunner measurement hardware with externally summed force sensors. The scope of the operation was to minimize the stress on the OTIS while moving it into position and to monitor vertical and shear static forces to determine correct alignment of the structure to the fixture. Force washers, each capable of measuring forces in three axes, were installed at six locations between the telescope and the vibration test fixture mounting fasteners. Some of the forces were summed using analog equipment before being connected to the m+p VibRunner measurement hardware suite.

During the lifting operation all forces were constantly measured by the m+p Coda software and verified against user-defined force limits, ensuring that stresses on the structure were minimized. When operators maneuvered the spacecraft, m+p Coda measured the in-axis (vertical) and shear (horizontal) forces and the values were displayed in real time.

A custom graphical user interface designed by m+p international displayed color codes to assist the operator in determining if the measured forces were within set limits. If one group of forces was under range, the measurement field in the user interface lit up green; when within range, the field was yellow; and when over range, the field turned red. These color codes gave the operator instant feedback on how the landing was progressing and safeguarded the spacecraft while being mounted on the test fixture.

Given the complexity, enormous size and weight of the OTIS structure with its test fixture, the m+p Coda-based measurement and monitoring system permitted a stable overview of the forces between the spacecraft and the mounting fixture while reducing the risk of misalignment during installation in preparation for vibration tests.

m+p Coda's versatility and vast application capability made it a good fit for this project and, thanks to m+p international US operations, the system was quickly adapted and delivered in under a week to provide NASA a monitoring solution without the need for extensive design work or expensive custom development. \\



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2

1 // JWST being lifted onto the OTIS structure. (Photo: NASA)

2 // Large real-time display with color indicators for loading conditions

CRYSTAL STARS IN TESTING

Environmental testing can validate the design criteria in product development to ensure reliability goals are met

Environmental testing involves evaluating performance of different aspects of a product or component during the development process in industries such as automotive, aerospace and consumer products. Typically, test units are exposed to combinations of vibration stress and thermal stress. These tests further divide into highly accelerated life testing (HALT) and highly accelerated stress screening (HASS). HALT is typically performed to discover design flaws before a product is manufactured.

HASS is used on production assemblies using thermal and vibration stresses. The intent is to identify weak components and manufacturing defects that will cause early failure. Combining HALT and HASS testing improves product reliability, reduces warranty expenses and ensures a satisfied customer.

Environmental testing may also be used as a screening process in production. Environmental stress screening (ESS) is typically used on production electronic components for military and aerospace applications to force latent defects to manifest themselves through failure during the screening process.

For many reasons, it is crucial to manufacturers that such testing should accurately measure and characterize a product's life cycle. For example, it helps ensure that the product complies with safety and other regulations, with the warranty period offered, and the stated lifetime.

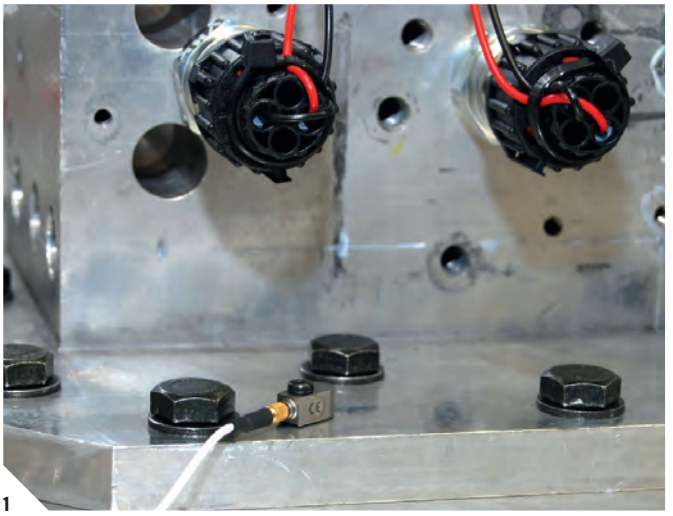
Until recently, accelerometers were a major source of uncertainty in measurements from environmental testing. For the popular Integrated Electronics Piezo Electric (IEPE) accelerometer, the core component is a piezoelectric crystal – one that develops a charge when mechanically stressed. A problem with commonly used materials, notably quartz and piezoceramics such as PZT (lead zirconate titanate), is that the amount of charge developed – the device sensitivity – varies with temperature. If the environmental test regime involves temperature cycling, acceleration measurements will be distorted. This produces uncertainties with both the input control (the shaker is monitored by one accelerometer) and the output data (the structural response of the tested product is monitored by another). Logging the test temperature and applying corrections to the accelerometer outputs can solve this problem, but this is time-consuming and prone to errors.

The need to compensate for temperature is virtually eliminated by the use of Kistler's PiezoStar IEPE accelerometers. These models are based on PiezoStar, a proprietary artificial mineral developed by Kistler in the mid-1990s. Combined with a high-gain hybrid microelectronic impedance converter, these materials produce sensors which, with temperature variations, exhibit very low changes in device sensitivity. These accelerometers are typically rated for -54°C to 165°C and have been successfully used in cryogenics down to -196°C.

