MARCH 2018

Aerospace TESTING INTERNATIONAL

Inside this issue

// A330 NEO
The Airbus re-engined wide-body airliner is breaking new ground in test methodology to reduce time-to-market

// NDT: ROYAL NAVY
How a squadron dedicated to maintaining the Royal Navy's aircraft delivers non-destructive testing in uniquely challenging environments

// BEST OF BOEING
Exclusive Q&A: The US company's chief test pilot in the UK talks localization and the future of test campaigns

Survival kit fit for Mars

Test engineers push spacesuit design and materials to the limit for the next generation of human spaceflight

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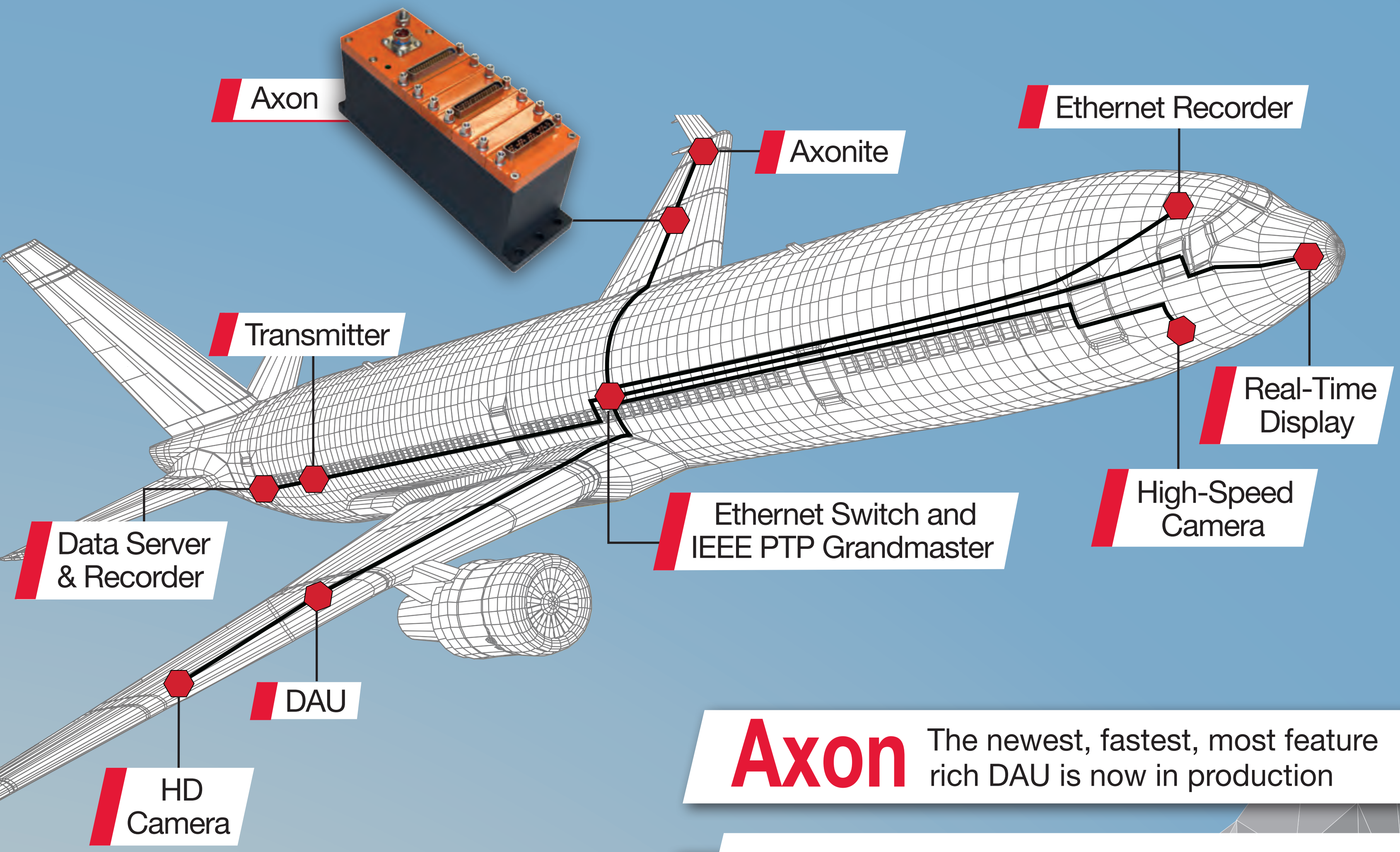

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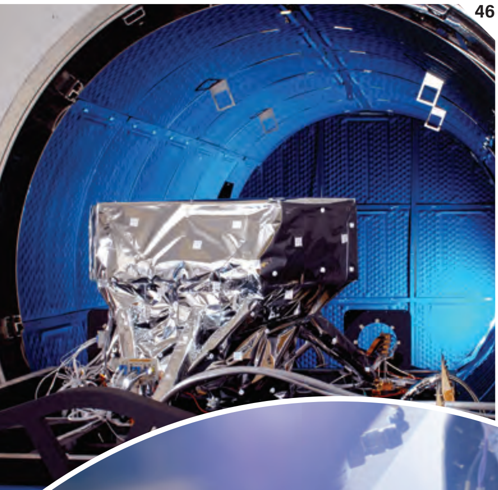
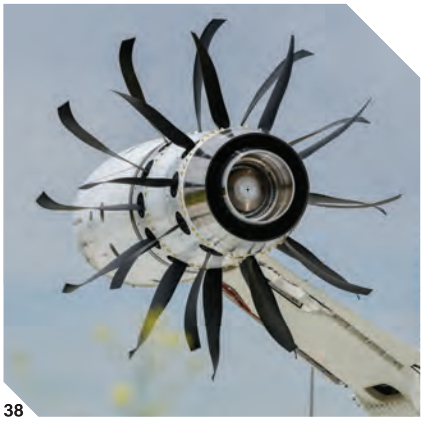
Global briefing

16
46





38
62

32

Inside this issue

// Why the small stuff matters

One of the first factories I visited as a journalist was Airbus's A380 wing manufacturing plant in Broughton, North Wales, a few years after production had started in 2006. My overriding impression was of the vast size of the operation. Standing on a platform in the massive hangar in which the wings were fabricated, assembled and tested made me realize the huge scale of the industry behind the endeavor of flight.

It's a realization that has stayed with me to this day as we delve deep into the detail of the technologies, processes and vehicles under development in the aerospace sector right now. It's a very exciting time to be involved in the sector, as arguably there's more innovation and change than when the first A380 rolled out of the hangar in Toulouse in 2005.

There's a renewed push toward space exploration and commercialization. This is reflected in the increased test and development activity taking place this year (see page 10) and projects like the Stratolaunch (see page 6). In our cover story, starting on page 16, there is also a rare insight into NASA's development of spacesuits. Personal protection from the harsh environment of space is a seriously complex engineering undertaking, so much so that NASA engineers call the suits "mini-spacecraft". The article provides an extreme example of how testing is integral to aerospace development.

But we're not all aiming for the stars. Some of us are happy in the clouds, and that includes people like Boeing's chief test pilot in the UK, Rich Pillans. In his interview on page 32 he relates how risk is managed during flight tests and the value human pilots still bring to aircraft development.

Meanwhile the removal of humans from piloting aircraft is the aim of much UAV development, whether that's air taxis such as Chinese firm Ehang's, Airbus's Vahana or delivery drones. Engineers are busy updating the testing hardware and software vital to testing the increasing number of small UAVs expected to inhabit our skies, as the article on the NASA Delivery project on page 62 shows.

It's easy to be impressed by size, as I was by the A380's wings, but several years later I was writing about the cracks found in those same wings. Airbus has been dealing with the fault, which lies in some of the brackets used in the wings, ever since.

It's proof, if any is needed, that it's the small things that matter in aerospace, like the correct fitting of a rivet in a fuselage, a smaller but more accurate accelerometer used in flight test or an incremental improvement to simulation software. Testing is often about ensuring these small things are right. It's that necessary attention to detail that engineers, technicians and flight crews in aircraft development bring to the industry every day that enables aircraft to fly safely.

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WORLD *test update*

// BOEING 737 MAX 7 STARTS FLIGHT TESTS

Boeing's first Max 7 aircraft has begun its inaugural test program.

The 737 Max 7 has the longest range in the 737 family, 3,850 nautical miles, around 1,000 more than its predecessor, the 737-700, while still managing 18% lower fuel costs per seat.

The first of the two Max 7 test aircraft is the 1E001, which has undergone system checks, fueling and engine runs on the flight line in Renton. Boeing said the aircraft contains nearly nine miles (14km) of wiring, to transmit data from sensors to instrumentation racks, for engineers to analyze the airplane, from its dynamics to brake temperatures.

The 737 Max 7 is scheduled to enter service in 2019. The launch customer is Southwest Airlines.

Keith Leverkuhn, vice president and general manager of the 737 Max program for Boeing Commercial Airplanes, said, "We look forward to demonstrating the flexibility and range of this airplane."

READ MORE ONLINE!

Renton, Washington, USA

// US ARMY TESTS V-280 VALOR TILTROTOR

The US Army has officially flown Bell Helicopter's V-280 Valor.

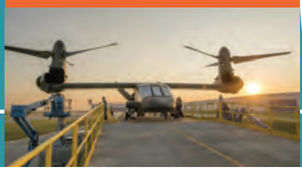
The flight, which took place in February, showed the aircraft performing hover in ground effect repositioning, pattern flight and roll-on landings.

WATCH THE VIDEO ON OUR WEBSITE

Bell began ground testing of the V-280 Valor tiltrotor aircraft in October and it made its first flight in December 2017. The Bell V-280 Valor reached a flight speed of 80kts at an altitude of 1,000ft above ground level during the first part of its flight test campaign. The tiltrotor is described by Bell as the next generation of vertical lift aircraft for the US military.

Mitch Snyder, president and CEO of Bell Helicopter, said "The Valor is designed to revolutionize vertical lift for the US Army and represents a transformational aircraft for all the challenging missions our armed forces are asked to undertake."

Amarillo, Texas, USA



// ISRAEL TESTS MISSILE INTERCEPTOR SYSTEM

The Israeli Ministry of Defense successfully completed the first flight test of its Arrow 3 missile defense system.

Arrow 3 is designed to defend against ballistic missiles which travel outside of the atmosphere in space during their flight, such as intercontinental missiles.

The missile is part of Israel's defense array, which has four layers: Iron Dome, David's Sling, and the Arrow 2 and Arrow 3 systems. The Arrow 3 test was conducted by Israel Aerospace Industries (IAI) and the Israeli Air Force.

The Arrow 3 interceptor has been developed by Boeing and IAI alongside the US Missile Defense Agency, which also supported the recent test. "The success of the test is a major milestone in the operational capabilities of the State of Israel and its ability to defend itself against current and future threats in the region," said the Israeli Defense Ministry.

Additional tests of the Arrow 3 are planned in Alaska, USA, later this year.

Central Israel

// HYBRID HELICOPTER ENGINE TESTBED SELECTED

Safran is to flight test its Aneto-1X hybrid engine technology for the first time on Airbus Helicopters' Racer high-speed demonstrator.

The Racer (Rapid and Cost-Efficient Rotorcraft) will use twin Aneto-1X engines to help it achieve a cruise speed of up to 400km/h (250mph). Final assembly of the demonstrator is expected to start in 2019, with a first flight planned for 2020.

READ MORE ON HELICOPTER TESTING ON PAGE 86

The Aneto engine features Safran's Power Pack Eco Mode configuration, which uses a high-power density electric motor for more efficient use of the power generated. The Power Pack Eco Mode has been validated in ground tests and its maiden flight will be aboard the Racer.

Eco Mode enables a pilot to pause one engine while in cruise, to generate fuel savings of around 15% and greater mission range, according to Safran. When needed during maneuvers such as acceleration, landing or autorotation, the idling engine will rapidly and automatically be restored to full power using the electric motor.

Marignane, France

// AIR TAXI PERFORMS FIRST MANNED FLIGHT

Chinese UAV developer Ehang has conducted the first manned test flights of its self-flying passenger aircraft, the Ehang 184.

The demonstration flights included a trip with Ehang's founder and CEO, Huazhi Hu, who said, "What we're doing isn't an extreme sport, so the safety of each passenger always comes first. Now that we've successfully tested the 184, I'm really excited to see what the future holds for us in terms of air mobility."

The Ehang 184 can carry a single person at speeds of up to 130km/h (80mph).

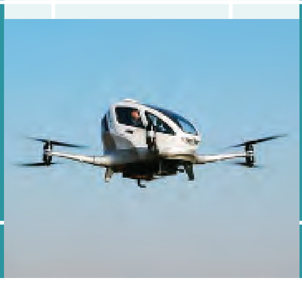
The company said the manned test flights are the latest in a series of safety tests before the 184 is made available for public use "in the near future".