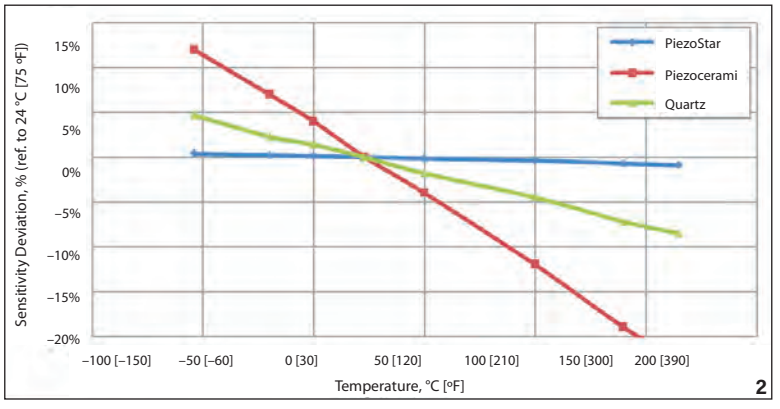
PiezoStar models such as the 8703A and 8705A are rated with a -0.004%/°C temperature sensitivity coefficient – a factor 10 times better than those based on quartz and 40 times better than those based on common PZT piezoceramics.

These properties make PiezoStar-based IEPE sensors ideal for precision vibration measurement across a wide range of operating frequencies and temperatures.

The IEPE accelerometers come in several variants including ±50*g* and ±250*g*, ground isolated, and single-axis linear and tri-axial linear. As an out-of-the-box solution for precision vibration measurement in dynamic temperature applications, they complement ISO/IEC 17025 in situations where the highest standards of environmental testing procedures are crucial. \\



1 // A PiezoStar IEPE accelerometer mounted on a test fixture



2 // A comparison of the typical characteristics of PiezoStar IEPE sensors with those based on quartz and piezoceramics

HIGHER AND TO THE LIMITS

A family of new environmental testing chambers for temperature, pressure and humidity is available to conform to this important and required aspect of aircraft system development

1

All modern aircraft, whether airplanes, helicopters or UAVs, are exposed to extreme stresses during use. Most of this arises from external environmental conditions such as temperature, pressure and humidity encountered either on Earth or at high altitude. Studying the impact of such stresses on the properties, function and lifespan of components and subsystems is required to ensure the safety of people and the aircraft's integrity.

To study stresses, climatic conditions need to be simulated as closely as possible to the real ones and in a very reproducible way. For this purpose, Weiss Technik has developed Sky Event, a new standard range of altitude chambers that meet the strict aerospace industry needs and standards.

With an ultimate pressure level of 5mbar, the Sky Event chambers can simulate altitudes ranging from ground level up to 36,000m (117,000ft). The basic model allows accurately control of temperatures between -70°C and +120°C from atmospheric pressures down to 150mbar, which corresponds to 13,500m (44,000ft). Such performance allows re-creation of the temperature and pressure conditions encountered at most flight altitudes of both commercial and military aircraft. In its thermal and climatic (TAH) version, the Sky Event chamber also controls humidity at atmospheric pressure.

With these specifications, the chamber covers the broad range of climatic tests described in the main aeronautical standards, such as MIL-STD-810G and RTCA DO-160G.

As an example, the main tests of the 'temperature/altitude' (Section 4) and 'temperature variation' (Section 5) sections of the 'Environmental Conditions and test Procedures for Airborne Equipment' DO-160G standard are achievable with Sky Event chambers. With the TAH model, most tests from the 'humidity' (Section 6) section are also covered.

2

Besides the best possible performance, Weiss Technik developed the chamber with a customer-oriented design that ensures ease of use, availability and reliability.

With the basic model including features such as castors for mobility, view window and internal light to keep an eye on the equipment under test, as well as portholes to instrument it and gather critical data, ease of use is guaranteed. The control and supervision of the test can be done either via a touchscreen panel fixed on the chamber or remotely from any workplace PC.

The equipment integrates only proven components that are in maintenance-friendly locations to speed servicing. With the Spirale VS control and supervision software, automatic reminders and planning for maintenance can be programmed allowing scheduling and optimization of test runs.

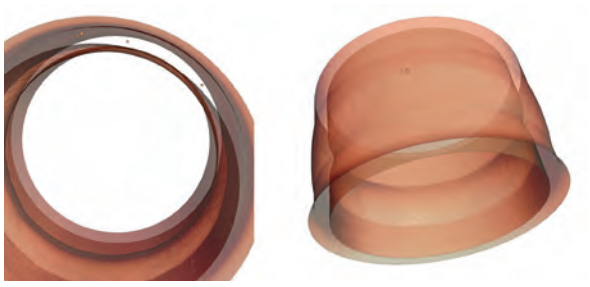
A priority in the development of the Weiss Technik Sky Event chambers was to ensure their continued safe use after 2020 when European refrigerant regulations changes might come into effect. One regulation may be the banning of refrigerants with a global warming potential (GWP) of 2500 or higher, which includes the refrigerant used in most climatic chambers. Weiss Technik anticipated this evolution of the regulations and has designed its machinery to use the new refrigerant R449A, which has a GWP of 1397, making the Sky Event chambers one of the most environmentally friendly test units.

Performance, ease of use and reliability were the backbones of the Sky Event altitude chambers development project. After months of study and design, the new range was finally launched in January. \\

1 // The Weiss Technik Sky Event environmental testing chamber

2 // Spirale VS control and supervision software is designed for use with Sky Event chambers

CT INSPECTIONS OF COMPONENT PARTS



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What aspects should be considered when using CT x-ray imaging equipment to inspect aerospace turbine component parts?

When inspecting complex turbine components using computed tomography (CT) x-ray technology, it is important to examine several aspects of the blade to ensure quality and performance.

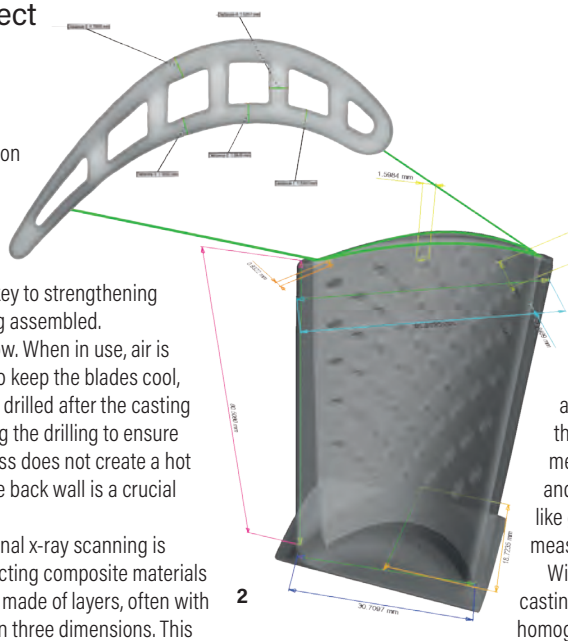
Typically, turbine manufacturers are concerned with the wall thickness, erosion and wear of the blades. Conducting a wall thickness analysis using third-party software can be done as this allows you to color-coordinate wall thickness to scale. You can then set up predefined inspection with inspect/reject requirements to indicate if the wall is too thin.

During quality inspection, composite manufacturers are looking for delamination, porosities, wrinkles, fiber orientation problems and lack of material. Composite manufacturers are concerned with the layers becoming delaminated as this can cause a lack of reinforcement, which could in turn compromise the integrity of the structure.

Porosity detection is a stress factor that can create delamination or a crack. Fiber orientation is the key to strengthening the structure being assembled.

Another is airflow. When in use, air is pumped through to keep the blades cool, and vent holes are drilled after the casting process. Inspecting the drilling to ensure that the drill process does not create a hot spot by striking the back wall is a crucial part of this step.

Three-dimensional x-ray scanning is beneficial to inspecting composite materials as composites are made of layers, often with fibers distributed in three dimensions. This makes the properties of the material anisotropic, meaning having a physical property that has a different value when measured in a different direction.



2

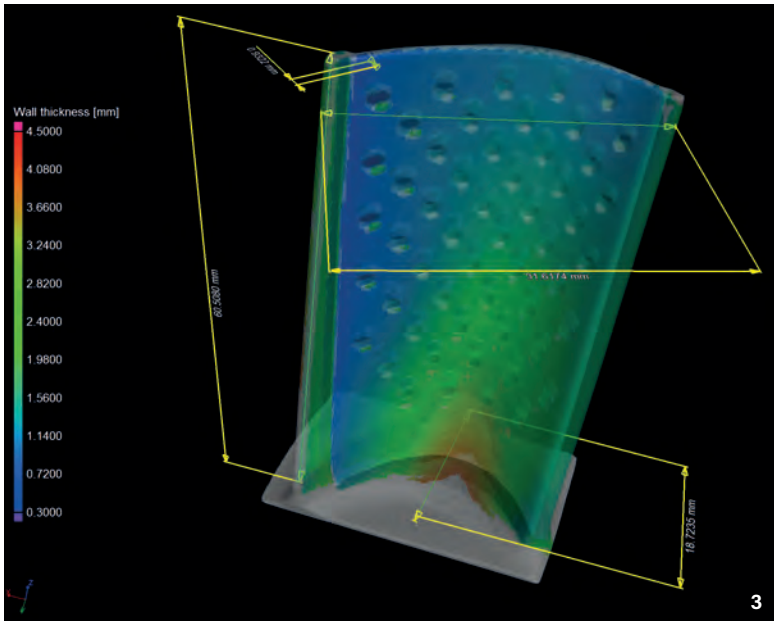
Computed tomography allows users to focus on seeing the true indication and its location. Using 3D images, they can see the relationship of the actual indications, quantify their size, and see the relationship to machine surfaces and edges.

Another dynamic feature of CT is the ability to create a surface rendering of the component. Creating a polygonal mesh to extract the surface information, and the ability to define or surface items like gas porosity within a weld, increases measurement ability and accuracy.

With products such as tube welds or castings, where the material is relatively homogeneous, the surface extraction can be very simple. For a tube weld, the porosity indications have a surface created around them, enabling post-processing software to measure these features or create a porosity report based on threshold size settings for minimum and maximum indications.

At this stage of the inspection, the CT user has the full capability of reviewing the data in 3D. The user can measure the indication, review spacing and orientation, and make decisions on the quality of the component using available new data.