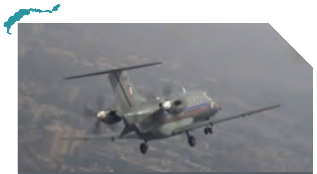
The aircraft has passed a vertical climbing test up to 300m (980ft), a loaded test flight carrying approximately 230kg (500 lb), a routed test flight covering 15km (nine miles), and a high-speed cruising test.

Ehang's 150 engineers are now working on improving passenger experience and adding optional manual control.

Guangzhou, China

WATCH THE VIDEO ON OUR WEBSITE





// INDIA'S SARAS GETS SECOND CHANCE AT TESTING

An improved version of the Saras light aircraft has started flight testing, with the Indian Air Force committed to buying 15 of the Indian-produced aircraft.

The first flight took place on January 24. Some 20 test flights are planned for the test aircraft PT1N, with testing expected to be completed by July this year. The production version aircraft will have 19 seats and will undergo civil and military certification.

The aircraft is being developed by India's National Aerospace Laboratories (NAL) and is being tested by the Indian Air Force. NAL has made several improvements to the Saras, such as two 1,200shp engines and 2.6m (103in) diameter propeller assemblies, improving the flight control system, the rudder area, main wheel and brakes to cater to 7,100kg (7.8 tons) AUV, as well as a stall warning system.

The government-owned Hindustan Aeronautics (HAL) will produce the military version, while the production of the civil version will be given to private companies.

The original Saras program ended in 2009 after an accident.

Bangalore, India

// FIRST FLIGHT FOR RUSSIAN TANKER

The Russian Air Force flew the prototype of the IL-78M-90A aerial refueling tanker for the first time in January.

The maiden flight took place at the manufacturing facility of Aviastar-SP in Ulyanovsk, western Russia, and lasted 35 minutes. The aircraft was piloted by Chief Pilot Nikolai Dmitrievich Kuimov.

This aircraft is the first tanker to be developed in Russia since the end of the Soviet era and was designed by the Ilyushin Aviation Complex. It is able to refuel two front-line aviation aircraft simultaneously. On the ground it can fill up to four aircraft at the same time.

The IL-78M-90A is based on the Soviet-era Il-76 Candid airlifter, with more efficient engines. It has modernized control and navigation systems and a digital glass cockpit to increase flight safety.

Re-equipping it at an air base enables use of the IL-78M-90A as a military and transport aircraft.

Ulyanovsk, western Russia

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WORLD'S LARGEST AIRCRAFT COMPLETES TAXI TESTS

Stratolaunch Systems has performed the high-speed taxi tests for the world's largest aircraft by wingspan, as the airplane makes progress toward its maiden flight, scheduled for 2019.

The Stratolaunch carrier aircraft will serve as an air-launch platform for spacecraft, including Orbital ATK's Pegasus XL, and is planned to enter service in 2020. An air-launched rocket, The Pegasus XL is capable of carrying payloads into low Earth orbit.

The double-fuselaged, all-composite aircraft has a wingspan of 385ft (117m) and is powered by six Pratt & Whitney PW4056 turbofan engines. It has a maximum take-off weight of 1,300,000 lb (590,000kg) and a payload capacity of around 550,000 lb (225,000kg).

A number of ground tests have been carried out on the aircraft at the Air and Space Port in Mojave, California, since it was first revealed in May 2017, including low-speed taxi tests and testing of all six of the engines.

Brandon Wood, test lead at Scaled Composites, the Northrop Grumman-owned company developing the aircraft for Stratolaunch Systems, said, "The sheer number of systems incorporated into this aircraft dictates a relatively complex aircraft data acquisition and telemetry system. The aircraft configuration, specifically the distance between the dual fuselages, presents challenges during ground operations.

"The aircraft is incompatible with many airports, and ground operations, such as towing, require more planning than for conventional aircraft. The flight testing techniques will, however, be fundamentally similar to other large aircraft."

Stratolaunch was founded by Microsoft co-founder and philanthropist Paul G Allen and SpaceShipOne designer Burt Rutan, with the aim of significantly reducing the cost of space travel and improving access to Earth's orbit for private and commercial endeavors.

Stratolaunch says it is in active discussions with potential customers from both the private and public sectors. //

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// The Trent 1000 is being used as a testbed for the ALECSys process

LEAN BURN ENGINE FIRED UP

Engineers at Rolls-Royce have run a lean burn combustion process for the first time on a test engine at the company's facility in Derby, UK.

The ALECSys (Advanced Low Emissions Combustion System) will be used in the company's future jet engines, such as the Advance3 and UltraFan, which are planned to be on the market by 2020 and 2025 respectively. The development of ALECSys has been part-funded by the European Union's Clean Sky SAGE (Sustainable And Green Engine) program.

ALECSys improves the pre-mixing of fuel and air before ignition to deliver a more complete combustion of the fuel and lower NO_X and particulate emissions. The system was housed within an adapted Trent 1000 engine for the test.

Andy Geer, chief engineer and head of program for UltraFan, Rolls-Royce, said, "We are very proud to see this technology come to life for the first time. We are confident that the ALECSys system will offer significant benefits for our customers and look forward to putting the demonstrator through its paces."

Other testing milestones at Rolls-Royce include the running of its Advance3 test engine for the first time in November, and the testing of the gearbox for the UltraFan engine in September 2017. The UltraFan is a geared, scalable engine, designed to offer 25% fuel efficiency improvement over the first generation of Rolls-Royce Trent engines. The gearbox reached 70,000hp – a record level of power transmission in the aerospace sector – while being tested at the Rolls-Royce facility in Dahlewitz, near Berlin, Germany. //

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SUMMER OF SPACE LAUNCHES ON SCHEDULE

Test and certification of rocket engines that will propel the next generation of US manned spacecraft into orbit, to the moon and to Mars, are moving forward on schedule, setting the stage for vital first flights and tests during the coming months.

In the private sector, Boeing is planning the first uncrewed test flight of its CST-100 Starliner/Atlas V system in August and the first crewed test flight in November. SpaceX has a similar schedule, with the first uncrewed test flight of its Dragon/Falcon Heavy system also scheduled for August and a crewed test flight in December.

Both spacecraft will transport astronauts to the International Space Station.

The Design Certification Review of the Atlas V was completed in January. Space X's Falcon Heavy successfully lifted off from the Kennedy Space Center in Florida in February.

The Falcon Heavy uses three Falcon 9 rockets, each of which has nine Merlin engines, to generate more than 5,000,000 lb (2,300 metric tons) of thrust at liftoff.

Meanwhile engineers on NASA's Space Launch System (SLS) program will be assembling and testing the 212ft (65m) tall core stage of the rocket. These include its four Aerojet Rocketdyne RS-25 engines, which are being recycled and modified from the Space Shuttle program and the intertank.

The intertank houses the avionics and sits between the SLS's two cryogenic fuel tanks and two solid rocket boosters. Its position means it is subjected to the strongest forces of any part of the rocket as its engines and boosters produce up to 8,000,000 lb (3,600 metric tons) of thrust during liftoff.

A structural test version of the intertank was delivered to NASA's Marshall Space Flight Center in Huntsville, Alabama, this month for testing in the summer. Engineers will use a 60ft (18m) tall rig that weighs 2,000,000 lb (900 metric tons) and 100 hydraulic actuators to simulate the forces the intertank will experience during launch.

The SLS is scheduled for its first test flight in 2019 at the Stennis Space Center in Mississippi and its first manned mission, which will take astronauts beyond low Earth orbit for the first time in almost 50 years, is planned for 2023. \\

// The Falcon Heavy test at Launch Complex 39A, the same pad used to launch Apollo 11

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// The 777 Freighter on loan from FedEx is testing a more efficient power system supplied by Safran

ECO DEMONSTRATOR BEGINS FLIGHT TESTING

Boeing's 2018 ecoDemonstrator flight test campaign has started, with a 777 Freighter carrying more than 35 different technologies taking off from Boeing Field, Seattle, Washington, on March 5. The ecoDemonstrator program flight tests prototypes of systems and equipment designed to improve the environmental performance and safety of future aircraft. The FedEx-owned 777 Freighter being used this year as a testbed was delivered in October 2017 and then returned to Boeing in January, to be fitted with instrumentation and the demonstration technologies.

The 777, nicknamed Hollie, flew on 100% biofuel. Flight testing will continue during April, before the aircraft is refurbished and returned to FedEx in June. The 35 technologies being tested include a compact thrust reverser designed to save fuel, flight-deck improvements to help make operations in and out of busy airports more efficient, and prototype aircraft parts made with manufacturing techniques that reduce materials waste.

Alain Sauret, president of Safran Electrical and Power, one of the companies participating in the program, said, "We are providing the Boeing ecoDemonstrator with an electric power source and a complete electrical channel. It is a prime example of our capabilities to design tomorrow's optimized electrical systems and we are very proud to contribute to Boeing's environmental efforts."

The power source being flight tested is a variable-frequency geared generator, which has 60% less thermal losses and is 15% lighter than the existing generation system used on the Boeing 777. Safran is also testing more efficient power distribution and ventilation systems in the cabin.

The ecoDemonstrator program has run since 2011 and has so far used four different aircraft to test more than 60 technologies. \\

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MATERIALS FOR DE-ICING

Matt Asper from the University of Virginia reveals how his ground-based tests are helping to solve the challenge of ice accretion at high altitudes

Icing on aerodynamic surfaces such as aircraft wings and engine inlet guide vanes usually happens when supercooled droplets accumulate at high altitudes. Once formed, the ice reduces performance. In severe conditions, aircraft may stall and lose engine power.

I have been conducting research with a PhD candidate at the University of Virginia's (UVA) icing facility since May 2017 to try to find a solution to this icing problem. We have been conducting ice accretion/adhesion tests on various objects in an icing wind tunnel, and then using hydrophobic surfaces to mitigate icing accretion.

We are testing two hydrophobic materials – an oil-infused elastomer developed at UVA and a ceramic cylindrical porous material developed by two Greek researchers.

After characterizing the coating by measuring droplet static contact and roll-off angles, the oil-infused elastomer is applied to an airfoil using the drop-cast technique. The airfoil is then inserted in the test section of UVA's on-site icing wind tunnel for icing tests. These tests are conducted at a temperature of -10°C (14°F), with an airflow velocity of 30m/s. Performance is determined by measuring ice accretion heights, time for ice to shed, and the maximum temperature at which ice accumulates.

My role is to aid in the testing of the coating in the icing facility by ensuring proper setup, coating application and development, and the running of icing tests. During my time on the project, I've improved the icing facility's air pressure setup, which increased its repeatability and testing capabilities. I noticed errors by comparing icing characteristics with NASA's LEWICE icing simulations and monitoring spray during testing.

The hollow ceramic cylindrical porous material uses a backpressure system to supply air through the inside of the material to 'levitate' water droplets impacting the surface. In theory, the backpressure will facilitate water droplets to roll off the surface, thus reducing ice accumulation. Before and after icing tests, the porous cylinder is inspected for cracks that may inhibit a uniform airflow through the material. It is then inserted into the test section of the icing wind tunnel and attached to the backpressure system. Icing tests are conducted at -10°C and -20°C (14°F and -4°F) with an airflow velocity of 30m/s, with a constant backpressure of 10psi supplied.

The sample's performance is evaluated by comparing the maximum ice height after each icing test to that of a solid aluminum cylinder. After every test, the porous cylinder is treated to recover its original wettability properties.

I am the point of contact between the Greek researchers and UVA on the porous material project. The material's performance is determined by measuring icing height when backpressure is supplied and comparing it to the height without backpressure. So far, I have made key observations of the material's repeatability by analyzing the degradation of the material's surface throughout icing tests. I limited material degradation by employing various recovery techniques.

Both the coating and the porous material projects are innovative approaches to allow aircraft to operate safely in icing conditions. Although ceramics have yet to be extensively used in aviation due to their brittle nature, their role in preventing aircraft icing may spark interest in the field. As I continue to investigate these solutions, not only will I improve my education to become an engineer, but also progress the work being done to improve the safety and performance of aircraft. \\

// ROB COPPINGER

Survival spac

Being stuck inside a spacesuit for six days is just one of the extremes NASA is addressing as it looks to a new age of space exploration

Were the pressure vessel of NASA's Orion spacecraft to fail during its next moon mission, its four-astronaut crew could spend up to six days exposed to hard vacuum. With this in mind, "You really need to look at materials performance and degradation over that long term," says Dustin Gohmert, NASA's Orion crew survival spacesuit project manager.

The last time a moonwalk spacesuit was used was in 1972, during the most recent Apollo mission to the moon, Apollo 17, but NASA has been working on returning Americans to the moon since a 2004 edict from the then president, George W Bush. Last December, President Donald Trump signed a policy that reconfirmed NASA's commitment to manned missions to the moon in 2023 and then into deep space and Mars in the 2030s.