A 3D rendering using the capabilities of an imaging software, like the efX-CT, allows for multiple virtual cross-sections through the part in multiple axes. This resolution often enables users to see individual composite fibers that are only a few micrometers in size. Delamination and wrinkles are detectable. Porosities are quantifiable and measurable. \\



3

1 // CT Scan of an aerospace tube weld showing porosity in the weld area

2 // 3D CT volume and 2D slice of a turbine blade showing the wall thickness measurements

3 // CT scan of a turbine blade showing wall thickness analysis with a 3D deviation plot and coordinate measurements

4K CAMERA EXPANDS RESEARCH OPTIONS

The global shutter in a new 4K high-speed camera is improving aerospace testing options by eliminating artifacts and improving visibility of phenomena and measurements

// The Flex4K-GS camera with its global shutter can capture up to 1,000fps with 4K resolution to enable detailed measurements without unwanted motion artifacts

The new Phantom Flex4K-GS high-speed camera from Vision Research offers a unique set of features for demanding applications in the science, defense and aerospace industries. The Phantom Flex4K, the predecessor to the Flex4K-GS, is well known in the cinema industry for its exceptional image quality and has become the industry standard high-speed camera for TV and motion picture production. Like the original, the Flex4K-GS employs a custom 35mm 9.4MP sensor that can capture up to 1,000fps at the highly desired 4K resolution. The key change from the classic Flex4K, and the reason it can now be used in new industries, is that the sensor technology has been updated from a rolling shutter to a global shutter.

Why a global shutter matters

A rolling shutter improves visual quality for cinema, but can negatively affect imaging in technical areas. In aerospace, many applications involve high-speed rotating components such as propellers and motors. Combining a rolling shutter with another high-speed rotating object can result in motion artifacts that make detail and measurements difficult to view.

The Flex4K-GS was developed with the global shutter because the aerospace industry is primarily concerned with obtaining detailed measurements with very low noise levels and minimal artifacts. Combining a global shutter with the 4K sensor results in every pixel being exposed to light at exactly the same moment. This detail is critical as it prevents unwanted artifacts and ensures timing precision throughout the entirety of each frame.

Resolution and durability

As technological needs progressed, researchers in the aerospace industry began to realize the need for more detail. Vision Research responded to this request by modifying the Phantom Flex4K. When it comes to high-speed imaging in general, there can never be enough speed, sensitivity and resolution. But as in most situations there are trade-offs between these three fundamental aspects of modern CMOS-based cameras. With the Flex4K-GS, pixel resolution is at the forefront, producing incredibly fine detail for improved phenomena visibility and measurements.

The aerospace industry often requires testing in harsh environments, such as at either end of the temperature spectrum, in dusty environments or in destructive situations. In such situations the camera's build quality and thermal performance are a priority. The Flex4K-GS has isolated electronics for increased durability and a thermal design that enables operation in the -20°C to +50°C range. These features ensure that extremely stable images are captured for added assurance that the data is consistent and reliable.

Data storage and controls

The Flex4K-GS has two data-storage methods. The first option is to record direct to the removable, non-volatile memory magazine called the CineMag IV. The second is to recording to the onboard 64GB or 128GB RAM buffer and then transfer the data to the CineMag IV or a computer. Using the CineMag IV enables an extremely fast workflow as the data is typically transferred offboard via a 10G Ethernet connection.

The Flex4K-GS leverages many of the versatile features of the original Flex4K. Battery mounts enable the camera to be powered remotely for several hours. On-camera controls, with a complete and intuitive onboard menu, enable altering the settings easily. A viewfinder and HD-SDI monitors are all powered from the camera body. These features provide researchers with the opportunity to be completely untethered as they work, increasing mobility and decreasing setup time.

The Phantom Flex4K-GS is the most recent example of Vision Research's dedication to providing the aerospace industry with the tools needed to complete its goals. With over 50 years in the imaging business, Vision Research demonstrates that the answer is not always developing something new, but making something better. \\

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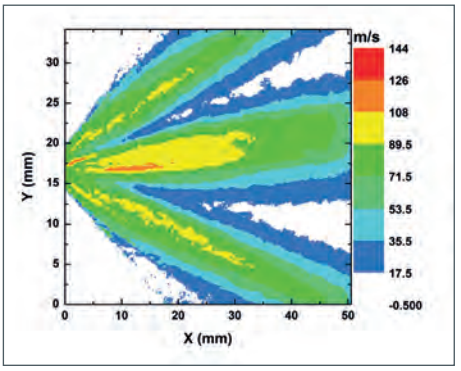
PATTERN IMAGING VELOCIMETER

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

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



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ROBOTIC INSPECTION

The intensive use of information technologies in production processes and the presence of robots able to communicate and cooperate are relatively new in the aerospace sector, but not in other industries such as the automotive. However, the need for quality assurance during aero-parts production by integrating fully robotized cells is one driver behind the so-called fourth industrial revolution (Industry 4.0).

The challenge in the manufacturing digitization drive is connectivity between cells in the production line, reducing the number of steps needed and making manipulators perform multiple tasks. Robotized solutions for ultrasonic testing of manufactured parts are frequently needed. Innovations from NDT systems suppliers are welcomed.