NASA is therefore pressing ahead with the development of spacesuits that will meet the demands of deep space missions to both the moon and Mars.

OPERATING UNDER PRESSURE

If, during that 2023 mission to the moon, the Orion spacecraft's loss of pressure were to be rapid, the spacesuit would need to be inflated to double its typical pressurization.

"If we had a rapid depressurization of the cabin, we would actually take our suit to 8psi (55,158 Pa) for a few hours," Gohmert says. After this time, the body would "naturally de-nitrogenate", like a deep-sea diver, he adds. Once the risk of the astronaut experiencing the bends – nitrogen bubbles in the blood stream – had passed, the suit pressure would be lowered to 4.3psi (29,647 Pa). Human beings can breathe in pressure as low as this, as long as the gas around them is oxygen. The pressure of a spacesuit is kept that low in order to ensure that it remains flexible enough for the astronaut to be able to move.

Ian Meginnis, NASA advanced spacesuit development team engineer, leads a group focusing on exploration suits, for space walks or for working on the surface of the moon or Mars. For space walks from the International Space Station, NASA astronauts use the extravehicular mobility unit (EMU). The EMU suits have been on the space station for many years. In 2013, NASA awarded ILC Dover, the company which produced the suits used for the moonwalk, an 18-month contract to design, manufacture and test an alternative, the Z2 suit.

The Z2 is a technology demonstrator for surface activity and is capable of collecting soil and rock samples, and maneuvering in and out of moon and Mars habitats and crewed rovers. The suit operates at pressures higher than 4.3psi to enable extravehicular activity

Higher pressures enable the introduction of inert gases such as nitrogen, reducing the flammability of the spacesuit interior. "We do pay attention to flammability," Gohmert says. "But in a 100% oxygen environment, everything is flammable, including the human inside."

To stop a fire breaking out inside the suit, NASA avoids the use of chemicals that have incompatibilities with oxygen, such as those made of hydrocarbons.

SPACESUITS 101

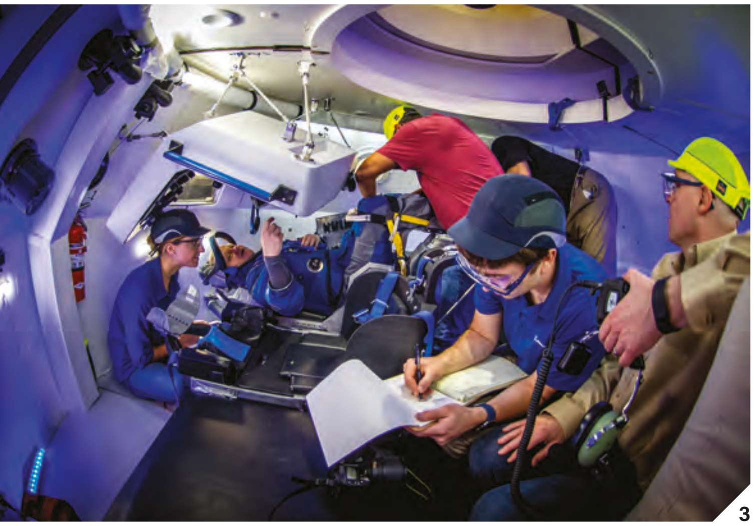
Spacesuits can be broadly divided into two types: intravehicular suits used for launches and descents, and extravehicular suits, which are used for spacewalks and moonwalks.

NASA's spacesuits are developed at the Johnson Space Center in Houston, Texas, and tested inside its thermal vacuum chamber and the Sonny L Carter Neutral Buoyancy Laboratory.

The space agency has several suits in development, including the Orion Crew Survival System, for use as intravehicular and limited extravehicular suits, and the Prototype Exploration Suit, for extravehicular activity. The Z2, another extravehicular suit, is being developed by ILC Dover for use on Mars.

NASA's Portable Life Support System (PLSS) is also currently under development at the Johnson Space Center. The PLSS is the backpack part of extravehicular suits and provides clean oxygen and water to the astronaut, as well as regulating suit pressure.

8
pounds per square inch of pressure within the spacesuit in event of cabin depressurization



1 // Astronaut Suni Williams wears the new spacesuit for astronauts flying on the CST-100 Starliner

2 // The Starliner suit worn by former astronaut Chris Ferguson

3 // Astronaut Eric Boe evaluates the Starliner spacesuit in a mock-up of the spacecraft *(Photos: Boeing)*

6
days of life support provided by a spacesuit if a catastrophic incident occurs

"We're stretching the boundaries of what we understand"

The agency also avoids energy sources, even a simple microphone. "We would tend to gravitate to a dynamic microphone that doesn't require any external power instead of an electric microphone that needs a bias voltage. This minimizes the potential for any arcing of current," Gohmert says. "That's how we minimize any fire potentials." A dynamic microphone uses the power of a person's speech, the force of the sound striking the microphone's membrane, to turn sound into an electrical signal, using electromagnetism.

And while science fiction films often portray future spacesuits with data projected onto the interior of the helmet visor, Meginnis says such electronics are too risky a proposition. "We really want to avoid putting high power electronics inside the helmet because it's a flammable environment," he explains.

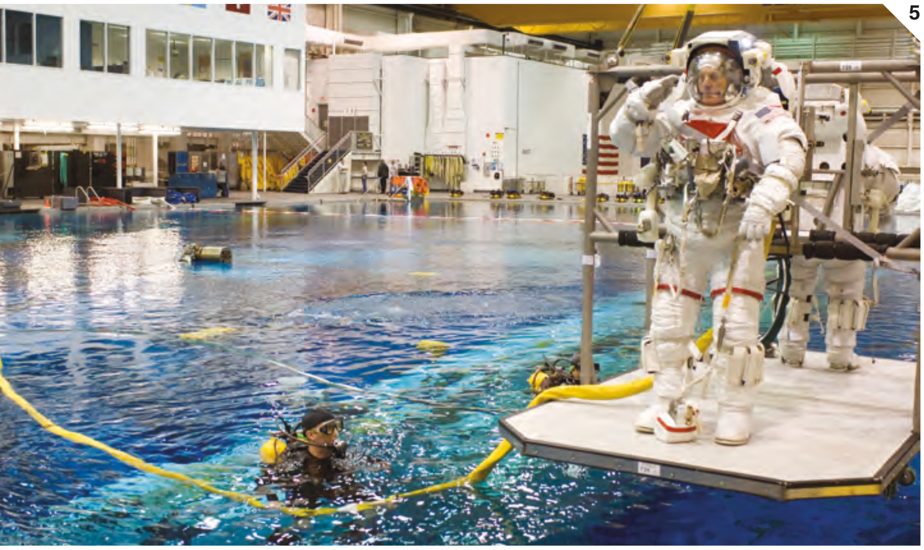
46
years since the last moonwalk, made by Apollo 17 astronauts in 1972

A development in suit electronics that Meginnis does foresee is audible warnings. "We are interested in and looking at ways to incorporate caution and warning tones to give audible feedback to the crew."

Exploration suits have a control unit display on the front that astronauts would use to control water temperature, audio levels, and other functions of its life support system. This is expected to be a feature of many future suits.

As well as higher pressures, the Z2 is partly made from composite materials, so it can be lightweight and durable while also providing protection from the harsh surface environment. The suit also has an adjustable shoulder and waist, to accommodate crew members of different sizes.

4 // The spacesuit for astronauts as they travel on the SpaceX's Dragon spacecraft *(Photo: SpaceX)*



5 // The Neutral Buoyancy Laboratory has a large pool to simulate extra vehicular space activity *(Photo: NASA)*

DEALING WITH BODY HEAT

NASA is also developing the Prototype Exploration Suit (PXS), a technology demonstrator with parts that could be 3D printed in space, on the moon or on Mars. The space agency has studied more efficient carbon dioxide removal and water evaporation systems for this project. Water evaporation systems are being developed for temperature control. These systems will help expel the heat generated by the human body and to keep the astronaut comfortable.

Gohmert says, "We're stretching the boundaries of what we understand, specifically in the water loop that's used for cooling the crew members. Those materials are undergoing quite a bit of testing."

100%
Oxygen atmosphere within a spacesuit

A major hurdle is developing biocides that can last a long time in the water loop. Biocides prevent biofouling of the water and inhibit corrosion of metal parts. The tubes that carry water can also leach out chemicals that may, "foul sublimators or gas traps or other equipment used in the cooling systems," Gohmert explains. A gas trap is a membrane that can absorb and trap a gas's bubbles. A sublimator is a device that can change a solid to a gas without it passing through a liquid phase.

"We have to be very careful with the water loop materials compatibility. Therein lies a vast majority of our testing," Gohmert says. "Honestly, that's a significantly deeper black hole to delve into than the suit materials themselves because they have such a good amount of history behind them."

Those water loops snake through what is known as the soft goods – the materials that make up the bulk of the outfit. These consist of a Gore-Tex liner, a pressure bladder and a Nomex cover layer, similar to a flight suit. The helmet, not considered a soft good, is a fiberglass composite and the suit's metal components are all typically 70% to 75% aluminum. All of these materials have a history of space flight use.

Unusually, the Orion spacesuit could have to endure days in vacuum, and be able to perform extravehicular activity such as space walks and surface exploration, so the traditional materials will still be used.

However, the Orion differs to the EMU and EVA (extra vehicular activity) suits in that it does not have a back pack, or Portable Life Support System (PLSS). Instead the PLSS functions are provided by the spacecraft. This also means that the only electronics in the Orion suit are the headphones and microphone.

For Orion, long umbilical cables provide the oxygen and take the carbon dioxide back to the spacecraft for scrubbing. "The vehicle scrubs the air, replenishing the oxygen that was consumed. It also provides the cooling water and the communications. Then that's routed to the suit via the umbilical," Gohmert says.

SHOCK AND VIBRATION TESTS

The astronauts do not have a PLSS with their launch and evacuation suits because they have to be fixed to the seat. Gohmert says, "The critical aspect of the crew survival suit is the seat interface, because every landing is somewhat of a controlled crash." To help the astronauts cope, the seats are conformal and have five-point harnesses. "We spend a lot of time testing them," he adds.

The suits' components undergo vibration and shock testing. The shocking events include: parachute separation from the spacecraft, parachute deployment during atmospheric re-entry, and when the onboard motor fires to control direction "We look at the worst-case environment. Some of these shock loads are quite severe and the vibration environments are significant as well on launch," Gohmert says.

Some spacesuit testing is more benign and focuses on the simple wear and tear of human use. Robots that can move joints through 0° to 90° have been used. Where suit joints use bearings, those are tested by rotating them for thousands or tens of thousands of cycles at different atmospheric pressures. "But more complex joints such as shoulders or hips would potentially need human testing to really evaluate the full range of motions and the strains put on them," says Gohmert.

"You can look at a bearing. You can look at a hip, a joint, things like that, and cycle them separately," Meginnis adds. "When you put them together, put a person in there and have them do work, that's where you see a lot of different types of wear."

HIDDEN DANGERS

Among the hidden sources of wear and tear on suit systems is radiation. The ISS astronauts operate within the Earth's magnetic fields, which protects them from cosmic and solar radiation. Exploration of the moon and Mars will expose astronauts and their equipment to far higher levels of radiation. Spacesuit components must therefore be tested for their resilience to it.

"Any electronics we fly have to be extremely well vetted from radiation effects, from ionizing radiation, single event upsets and similar events," Gohmert explains. "Electronics are commonly designed for terrestrial applications and aren't designed to withstand those things. So, we spend quite a bit of time looking at those aspects, once we add more complex electronics to the situation."

NASA has several different facilities around the USA that can and have provided radiation testing. Meginnis says that the Brookhaven National Laboratory in Long Island, New York, was recently used for this purpose. Such radiation testing can involve individual components or even the system itself.

Where a system is not tested for radiation tolerance, a probabilistic risk assessment is carried out. "A probabilistic risk assessment is where we add up the reliability of each one of the components, including its tolerance bands, to understand the worst-case effects of any specific failure along that chain. It's a worst-case analysis," Gohmert says.

Cosmic radiation, flammable atmosphere, extreme shocks and temperatures, vacuum, biocides, joint resilience, 3D printed parts – it's a small wonder that the spacesuit is described by space agencies as a mini-spacecraft and considered almost as complex. \\

COMMERCIAL SUITS

As well as the work for Orion and the improved EVA suits, NASA is funding the development of other spacesuits through its Commercial Crew program.

Boeing and SpaceX have both published images of the launch and evacuation suits for their respective spaceships, the Starliner and Dragon V2.

These suits would only be used by astronauts travelling to the ISS and back. Boeing and SpaceX have contracts to provide astronaut transportation to and from the space station.

According to NASA's website, "astronauts heading into orbit aboard Boeing's Starliner spacecraft will wear lighter and more comfortable spacesuits than earlier astronauts wore."