Tecnatom has long experience providing these novel solutions. For instance, by providing robotized cells with interchangeable headers adapted to the characteristics and geometry of the area to be inspected, safer, more productive and human-error free operation is achieved. Headers can be managed by one or two robots, and entirely disassembled and assembled by an automatic header changer without physical operator intervention.

Implementation of IoT technology, to improve process efficiency and cost savings, allows a fully automated inspection operation, including capture of the part geometry, generation of inspection paths, launching and reporting, thereby increasing connectivity between the elements of the production and the human environment and plant management. Within the factory environment, Tecnatom equipment is getting very encouraging results, so data and information can be generated and monitored and available for review on management systems. \\

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ON TRACK WITH EXPRESS

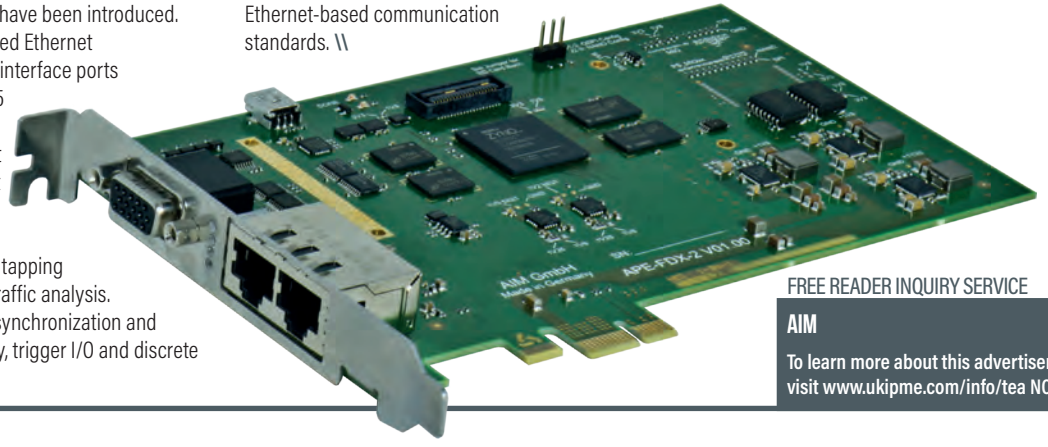
Recently AIM released the APE-FDX-2, AFDX/ARINC664P7 PCI Express test and simulation interface module (PCIe 2.0 x1), which is on track to be the successor of the formidable API-FDX-2 (PCI/PCI-X) module.

With full software compatibility with its predecessor on both the API and PBA.pro layers, the new APE-FDX-2 comes with the latest AIM Common Core architecture, using the latest system-on-chip (SOC) design.

In addition to its predecessor's rich set of field proven test and simulation features, two additional features have been introduced. First, two triple-speed Ethernet (10/100/1000Mbps) interface ports with standard RJ-45 copper front-end connectors support single or redundant configured AFDX/ARINC664P7 links. Second is a built-in tapping function for inline traffic analysis. Support for IRIG-B synchronization and generator capability, trigger I/O and discrete I/O are included.

An onboard LINUX operating system is executed on one CPU of the dual-core processor. The second core CPU implements the hard real-time bus interface unit that communicates with a customized MAC controller in the FPGA section.

This new architecture offers a powerful and flexible platform for today's and future standard AFDX/ARINC664P7 test and simulation tasks, including support of the Boeing ARINC664P7 variant and other Ethernet-based communication standards. \\



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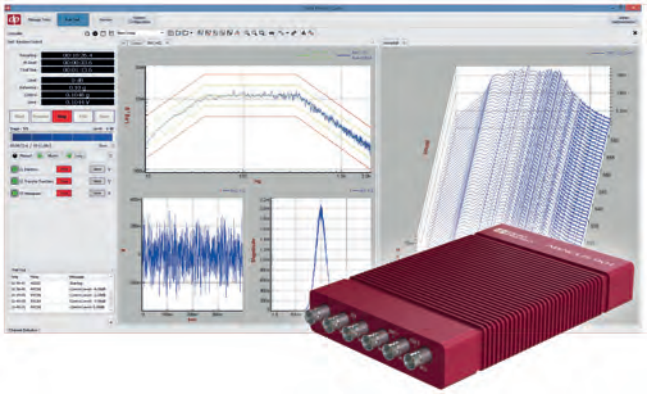
MODULAR, SCALABLE SIGNAL ANALYZERS