The Starliner suit weighs 9kg (20 lb) which is half the weight of the Space Shuttle launch and entry suits. The first commercial crew flight that will take astronauts to the station is expected in 2019 and should be by SpaceX, with Boeing flying a few months later.

The next few years will see three new spacesuits: the Orion's and the two commercial crew suits. Then, in the 2020s, two more could be developed for deep-space walks and moon surface exploration.

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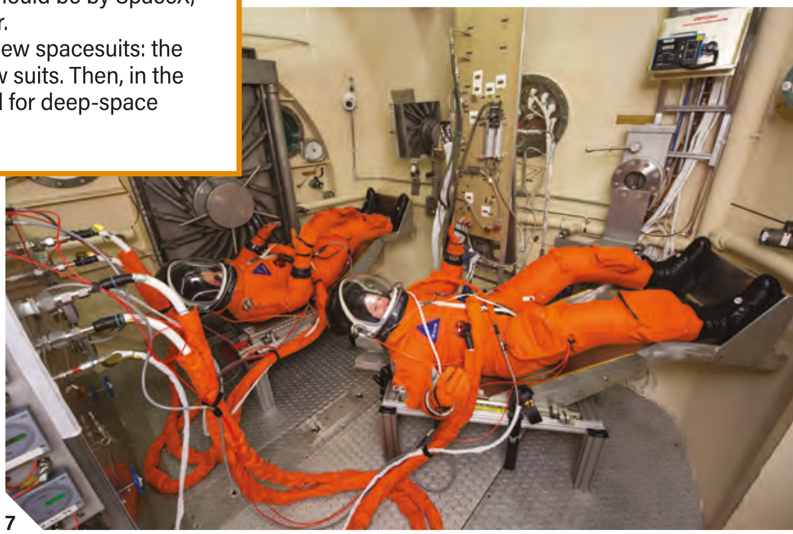
6 // NASA's Z2 spacesuit for exploring the surfaces of other planets *(Photo: NASA/Bill Stafford)*



7

7 // The Modified Advanced Crew Escape Suit's life support system being tested at the Johnson Space Center *(Photo: NASA/Bill Stafford)*

Full cir

The Boeing 787's troubled service entry and new engine technology have given the Airbus A330 a new lease of life

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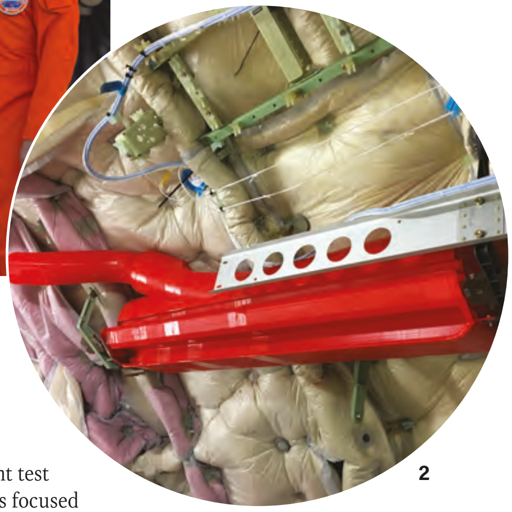
1 // The A330neo first-flight crew in October 2017



2 // A 3D-printed air nozzle for the cabin's climate control system is being tested on the A330neo

Briefing witnesses to the first flight of the Rolls-Royce Trent 7000-powered A330neo (New Engine Option), Airbus head of flight and integration tests (F&IT) Patrick du Ché told them: "We're targeting a go-around, so you will see the aircraft flying at 300ft above the runway. Then, we're coming back around for a final landing."

The prototype A330neo, the first of four aircraft being used in the re-engined model's flight test campaign, duly flew by before touching down at the Airbus F&IT center in Toulouse, France, on October 19, 2017. In completing that circuit, it also brought the A330 program full circle. The current A330 first took to the air as the A330-300 variant in 1992.

CYCLE OF SUCCESS

By 1998, Airbus found it needed to compete against US competitor Boeing's long-range 767-300ER. So, the European aircraft manufacturer brought out the smaller A330-200. This short-bodied variant of the A330 gave the company the traction it needed in the long-haul 'big twin' market.

It is ironic that after the A330's success against the 767 prompted Boeing to develop the 787, the European aircraft has enjoyed a renaissance partly driven by the 787's troubled entry into service. Indeed, A330 head of marketing Crawford Hamilton argues that the 787 is "the best thing that happened to the A330".

Now, the A330 is once again challenging Boeing's 787. Airbus has re-engined its design and added other refinements. A330neo program head Odile Jubécourt says the model is "almost all-new – technically and industrially and the result of new ways of development".

KNOWLEDGE TRANSFER

Airbus has followed a similar test and development path to that used with its smaller, re-engined stablemate, the A320neo single-aisle twinjet, by aiming to make the time-to-market as short as possible. The company is five months into a 1,100-hour flight test schedule. The test campaign is focused on the A330neo's new 68,000-72,000 lb thrust engines, the new pylons to carry the powerplants, and the new nacelles to house them. Modified wings and the new Airspace cabin interior complete the package.

As well as experience from the A320neo's development, Jubécourt says Airbus has used its know-how from the larger A350 twin-aisle twinjet to produce a truly integrated and optimized aircraft. The A330neo is being offered in two versions: the standard A330-941 and the short-bodied A330-841. As of February 2018 the two A330-941neo prototypes MSNs 1795 and 1813 had together accrued more than 310 flight hours and almost 90 flights.

1,100
flight hours in the A330neo test schedule

The manufacturer terms this "a very strong start", with a test campaign which "confirms that aircraft behavior is in line with predictions".

During March and April, du Ché and his test flight engineers are continuing to focus on external campaigns. "MSN 1795 will perform the cold weather trials and external noise tests and MSN 1813 will undertake natural icing tests and the first part of warm and hot weather campaigns," he says.

Simultaneously, handling qualities and identification flights continue on both aircraft, while overall aircraft components and systems are maturing, adds du Ché.

Airbus claims "much has been achieved" during flight testing of the first two aircraft. The flight envelope has been fully opened in both 'normal' and 'direct' flight control laws; high- and low-speed anemometry has been calibrated; engines have been calibrated at both low and high speeds; flutter tests and load calibration

3 // The Airspace cabin's business class configuration is designed to maximize privacy and comfort

AIRSPACE CABIN

A330neo testing has been used to launch Airbus's Airspace cabin, which program head Odile Jubécourt describes as an "efficiency enabler" for passenger capacity and appeal. The cabin has a new entrance, galley area and upgraded lighting. It has been fitted to test aircraft "partially to check we have the right understanding on how it behaves in flight".

has been done; stall tests have been performed and strake configuration frozen; autopilot tests, including automatic landing, have been started; and climb- and high-speed performance tests are underway.

Some early A330neo flights confirmed that, for example, the A330neo has the right flight control law protection when flown in natural icing conditions. "We did that with ice shapes that we glued onto an A330ceo [Current Engine Option] first to see what the aerodynamic effect might be on the neo," says du Ché.

WEIGHT REDUCTION

Assembly of the third machine, A330-841 MSN 1888, is progressing rapidly. As of February 2018, the airframe was structurally complete, the flight test installation (FTI) was being fitted, and the aircraft was soon to undergo final painting. Manufacture of the initial production aircraft on the final assembly line was progressing to plan and Airbus had completed initial installation of the new Airspace cabin furnishings on first-production aircraft, the A330-900 MSN 1819.

Jubécourt says that the adoption of carbon fiber, lighter aluminum alloy and glass-fiber materials has enabled Airbus to meet weight-saving targets. For example, she identifies the fully integrated composite upturned wingtips as one of the "most noticeable" differences among several big modifications to maximize efficiency and minimize drag.

As a result of the changes, the A330's effective wingspan has grown from 60 to 64m – allowing the use of the maximum available span limit and providing aerodynamic benefits, according to Jubécourt. Other aerodynamic modifications have introduced re-contoured wing leading-edge slat and trailing-edge flap-track fairings, composites wing-to-body and upper-belly fairings, and a three-dimensional optimized wing twist.

FLIGHT HOURS REDUCTION

Having been flying for almost seven weeks longer, the first prototype, MSN 1795, had by February 1 recorded twice as many flights and almost twice as long in the air as the second prototype, MSN 1813, which was delivered to the F&IT center on November 16 and made its first flight on December 4. MSN 1813 had logged 119 flight hours in 29 flights, compared with the 198 flight hours generated by MSN 1795 in 58 flights.

According to du Ché, Airbus has done its best to keep the flight test campaign short. "The engine was a derivative, and was flying on the Boeing 787. It is essentially about checking the wing," he says.

Indeed, the manufacturer had completed early test work on A330ceo MSN 871 – the A330 flying testbed. Airbus performed some 130 flight hours of A330neo-related tests on the earlier airframe to de-risk aircraft systems, validate upgraded flight control laws and icing performance, and to check the Airspace cabin interior.

MSN 871's duty to define main tuning for A330neo initial development has been completed, with all test flying assigned to the prototypes. Du Ché identifies a number of key features impacting the program: a new-generation engine, optimized engine pylon, nacelle and zero splice air inlet, and modernized systems, as well as the new Sharklet-equipped wing.

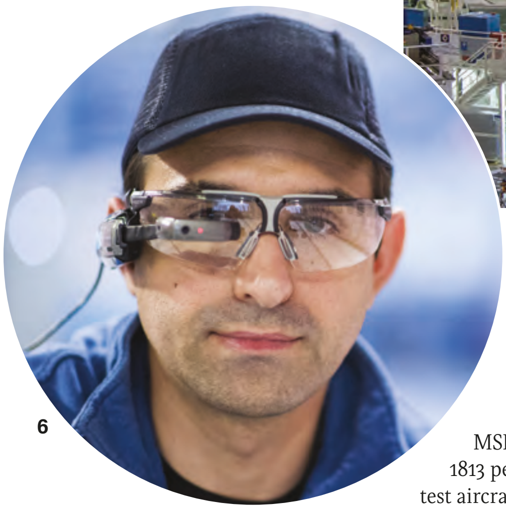
Flight testing of the A330neo comprises five phases. Du Ché explains, "We start with initial development at the first flight, testing the flight control laws at Flight Level 100 [10,000ft altitude], then we go up a flight level.

"Then, before we start third-phase certification we have close to three to four months of development."

60GB
data gathered in a one-hour test flight (gigabits)

4 // Flight test engineers Gert Wunderlich (left) and Jean-Philippe Cottet (right) on the A330neo's first flight

5 // A330-800neo MSN 1888 at Station 40 in Toulouse



6 // Technicians used augmented-reality glasses to install flight test equipment

FTI: FIT TO FLY

Airbus flight and integration tests center head Patrick du Ché summarizes the European aircraft manufacturer's approach to meeting airworthiness-approval requirements that lead to formal type certification. "We fly to get the data we need for analysis. Therefore, we need to have the right flight test installation [FTI]."

For the three flight test A330neos, the company has gone for a core modular FTI fit, which provides some 1,375 measurements, giving access to 98,000 parameters. A single hour's test flight can gather as much as 60Gb of data.

For example, the first two A330neo prototypes were initially equipped with trailing cones fitted to their tails for anemometric air-pressure measurement, used to calibrate airspeed and altitude indication. Measuring equipment was also fitted on one of their two Rolls-Royce Trent 7000 powerplants. "We do a lot of engine tests – so we need a lot of instrumentation," says du Ché. The flight test station was used principally for engine monitoring, with two specialists monitoring the engines, accompanied sometimes with a flight test engineer from Rolls-Royce.

He says, "During this time, we update the software and eventually the hardware, and then we go for certification tests, the fourth-phase EIS [Entry Into Service] preparation, and finally the full EIS support."

According to the manufacturer's schedule, MSN 1795 is to fly 600 flight hours, with MSN 1813 performing the remaining 500. Short-body test aircraft MSN 1888 will log 300 flight hours.

Du Ché outlines the A330neo flight test program: "We have to certify with new engines on a new wing, a new shape and new airframe. We use five different streams of testing – so a lot of flights."

MSN 1795 will be used for three streams, while MSN 1813 will perform the fourth and fifth.

"First of all, there are a lot of tests in handling qualities. For certification, we have to completely repeat the A330ceo flight manual work," says du Ché.

There will also be noise certification testing for take-off and landing, because flight manual and noise requirements have changed since the original A330-300 was certificated in Europe and the USA in 1993. "Then, of course, there is power management – a lot of tests to satisfy new regulations and [Category III] automatic landing," concludes du Ché.

5
phases in overall flight test campaign

98,000
parameters of flight test information accessible

TEST AIRCRAFT DIFFERENCES

Airbus has different programs for each A330 test aircraft, says du Ché. MSN 1795 is being used to assess handling qualities and is involved in engine development, with its Number 2, right-hand powerplant "very well instrumented" for the cold weather campaign. "We also have external noise, which is the chief feature of the campaign, and autoland," he says.

Each A330neo prototype has each been equipped with a medium FTI fit: twin head-up displays and activated avionics functions, including the flight management system (FMS), ground-based landing systems and airborne-traffic situation awareness, transponder-equipped traffic and terrain collision avoidance, and runway-overrun prevention systems.

Nevertheless, the aircraft systems are not identical. MSN 1795 is fitted with Messier-Goodrich brakes and Honeywell FMS and satellite communications. MSN 1813 has Honeywell brakes, Iridium satcom equipment and a Thales FMS.

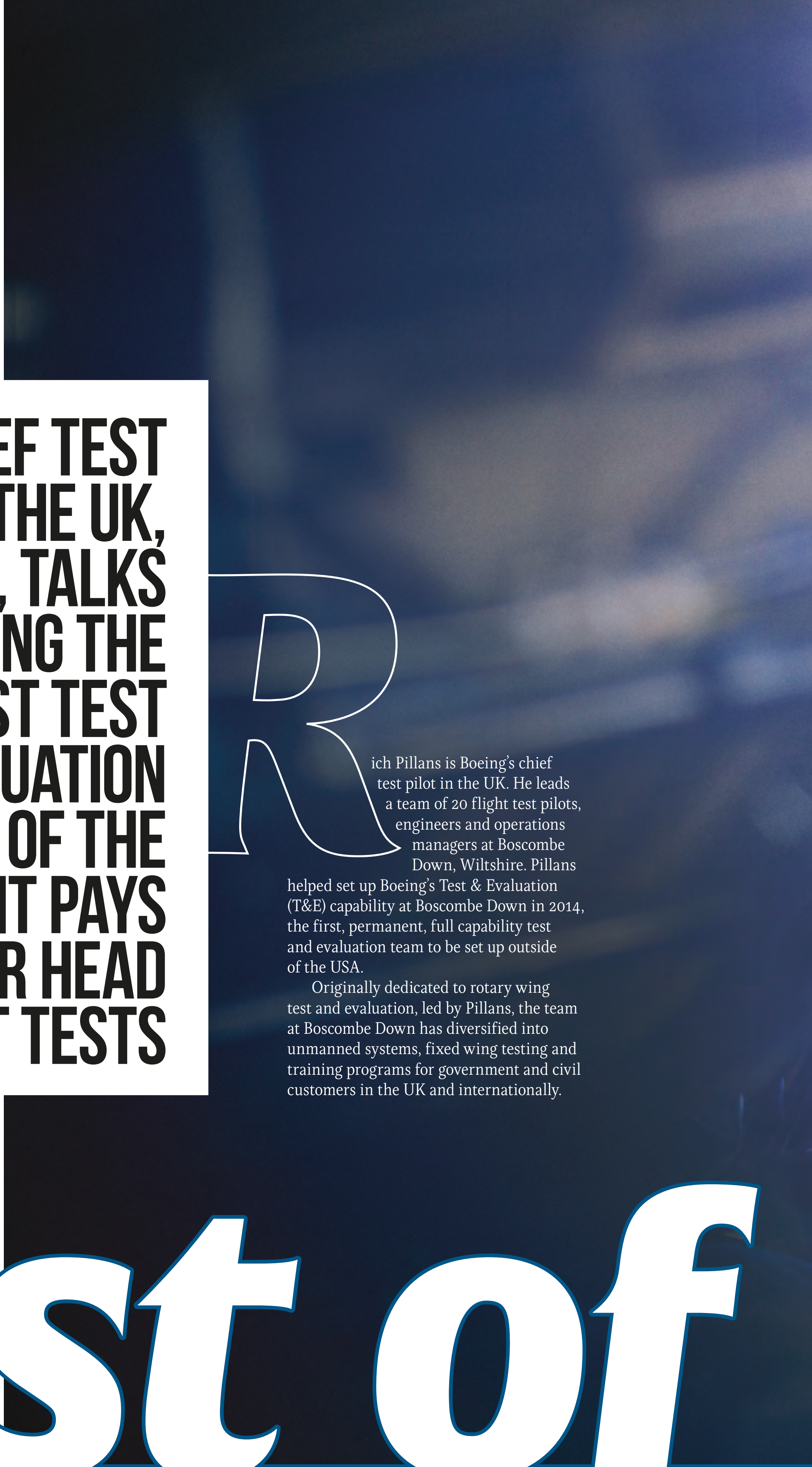
Further differences are the first machine's tail bumper, required for the Vmu minimum take-off speed test and the second prototype's engine rakes – pressure taps in the powerplant primary and secondary gas flows so the thrust can be compared with the ground test results.

MSN 1819 has a light FTI fit in its production- and cabin-checks role, and will be used to validate air-conditioning system performance. Its cabin furnishing was installed in early 2018, which left painting and engine installation to be completed before a scheduled first flight in the second quarter of the year.

The third flight-test machine – A330-841 MSN 1888, the initial smaller, longer-range variant – is to have a medium FTI fit and will duplicate MSN 1795's systems specification for certification. Having entered final assembly in early November, it is scheduled to fly in the middle of this year.

An area in which the A330neo flight testing has benefitted from the manufacturer's most recent new design of the A350, is the use of microelectromechanical systems (MEMS). "We have been using MEMS to look at the aerodynamic pressure distribution on the wing," says du Ché. "It's a tool we developed during the A350 flight test campaign. We can measure the pressure distribution all along the wing, and this is the key to understanding the performance of the aircraft. It has been used on the A330ceo and we are using it on the second A330neo."

Airbus has conducted back-to-back tests between the original and re-engined A330 variants for wing structural validation, using structural analysis focused on load and pressure differentials, according to du Ché. The MEMS equipment involves less data analysis and fewer flights. \\



BOEING'S CHIEF TEST PILOT IN THE UK, RICH PILLANS, TALKS ABOUT RUNNING THE COMPANY'S FIRST TEST AND EVALUATION CENTER OUTSIDE OF THE USA AND WHY IT PAYS TO KEEP A CLEAR HEAD DURING FLIGHT TESTS

Rich Pillans is Boeing's chief test pilot in the UK. He leads a team of 20 flight test pilots, engineers and operations managers at Boscombe Down, Wiltshire. Pillans helped set up Boeing's Test & Evaluation (T&E) capability at Boscombe Down in 2014, the first, permanent, full capability test and evaluation team to be set up outside of the USA.

Originally dedicated to rotary wing test and evaluation, led by Pillans, the team at Boscombe Down has diversified into unmanned systems, fixed wing testing and training programs for government and civil customers in the UK and internationally.

Best of

Boeing

// HOW/WHY DID YOU BECOME A TEST PILOT?

I don't think I could say that I always wanted to be a test pilot, but in retrospect the decisions I made when younger have very conveniently led me to this career.

I had my pilot's license at 16, before I had my driver's license. I'd also always been interested in engineering and was keen to do something that had a specialist element to it, so chose avionics systems engineering at the University of Bristol.

My interest in being a test pilot started during my time there. The degree was a key part of my journey to becoming a test pilot. I was part of a team that built and launched a rocket for the National Rocketry Championships. My role was to build a control system that would help stabilize the rocket, which I ended up using as my final year project. I designed and built everything from scratch – from the circuit-board layouts to the servo-controlled canards. After university and a couple of operational military tours, I could have taken a 'sunshine' tour in Belize or Brunei, but instead opted to apply for the Empire Test Pilots' School [ETPS], and I never looked back.

// WHAT WAS YOUR FIRST JOB AS A TEST PILOT?

Straight after completing the ETPS course, I completed an Apache conversion and went on to conduct high AUM [all up mass] lateral CG [center of gravity] testing and weapon firing to clear new under-wing fuel tanks.

Testing the Apache at the extremes of the envelope during high altitude, high AUM landings in the USA and weapon firing in the UK were a great entry to the test world. My journey as a test pilot was helped by the fact that I was following in the footsteps of army test pilot Tim Peake – before his current fame as an astronaut.

// WHAT DID YOU LEARN IN THE EARLY DAYS OF YOUR CAREER?

I was fortunate to have a varied career early on. For one year before university and seven years after, I spent no longer than six months in any one place. I enjoyed two stints in the Royal Electrical and Mechanical Engineers, two with infantry regiments, flew two different operational helicopter types, and flew in two different operational theaters.

Even after becoming a test pilot, I was honored to serve on the Rotary Wing Test and Evaluation Squadron, where I learned the trade flying with some great test pilots. I also led testing on Apache, Lynx, Chinook, Dauphin and Puma helicopters. The variety of so many flying and non-flying appointments showed me that diversity really is the key to solving problems.

// HOW DOES THE RELATIONSHIP WITH BOEING IN THE USA WORK?

The company has established processes suitable for the US environment, but you still need to respect local regulations. Prior to setting up in 2014, we would parachute people in from the USA when they were needed. Having the UK and other international T&E centers means we can better meet customers' needs. It's Boeing's philosophy to use local staff whenever possible.

Members of my team also support US development programs, including those concerning new commercial aircraft and unmanned aerial systems.

// WHAT ARE YOU CURRENTLY WORKING ON?

We do most of our flying on Chinooks at the moment. We recently finished an upgrade to its digital autopilot, the Digital Automatic Flight Control System (DAFCS), which, after 450 flight hours on two versions of Chinook, has been shown to be a great success. The DAFCS really improves the safety and capability of the aircraft. We're now about halfway through modifying all Mk4 and Mk5 Chinooks in the fleet with DAFCS, a job that should see the entire 60 helicopter fleet done by October 2019.

There are various other Chinook, Apache, P-8 and other fixed-wing programs around the corner, so it's my role to ensure that we have the right people with the right training to support the British Armed Forces effectively. I am also working to support capability expansion and integration across the armed forces with international colleagues as we continue to grow our presence in the UK.

// WHAT ARE THE CHALLENGES / UNIQUE ASPECTS OF YOUR CURRENT PROJECTS?

All flying has to be treated with the utmost respect, and test flying is no different. While you can plan for almost all eventualities, dealing with emergent test requirements is one of the most rewarding aspects of a test team's role. One of the hallmarks of a test program is that you are testing because you don't know what the answer is going to be. You can forecast and predict, but when you press the button to go, you've got be on your game, because they are just forecasts and predictions.

Conducting additional safety testing requires the test team to keep a clear head under pressure and also helps

"The test pilot is often at the coalface of data gathering, especially for qualitative data"

CV

Prior to joining Boeing, Rich Pillans was the deputy director, aviation for QinetiQ at MoD Boscombe Down, where he was responsible for assuring all manned aircraft operations.

Pillans was also the lead test pilot for the UK MoD's Puma Programme whole-aircraft flight trials. Previously, he led numerous flight trials on Chinook, Apache, Dauphin and Lynx helicopters, flying developmental, experimental, and aircraft/systems clearance test flights including weapons firing and degraded visibility operations.

Pillans holds a degree from the University of Bristol with a BEng (Hons) in avionics systems engineering (first class) and graduated from the UK MoD Empire Test Pilots' School in 2006.

1 // Boeing in the UK has recently completed testing an upgrade to the digital autopilot for the RAF's Chinooks

to refresh lessons learned through training. The challenges are what makes this job unique and what makes my role even more rewarding.

// PLEASE DESCRIBE A TYPICAL DAY AT WORK.

I don't fly as often as I used to – maybe twice a week. More of my time is spent managing – I work with brilliant test pilots, instructor pilots, maintenance pilots, flight test engineers, instrumentation engineers, safety professionals and support personnel, every day. We work on a diverse range of programs, which I dip in and out of to ensure that we are working safely, compliantly and efficiently. The experience of a diverse early career helps me work efficiently in such a varied workplace!

// WHAT INFLUENCE DOES A TEST PILOT HAVE OVER A FLIGHT DEVELOPMENT PROJECT?

In many ways, the test pilot can have the most accurate understanding of a flight development project's issues. The test pilot is often at the coalface of data gathering, especially for qualitative data gathered using criteria like the Cooper-Harper rating scale for handling and assessment of the pilot's workload. Pilots are also the most knowledgeable about how the aircraft will be flown during operational missions. Test pilots can use their first impression of the flight test data to advise the wider team on its implications.

The test pilot's role in quickly determining where the issues are can ensure the program shifts focus to target the areas that matter most, before expensive testing opportunities are used up elsewhere. After all, the test pilot is the final component of Boeing's overall testing program, and so has the most human relationship with how those new designs perform in real-life scenarios. However, with great opportunity comes great responsibility, and so the team must ensure that the flight test engineer's perspective is also taken into account, in order to provide a check-and-balance.

// WHAT HAS BEEN YOUR FAVORITE AIRCRAFT TO FLY AND WHY?