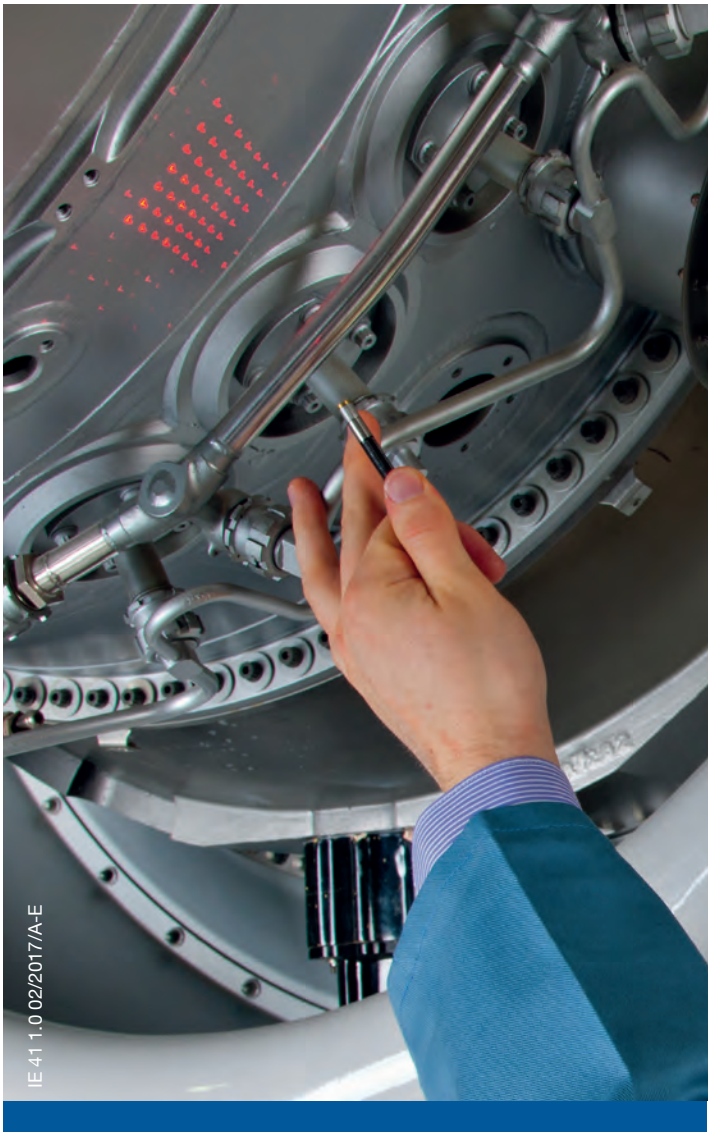
Data Physics recently introduced closed-loop vibration-control software to its SignalCalc 900 Series software suite. The SignalCalc 900 Series is an integrated suite of dynamic signal analysis and vibration control applications that incorporates a common database for managing all tests and data.

The new vibration control software options add the ability to control electrodynamic and hydraulic shakers to accurately produce vibration environments for product testing and qualification. The vibration control capabilities include random control with frequency ranges up to 80kHz and 51,200 frequency lines, sine control from 0.1Hz to 20kHz, and shock control with sample rates up to 216,000 samples/second. The new SignalCalc 900 Series vibration control software offers the most advanced control algorithms, including Data Physics's continuous convolution random control.

The SignalCalc 900 Series software runs on the new Abacus 900 Series hardware. The Abacus 901 is a compact, real-time, data acquisition and signal processing platform. Its compact size makes it well suited for both laboratory and portable dynamic signal analysis applications, and its hardware was designed for closed-loop control. The Abacus 901 employs multiple digital signal processors and an ARM processor running a real-time operating system in a compact six-channel chassis.

The Abacus 901 can operate independent of the client PC. All vibration control loop processing is done inside the Abacus 901 hardware, ensuring the highest accuracy and safety. The Abacus 901 includes a removable 64GB SD card to store data during the test. \\





GOOD AND BAD AUTOMATION

Engineers at Test-Fuchs don't like automation – they love it! It increases productivity and reduces human error, but how much is too much? Test-Fuchs answers this challenging question with a simple principle: keep the operator at the center of the test application. Automation and testing sequences are defined with the customer, with each step being determined as either manual, semi-automated or automated. The complete test sequence can be monitored, stopped and restarted and the operator remains in control. The operation and handling of a test becomes simpler while still transmitting understanding what the test rig is doing and how it is performing.

Automation provides more accuracy and speed as data acquisition, collecting and processing are done automatically. Results are then plotted into customized test reports that exactly meet the requirements. These reports are available immediately but also archived to ensure long-term data security.

New technologies and research at Test-Fuchs will soon lead to new functions. For example, your test stand may tell you it is time to recalibrate and guide you through the process. The stand may even help operators to anticipate wear or needed consumables and help them place the necessary order. As Test-Fuchs begins to harness the benefits of technology, they have decided to keep the operator in the driver's seat. \\

NDT UV-A STANDARDS-COMPLYING LAMPS

Aerospace industry standards for NDT/NDE inspection lamps are in place to ensure the safety and efficiency of ultraviolet A (UV-A) lamps used in fluorescent inspection of critical parts and infrastructure.

Both the ASTM and aerospace companies such as Rolls-Royce write standards to cover the procedures involved in testing the performance of UV-A LED lamps used in fluorescent penetrant and fluorescent magnetic particle testing. These specifications also include reporting and performance requirements of UV-A LED inspection lamps.

These tests are intended to be performed only by the manufacturer, to certify performance of specific lamp model features (housing, filter, diodes, electronic circuit design, optical elements, cooling system and power supply combination). This also includes limited acceptance tests for individual lamps delivered to the user. The test procedure is not intended to be carried out by the end user.

Spectroline complies with ASTM E3022 and Rolls-Royce RRES 90061 regulations with several of its lamp models. The company certifies the performance of lamps with rigorous in-house testing.