If I'm honest, I've enjoyed nearly all of the aircraft I've flown. The Chinook and the Apache are a pleasure to fly, because they are able to do what they have been designed to do so very well. I also fly the Bell-47 Sioux (of *M*A*S*H* fame) for the British Army Historic Aircraft

2

3

4

Flight, which is a joy to fly. I am continually impressed with how the designer, Arthur Young, harnessed straightforward flight physics with the invention of the main rotor stabilizer bar, making it very easy to hover.

// WHAT DO YOU LIKE BEST ABOUT YOUR JOB?

The early phases of an aircraft's lifecycle are very rewarding. The new or modified aircraft itself is exciting, but also having the opportunity to apply my knowledge and experience to making an aircraft safer, better, or more capable means I get to give something back to the aviation community. I get satisfaction from helping to provide safer and more capable aircraft to military personnel, despite having left the military.

// DO YOU SEE YOUR JOB AS RISKY?

There is the potential for extra risk for test flying any new product or design. But there are different risks for different types of flying. We can apply mitigations and control our environment to reduce the potential risks of what we do in a way the end-user cannot. The end-user has different, operational risks to us.

In addition, the significant amount of new product and design testing that happens in our labs – ahead of the eventual flight test – helps us to further mitigate any risks to Boeing pilots. All of this hard work goes toward developing, designing and delivering products to the world that are safe and perform as intended.

// WHAT'S THE MOST DANGEROUS SITUATION YOU'VE BEEN IN WHILE TESTING AN AIRCRAFT?

The considerable team effort that goes into identifying risks and mitigating them means that my test flying has always had a happy ending. That said, during testing of the low-speed envelope of a helicopter during my time on the military test squadron, I was required to fly the aircraft at incrementally increasing lateral airspeeds. As our flight instruments didn't show us lateral airspeed, we flew in formation with an anemometer-fitted pace car. During this test, the aircraft unexpectedly ran out of lateral cyclic authority, which caused the aircraft to roll left while full right cyclic was applied.

While we didn't expect this to occur in the configuration we were flying, we had identified it as a general risk and made sure we conducted the testing at 100ft [30.4m] above the ground. I was able to pitch the helicopter nose-down to trade height for forward airspeed. Then, with forward airspeed came greater control authority, and the aircraft 'popped' back into controlled flight.

It was the flight test engineer that recommended we perform these tests at 100ft above the ground. His input meant we safely flew away that day. Events like this remind all test personnel that preparation, risk mitigation and team working are the key to safe testing.

2 // The Chinook has a triple hook external load system and can carry up to 10 tons of cargo

3 // The RAF's Chinooks are also used for emergency response and search and rescue in the UK

4 // The Mk6 Chinook has a maximum cruising speed of 296km/h (184mph)

// HOW DO YOU THINK TESTING AND THE ROLE OF THE TEST PILOT WILL CHANGE IN THE FUTURE?

Although there is increased use of sensors and computer simulation, there is still space for qualitative data from the test pilot. Zeros and ones can say an aircraft doesn't meet requirements, but only a test pilot and their flying experience can tell that maybe the requirement is wrong and that the aircraft will do its job well on the front line. Equally, the zeros and ones can say it meets requirements, but an experienced pilot will still flag problems. The human-in-the-loop of aircraft testing will always be needed.

As a company, we're helping to pioneer technological advancements in aerospace and aviation, and we've seen considerable progress over the past few decades with improvements in flight simulation, safety and sustainability. We plan to continue this in the future and also aim to build upon our partnership with the UK.

As part of this, aircraft testing will continue to develop in the future, aiming to become even better, safer and more efficient than it is currently. I look forward to being a part of that! \\

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// Engineers are investigating the vibration created by new open rotor designs as part of the Clean Sky program *(Photo: Safran)*

In tune

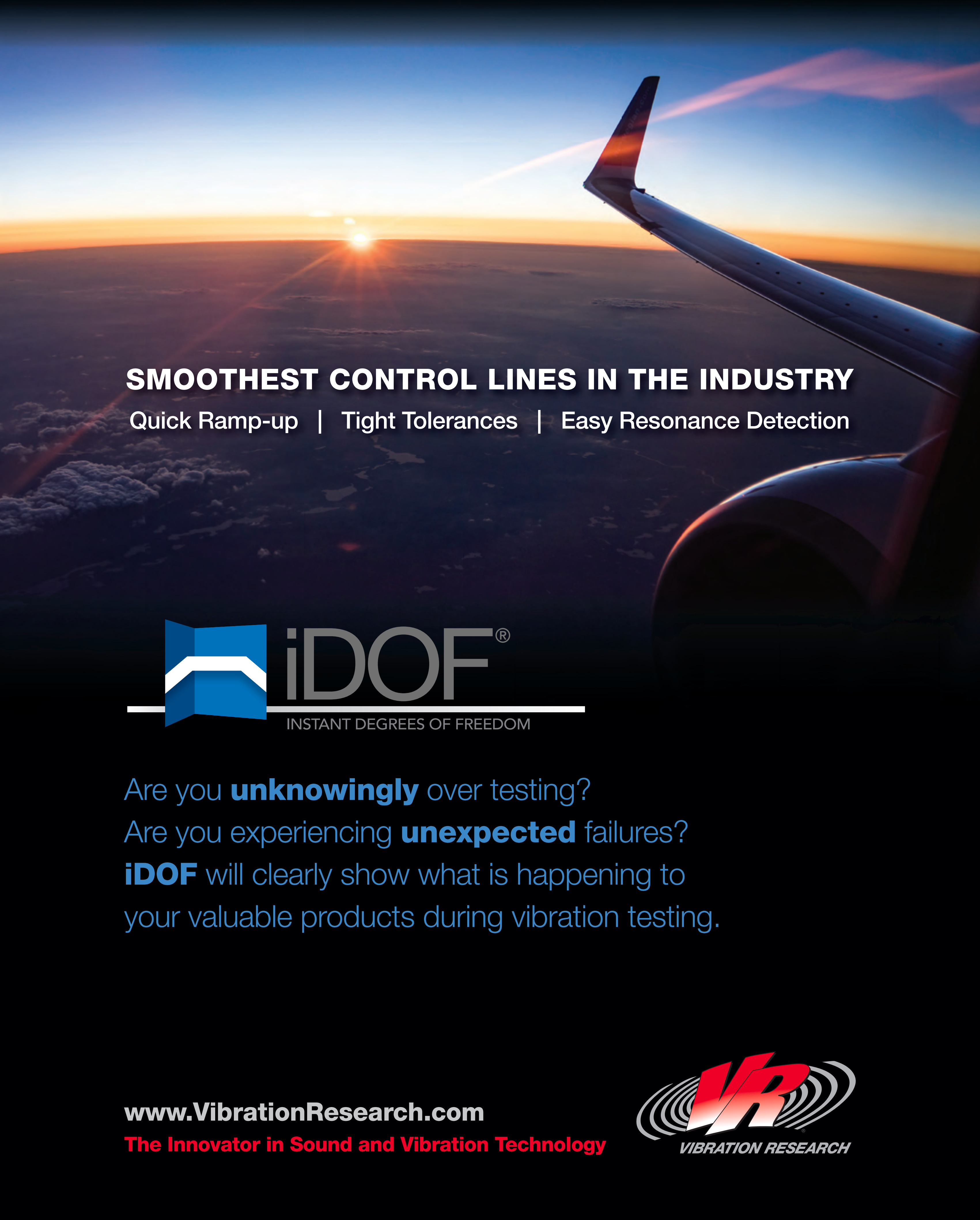
Advances in testing, simulation and monitoring are reducing vibrations and noise in turboprop engines

The use and development of turboprops is on the rise. According to market forecasts from Safran Aircraft Engines, the size of the turboprop market will double by 2037 to 3,500 aircraft, as airlines opt for smaller, more efficient planes to use on shorter routes under 500 nautical miles.

Traditionally turboprops generate more noise and vibration than turbofan engines. However, aero-engine developers are focused on mitigating vibration and noise in turboprops. Engineers are using the latest modeling and simulation tools to test for and design out levels of vibration and noise. As a result, perceptions of turboprop aircraft have been changing, adding more impetus to the growth of the market.

The latest generation of turboprops in development include Pratt & Whitney Canada's (P&WC) Next Generation Regional Turboprop (NGRT) and GE Aviation's Advanced Turboprop, recently renamed the Catalyst.

P&WC's NGRT is intended for use on 90- to 100-seat regional aircraft and is expected in service around 2023. The engine has a scalable design across the 4,500-8,000shp envelope and is claimed to be able to reduce fuel consumption by 20% compared with similar engines currently in use. P&WC engineers successfully completed the second phase of testing for the NGRT in 2016, focusing mainly on its compressor. Engineers on the project are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currently working closely with aircraft manufacturers to ensure it meets their needs and can be fully integrated with all aircraft's systems.

Meanwhile GE Aviation's Catalyst engine has been developed in just over two years. The company is looking to shake up the turboprop engine market, which has been led by P&WC for many years. The first engine testing took place in December 2017 at the GE Aviation site in Prague. The tests included gathering information on vibration. GE plans to build 12 Catalyst engines for testing over the next two years, which will include more high-vibration testing. Certification is expected to be completed in 2020. The engine will be launched on Textron Aviation's single-engined Cessna Denali aircraft at the end of this year on a test flight.

385
The number of components replaced with 12 3D-printed parts in GE Aviation's advanced turboprop engine (Catalyst)

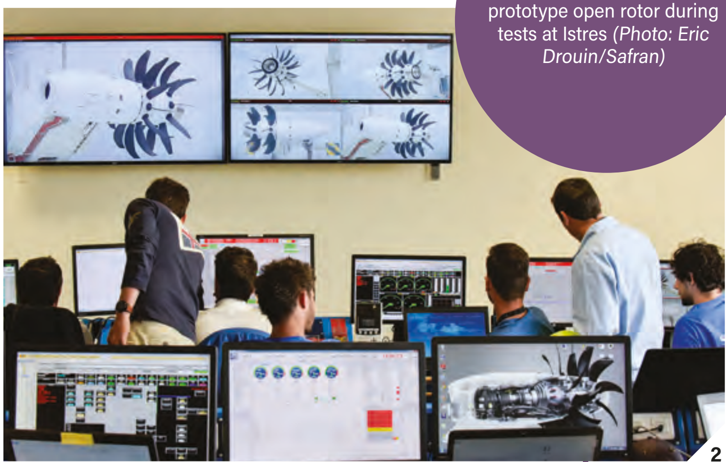
1 // Safran engineers were able to run the open rotor prototype at high speeds at Istres *(Photo: Safran)*

Many noise and vibration issues from turboprop engines such as the NGRT and Catalyst are tested for and designed out. For example, one of the ways vibration is kept to a minimum is by carefully adjusting the propellers by matching the weight of each blade and balancing the entire assembly.

BALANCE AND DAMPING MEASURES

Regional aircraft manufacturer ATR's latest turboprop aircraft family, the -600 series, uses six-blade propellers and features a vibration monitoring system (VMS) as standard. ATR made the switch from four-blade propellers to six around 18 years ago in its popular -500 series to address concerns about high levels of noise in its aircraft. The perceived noise in the cabin dropped from 86 to 79dB.

Fabien Darsonval, ATR's head of propulsion systems, says, "The evolution to six-blade propellers was evaluated and validated using live flight tests on aircraft. We still rely on live flight tests as the main method. Numerical analysis is used to predict operational benefits and simulation tuning is used to continually refine and optimize the performance of propellers. When we use numerical analysis to predict future benefits for noise and vibration mitigation, we use



2 // Engineers monitor the prototype open rotor during tests at Istres *(Photo: Eric Drouin/Safran)*

NEXT-GENERATION OPEN ROTOR AND VIBRATIONS

Safran Aircraft Engines' research and technology department is working with partners, including GKN Aerospace and Airbus, on a €65m (US$80m) project to develop an unshrouded open rotor engine architecture.

Work began in 2013 at the French national aerospace research center Office National d'Études et de Recherches Aérospatiales (ONERA). First the concept of contra-rotating propeller architecture was tested, where engineers observed the behavior and performance of two rows of propellers at different speeds.

"To do this, two sets of propellers were tested. The first was a set of basic propellers, the second was a set of propellers in a configuration identical to what has been tested in our Istres facility in southern France as part of the Clean Sky SAGE 2 program," explains Olivier Jung, advanced systems chief engineer at Safran.

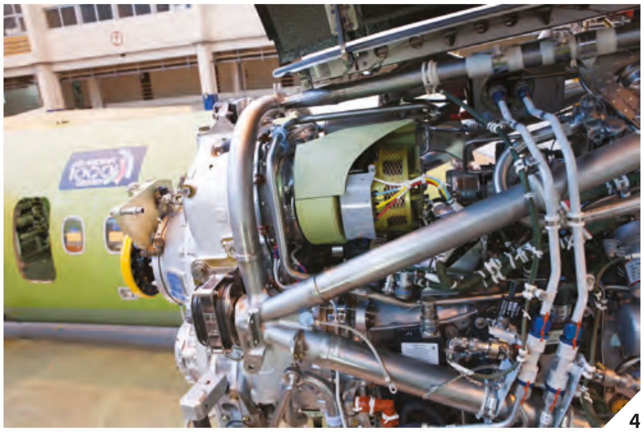
The benefit of conducting tests at the ONERA facility included being able to run the propellers at high speeds and adapt simulations and experiments to fit the project's needs. "It enabled us to gather large amounts of data, validate the design and to better understand the physical phenomena," says Jung.