Test performances are recorded on serialized certificates of conformance (ASTM) and validation reports (RRES), which show that the lamp has met acceptance test requirements, emission spectrum measurements and filter transmittance tests before it is shipped to the end user.

Spectroline invented the use of LEDs in fluorescent inspection lamps and is a world leader in UV-A lights and leak detection solutions, for the aerospace industry worldwide. \\

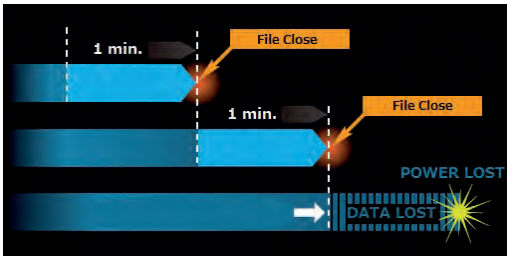
DEPENDABLE DATA RECORDING

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

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

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

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



STANDARDS-COMPLIANT UV INSPECTION LIGHTS

Failure is not an option in magnetic particle inspection (MPI) and fluorescent penetrant inspection (FPI), which makes Secu-Chek's UVE Series the right choice for optimized fast and secure inspection. The UVE Series, from the leading German manufacturer, offers maximum process security due to its revolutionary electronic UV LED and system health monitoring, which automatically switches the lamp off in the event of a critical failure to stop the inspection process and keep it secured.

The 18 flood lamp models in the UVE Series are approved to the new aerospace benchmark requirement for UV LED sources from Airbus AITM 6-1001 Issue 11 (published November 2016) and NADCAP AC 7114 / AC 7114-1 /AC 7114-2 as well as its supplements (to be used after the end of January 2017), in addition to Rolls-Royce RRES 90061, EN/ISO 3059 and ASTM-E 3022 qualification.

Ten hand lamps (with three to eight UV LEDs) and eight stationary UV LED lamps are available with three inspection areas ranging from 50-70cm (19.5-27.5in) by 40cm (15.5in).

The lamps are available as UV-only inspection lamps or optionally equipped with the groundbreaking automated stepless white light dimming features that allow optimized interpretation of indication by uninterrupted observation. The white light can be dimmed and raised in addition to UV or can perform a cross-fade between UV and white light.

The detailed and complete aerospace qualification is available as hardcopy or a PDF file. It shows all relevant information, data and testing results individually for every single standard as well as NADCAP checklists and its supplements. It allows the user to easily show evidence of conformance by the link-up of every line item of the certificate to the relevant sections, chapters and tables for the specific standards.

HIGH-LEVEL SHOCK ACCELEROMETERS

Shock accelerometer designs provided by PCB can improve measurement of both high-level shock (e.g. gun launch and penetration events) and pyrotechnic shock events. Pyroshock presents a measurement challenge due to its high frequency content, which typically excites the resonant frequency of the test accelerometer. As a result, the accelerometer can easily be driven nonlinear due to this resonance excitation.

Piezoelectric ICP accelerometers offer a high signal output range (+/-5V full scale) and ease of two-wire electrical connectivity. Their rugged internal and external design enables them to be severely over-ranged without damage. Internal mechanical isolation minimizes high-frequency stress that would otherwise damage the internal ceramic sensing elements. An internal two-pole electrical filter tailors the overall accelerometer response to ensure data quality to frequencies as high as 10kHz.

Piezoresistive shock accelerometers, manufactured using MEMS technology, operate through low power consumption while still providing +/-200mV full scale output at acceleration up to 60kg. The accelerometers are electrically compatible with the four-wire full-bridge circuit used to condition a strain gauge. They offer a wider operating temperature range of -65°F to +250°F (-54°C to +121°C). MEMS piezoresitive shock accelerometers operate in extended frequency ranges from DC (0Hz) to 20kHz. \\

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(Photo: Musée de l'air et de l'espace)

A giant retires

Airbus has donated its fourth flight test A380 to the Air and Space Museum at Le Bourget near Paris. It is the largest flight test aircraft to be preserved anywhere

(Photo: Musée de l'air et de l'espace)

An important part of aviation history, an Airbus A380 flight test aircraft, has been donated to the Air and Space Museum at Paris-Le Bourget Airport. Test registered as F-WWDD, the MSN4, as it was known by its manufacturer, first flew on October 18, 2005, and was never fitted with a passenger interior – it was dedicated to the test flight program and flew 3,360 hours.

More Airbus flight test aircraft, including the A320 MSN1, which was recently withdrawn from the test fleet, the A340-600 MSN360 and the A380 MSN2 are slated for preservation at Aeroscopia in Toulouse, France, within the next two years. All the donated aircraft will be displayed, but importantly they will benefit from the heritage preservation measures that will allow the public to view them and gain a better understanding of aerospace flight testing. Overall, these aircraft cover more than 30 years of flight tests and represent commercially successful designs for Airbus.

The first aircraft to be transferred for preservation was the A380 MSN4, which arrived at Le Bourget on February 14. On board were 50 passengers including engineers and technicians from Airbus's A380 program, partners and staff from the Air and Space Museum.

After the MSN4 test aircraft's arrival, it was moved to a location out of public view while preparations for its display at the museum began. This major technical project will be completed by a team of Airbus technicians. The first step was draining the remaining fuel. Other fluids and other pyrotechnic systems (emergency slide actuators) will be removed, as well as some items specifically dedicated to flight testing. The four Engine Alliance GP7270 engines will be replaced with replicas.