Work continued on the open rotor engine, and in 2017 Safran opened an 864,000ft^2 (80,000m^2) second open-air engine test stand at its Istres facility.

In October 2017 Safran's engineers at Istres successfully completed a six-month test campaign for the open rotor. The campaign demonstrated the maturity of key technologies used in the engine, including the propeller pitch control system and multivariable control, the power control, the counter-rotating propeller made from composites, the gearbox and the power turbine.

The open rotor engine's test campaign also demonstrated a 15% reduction in fuel consumption compared with the new-generation Leap engine and acoustic performance that is compliant with Chapter 14 of the ICAO regulations.

3



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3 // ATR's -600 series of regional aircraft use engines with six-blade propellers

4 // A -600 series on the manufacturing line *(Photos: ATR)*

commercially available professional software with proprietary adaptation.

"Noise is one parameter that influences propeller design. Others are blade shape and rotational speed. Overall integration at the aircraft level aims to minimize vibration and noise by selecting the most appropriate design features, such as the number of propeller blades and the optimization of integration through passive noise treatment."

Dynamic vibration absorbers (DVA) are regularly used between the engine and the aircraft to deaden mechanical vibration. Textron Aviation's Beechcraft King Air 350i was launched in 2008 with claims that its noise and passenger comfort levels were competitive with light jets. Textron engineers used DVAs to damp sound in the King Air 350i.

"We use very simple solutions to reduce noise and vibration," says Martin Tuck, technical marketing specialist at Textron Aviation. "The DVAs work in a similar manner to a tuning fork and are tuned to vibrate at the same frequency as the propellers, effectively damping out the vibration in the airframe. They are attached to the fuselage frames mainly in the forward section of the fuselage close to the propellers.

"The fuselage skin between the frames also tends to vibrate, but at a higher frequency, so we attach smaller cylindrical DVAs on the skin stiffening panels. Being simple mechanical devices, they require no power and no maintenance.

"We also use conventional skin stiffening panels and bagged insulation throughout the length of the cabin. The result is a cabin of equivalent loudness to that of a jet of similar size, although the overall environment is skewed a little towards lower frequency noise."

4M
Diameter of the two fans on the open rotor engine being tested at Safran's Istres site

MONITORING AND TUNING

Noise and vibration from turboprops engines and propellers can also be lowered by optimizing their location on the aircraft. "You can design out some of the non-uniform flow-induced vibration by putting the

MEASURING NOISE IN WIND TUNNELS

Large amounts of flow-induced noise and vibration are caused when a high-speed turbulent flow interacts with an object such as the components of a propulsion system, airframe or landing gear.

The Faculty of Engineering at the UK's University of Southampton and the ISVR Consultancy work in the area of mathematically modeling and developing noise control measures by interpreting the effects of flow, acoustics and structural dynamics through wind tunnel tests.

"Measuring vibration is relatively easy for a fixed test object because you put accelerometers in well-defined locations," says Dr Malcolm Smith, associate principal consultant with ISVR Consulting. "But measuring and interpreting noise is a much subtler task. Normally aerodynamic wind tunnels are relatively noisy places, so to measure the noise of turboprops or landing gears you need an aeroacoustic facility – an open section wind tunnel with an anechoic chamber installed around it, where arrays of microphones are fitted outside the flow."

There are only a few of these to be found in Europe, and many are large facilities that are expensive to power, potentially costing tens of thousands of Euros a day to operate.

However, the University of Southampton is soon to commission a lower-cost alternative. This small aeroacoustic wind tunnel will have significantly reduced operating costs.

"Our aero-acoustic wind tunnel will be 1 x 0.75m [3 x 2.5ft]," reveals Smith, "and it will have a maximum flow velocity of 80m/s [262ft/s]."

"You'll be working at quite small model scale, but can still do useful noise and vibration experiments. Our challenge will be interpreting the data and projecting it back to full-scale."

The university has two other closed-section wind tunnels, the 3.5 x 2.4m (11 x 8ft) R J Mitchell wind tunnel and a 2.1 x 1.5m (7 x 5ft) one.

propeller upstream of any obstructions," says Dr Malcolm Smith, associate principal consultant with Southampton, UK-based ISVR Consulting, which provides engineering development support for noise and vibration for aerospace companies.

"Normally turboprops are put on pylons on the leading edge of the wing, but in a pusher configuration they may be attached to the rear fuselage."

Wind tunnel testing is used to further minimize noise and vibration wherever possible. Test flights and monitoring systems record engine vibration levels and detect if propellers become out of balance. This information can also be useful for in-service aircraft. Kurt Morrison, senior technical leader for GE Aviation, says, "Vibration monitoring and analysis can indicate a lot about the health of the engine. If a blade sustains damage, for instance, the vibration signature will change. Modern algorithms can look for these changes and generate a maintenance message that a specific part of the engine should be inspected.

"Analysis of the vibration signature along with oil analysis and temperature data can indicate an issue with the lubrication, bearings, gear teeth meshing, engine mounts and numerous other issues before they lead to costly damage."

5%
Weight reduction in GE's Catalyst engine enabled by using 3D-printed parts

15%
Predicted fuel saving oft the open rotor engine compared with turboprop engines

INFLIGHT MONITORING

A number of solutions aimed at inflight monitoring of propellers are being launched by engine manufacturers and systems suppliers. In-flight monitoring systems are designed to replace ground maintenance systems used to measure engine and propeller vibration. Inflight monitoring systems currently available include P&WC's Flight Acquisition, Storage and Transmission (FAST) technology as well as ATR's VMS, which was developed in partnership with Meggitt Sensing Systems.

P&WC's digital propeller vibration monitoring system uses an ultra-sensitive accelerometer installed on the engine gearbox. The accelerometer has a sampling rate of 2,000 samples per second. Data from the accelerometer is sent to a data center for analysis and shared on landing. This allows changes to the propellers to be gauged on a flight-by-flight basis. P&WC is now looking to provide a remote balancing solution that will allow users to proactively balance propellers without waiting for vibrations to occur.

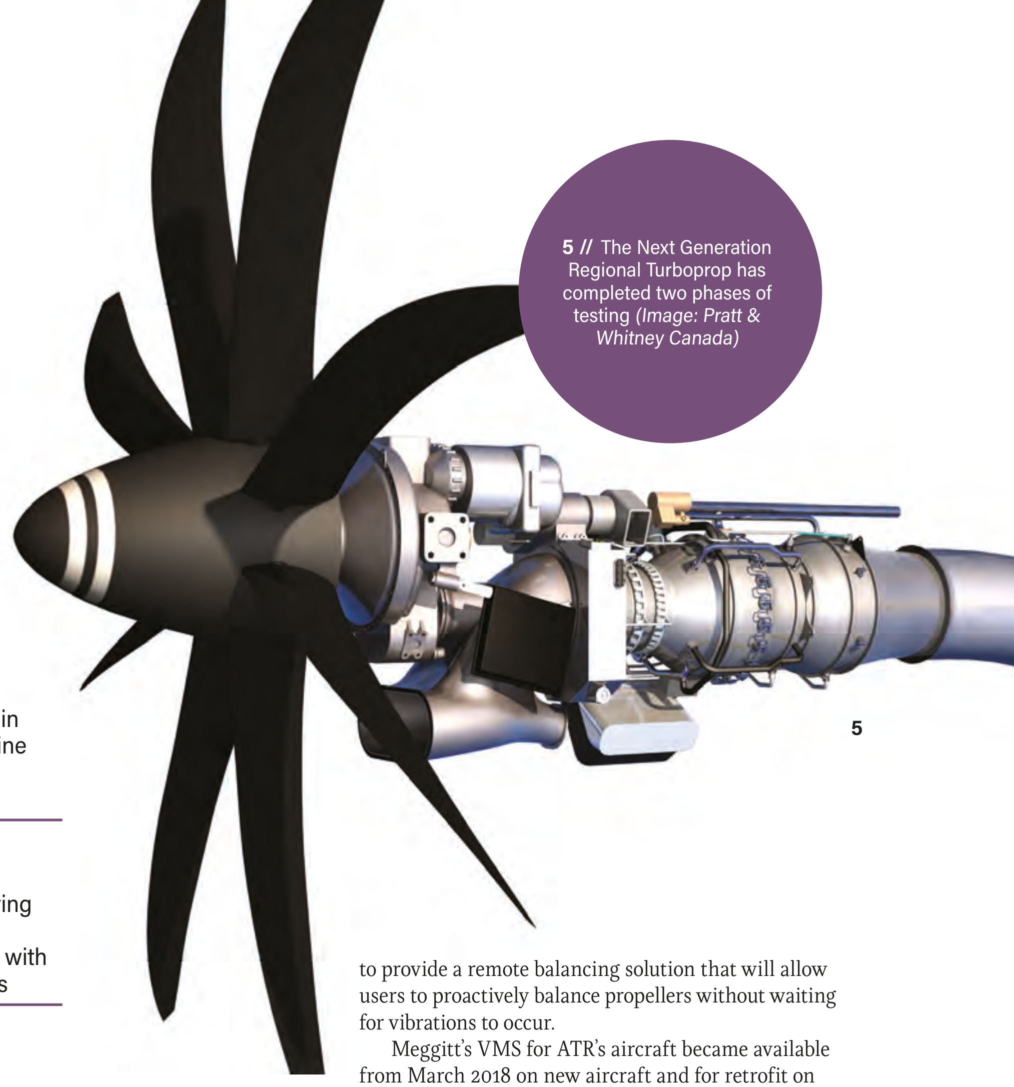
Meggitt's VMS for ATR's aircraft became available from March 2018 on new aircraft and for retrofit on in-service aircraft. It comprises a single vibration sensor and another sensor per propeller, together with a single data acquisition and processing unit per aircraft located in the pressurized area.

"The VMS acquires vibration data during flights. After aircraft landing, it calculates the need and solution for propeller balancing. It interfaces either via a multifunctional display in the cockpit or a maintenance laptop or tablet. The propeller can be balanced and the aircraft can go straight back out," says Pavol Rybarik, Meggitt's vice director of business development for aerospace condition monitoring systems.

"The VMS supports the acquisition of numerous data channels from various types of sensors, up to 24 in a single unit or more in a distributed multi-unit system, and provides processing power and storage capability to make the best use of any data," adds Lucas Sendra, business development manager, Meggitt.

"Essentially this is a quicker, more streamlined and efficient process for airlines," says Darsonval from ATR. "They automatically receive information immediately and regularly – allowing them to respond to, and therefore take advantage of, this data as soon as they receive it, rather than having to arrange specific testing with maintenance personnel."