Then the museum plans a unique refurbishment to showcase its operational role. Additional technical work will be carried out on the airframe to help preserve it structurally. All this work is scheduled to take several months, after which the museum plans to create a special exhibit inside the aircraft to enable people to visit it from 2018 and learn of its role in aerospace testing and the A380 program.

July 2017 is tentatively scheduled for positioning the A380 in public view in front of the tower of the historical terminal of Le Bourget Airport, but there will still be more development work before the public can visit the aircraft in 2018.

The other aircraft for preservation will be maintained by Airbus Heritage in Toulouse. They will move to Aeroscopia within two years when a display area at the northern part of the museum has been completed. \\

OCT 18, 2005
First flight

A380-861
Model number

79.8M
Span

73M
Length

560,000KG
Max. take-off weight

MACH 0.89
Top speed

MACH 0.85
Cruising speed

15,000KM
Range at full load

43,000FT
Ceiling

363KN
Thrust of each of the four GP 7270 engines

TELETRONICS
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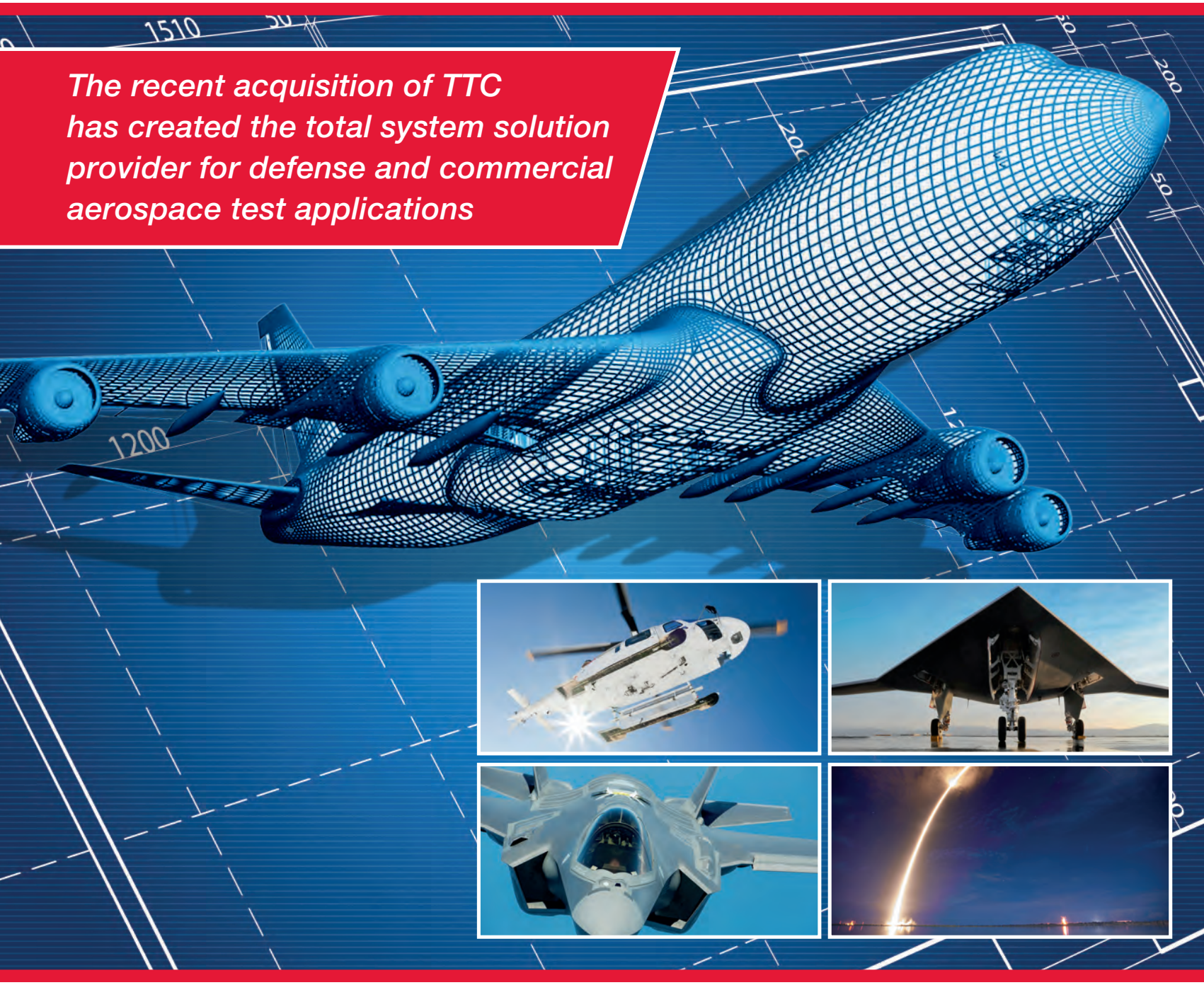
Comprehensive Flight Test Systems and Data Acquisition Technologies

The recent acquisition of TTC has created the total system solution provider for defense and commercial aerospace test applications



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