The turboprop renaissance looks set to go from strength to strength. Technological advancements have led to engines that produce less noise and vibration, and engineers are using the latest sensing and simulation technologies to test for and design out issues. The use of monitoring on in-service aircraft further mitigates any issues. It's an exciting time for the turboprop sector. \\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5 // The Next Generation Regional Turboprop has completed two phases of testing *(Image: Pratt & Whitney Canada)*

6


7

6 // The data acquisition unit for Meggitt's vibration monitoring system is fitted in the pressurized area of the aircraft *(Photo: Meggitt)*

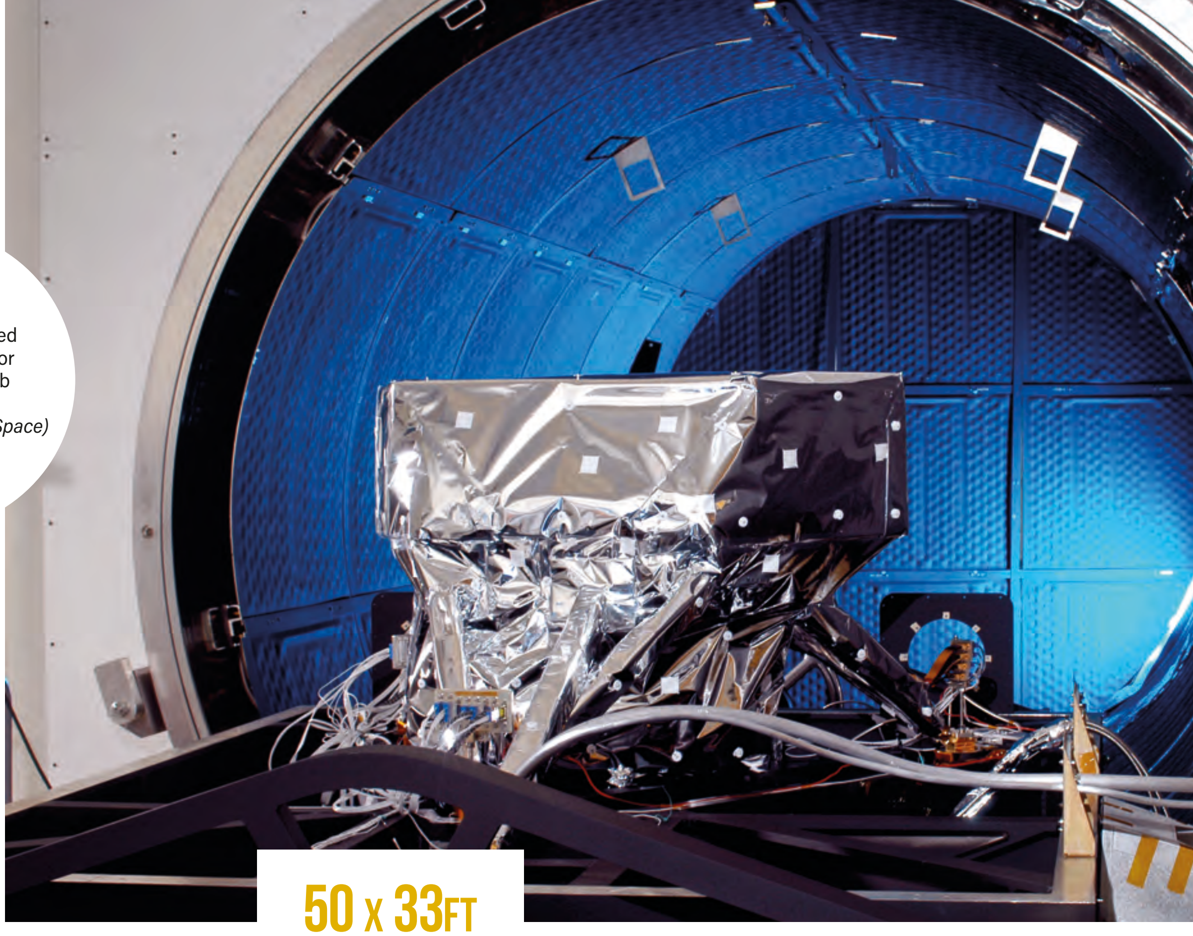
7 // Engineers prepare GE's Catalyst engine for its first test *(Photo: GE Aerospace)*

// ANDREW WILLIAMS

Space on Earth

Renewed commercial interest in space is driving innovation and investment in ground-based testing facilities and equipment

// Sentinel 2-B is placed in the vacuum chamber at the European Space Research and Technology Centre *(Photo: ESA)*



1 // The Mid Infrared Instrument (MIRI) for NASA's James Webb Space Telescope *(Photo: STFC RAL Space)*

Access to Earth's orbit is becoming cheaper and the demand for satellites and spacecraft is steadily increasing. As a result, investment into environmental testing facilities, especially equipment such as thermal vacuum chambers (TVACs), is also rising.

The development, production, testing and inspection of expensive commercial satellites is one of the toughest challenges in aerospace. Developers must not only be satisfied that satellites and spacecraft will survive launch, but also that the delicate and precise technology they contain will operate in orbit.

The world's top aerospace testing facilities are therefore building larger TVACs and developing technologies and techniques to better simulate the conditions found in space, to ensure they stay relevant to aerospace testing and research in the future.

50 x 33FT
Height and width of ESA's Large Space Simulator, ESTEC, Netherlands

5 x 4.7FT
Length and width of the Simles TVAC chamber at the Airbus Defence & Space Test Centre, Toulouse, France

SPACE CONDITIONS

In Europe the largest and best equipped environmental testing facilities with TVACs are at Airbus Defence & Space, France in Toulouse, the IABG test center in Munich, ESA's European Space Research and Technology Centre (ESTEC) in Noordwijk, Netherlands. Thales has TVACs in Cannes and Rome and there are also several at the Centre Spatial de Liège in Belgium

ESTEC performs tests on a wide range of large spacecraft in environmental conditions that simulate the conditions during launch and early operation phases. Europe's largest vacuum chamber is on the ESTEC site. The Large Space Simulator (LSS) is 50ft (15m) high and 33ft (10m) wide. Also on the site is a 38ft (12m) long and 15ft (4.5m) wide TVAC called Phenix. There is also a smaller vacuum chamber, VTC 1.5, which is 11.5ft (3.5m) long and 6.6ft (2m) in diameter and features the ability to simulate high intensity solar fluxes.

In addition ESTEC hosts Europe's largest reverberant acoustic noise test chamber, the Large European Acoustic Facility (LEAF), which is 36ft (11m) wide and 54ft (16.4m) high. It is also equipped with a 6DOF microvibration unit for testing jitter in satellites that will carry sensitive instrumentation, a 320kN horizontal and 640kN vertical electrodynamic shaker system and a large electromagnetic compatibility (EMC) test chamber.

Mark Wagner is head of the test support section in the mechanical department at ESTEC. He says, "The LSS is used to test full-size spacecraft in representative space conditions. To verify the design and correct functioning of spacecraft it is important to simulate the expected conditions in the best way possible while still on the ground. By doing this we can gain confidence in the design or identify improvements."

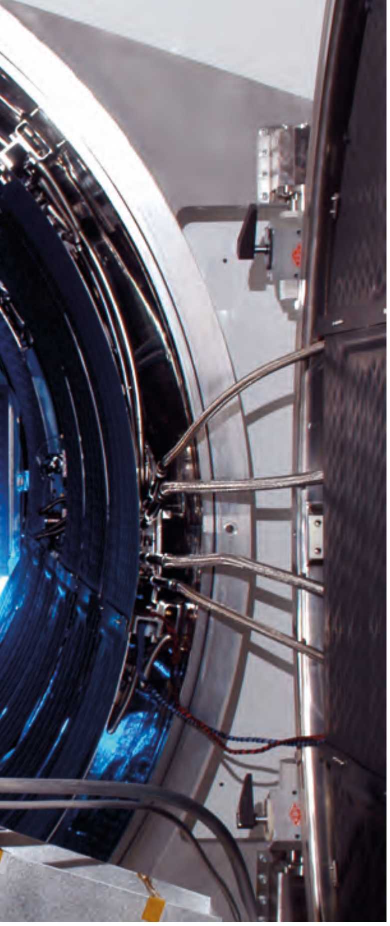
LARGER CHAMBERS FOR LARGER SATELLITES

The evolution of thermal vacuum chamber capabilities around the world received a substantial boost last year when the UK government announced it was to fund a National Satellite Test Facility (NSTF) at RAL Space in Oxfordshire.

The plans for the NSTF include the installation of a vacuum chamber 26ft (8m) wide and 33ft (10m) long – building on the existing capabilities at RAL Space, which already houses two 16 x 20ft (5 x 6m) chambers, the largest of their kind in the UK.

Mark Anderson, facilities technician at Rutherford Appleton Laboratory, says, "The investment is a result of a national review of UK space facilities, which found an increasing need for assembly integration and test facilities in the UK.

"The larger thermal vacuum chamber will be located alongside a suite of other test facilities. These include larger vibration facilities, to provide a facility for industry and academia to assemble and test their spacecraft all in one location."



CRYOGENIC TESTS

Another crucial element of the planning and development phase of many spacecraft is cryogenic testing. One of the most interesting recent examples is the telescope element of the James Webb Space Telescope (JWST) – termed OTIS, for Optical Telescope Element/ Integrated Science Instrument Module – which recently underwent a 100-day cryogenic vacuum test in the cryogenic chamber at the Johnson Space Center (JSC) Chamber A facility.

According to Doug McGuffey, the OTIS systems engineer, "By all accounts the test was likely the most complicated vacuum test ever conducted by NASA and was very successful, demonstrating that the telescope was aligned and functioned properly in space-like conditions. The need for cryogenic testing of space vehicles has increased recently with the advent of viewing targets in the infrared portion of the light spectrum. JWST was uniquely positioned in this regard, being the largest space-based telescope ever flown."

The cryogenic chamber provides a flight-like environment for JWST by pumping the air out to a very high vacuum, simulating the condition of space, and then using two shrouds, one cooled by liquid nitrogen and an inner shroud cooled by gaseous helium, to achieve 20K. This condition then cools the telescope to the 40K operating temperature. The shrouds can then warm back to room temperature once cryogenic testing is complete.

As long as missions are developed to view light in the IR spectrum, McGuffey predicts that cryogenic testing will be needed. Thanks to the JWST program, Chamber A at JSC is now well-situated to "perform cryogenic vacuum testing on large space-based missions reaching up to mid-infrared wavelengths".

He adds, "In the future large, space-based telescope missions may be more in the near infrared, visible and ultraviolet regions of the spectrum, so these missions will be tested to function in the cold, airless environment of space but will not need to be nearly as cold as for the JWST."

The main chamber of the LSS consists of a vertical cylinder containing a stable, seismic foundation with a specimen support platform. The cylinder itself is mechanically decoupled from both the chamber and building movement, providing a very quiet mechanical environment. Wagner points out that this attribute is "very important for dynamic tests, optical calibration and heat-pipe operations during heat balance phases".

PUMP UP THE PRESSURE

The LSS also features an auxiliary chamber made up of a horizontal cylinder that provides a stable interface for the integrated solar simulation optics, and houses a lens that produces a parallel solar beam. Both main and auxiliary chambers are equipped with a number of black-painted stainless steel shrouds that control chamber temperature. Liquid or gaseous nitrogen is used to achieve temperatures ranging from 350K (77°C) down to lower than 90K (-183°C), depending on the operational mode selected.

The simulator chamber is depressurized using an oil-free central pumping system alongside a dedicated high-vacuum pumping system, which achieves a typical vacuum level of less than five-millionths of a millibar using four turbo-molecular pumps and two closed-cycle refrigerator cryopumps.

"It takes about eight hours to evacuate the test chamber to a pressure level below 10^{-6}mbar," says Wagner. "Two cryopumps are also available in the auxiliary chamber if engineers require extra pumping capability, for example to release gas via the thrusters."

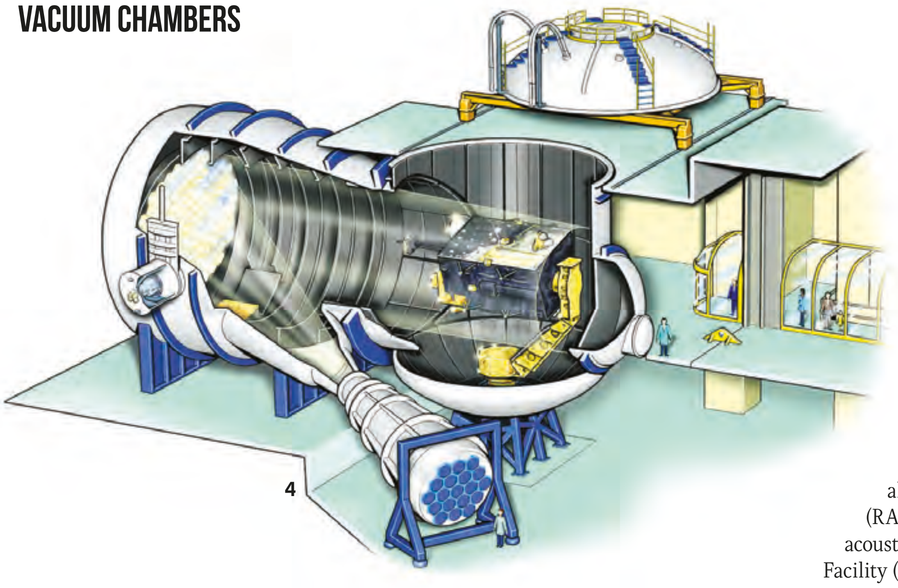
For repressurization, the chamber is vented using nitrogen gas to up to 100mbar and then with clean air up to atmospheric pressure. The total repressurization time can be adjusted from 5 to 24 hours depending on the specimen requirements. Two independent scavenger panels, activated early in the chamber evacuation phase and reconditioned only during venting, also provide protection against contamination for both the test object and the facility optics.

Other key elements of the LSS include a sun simulator subsystem – with an array of powerful xenon discharge lamps to reproduce the unfiltered sunlight encountered in Earth orbit or even closer to the sun – and a motion simulator to recreate better real orbit conditions via a robotic motion system that moves and rotates the spacecraft during its thermal vacuum test. "This allows engineers to place a test article in almost

2 // The calibration rig for the Sentinel 3 satellite's sea and land surface temperature radiometer *(Photo: STFC RAL Space)*

3 // BepiColombo is loaded into the Large Space Simulator *(Photo: ESA)*

122x120FT
Height and width of the TVAC at NASA's Plum Brook Station



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any position relative to the solar radiation axis in the LSS," says Wagner. "The drive systems and controls make it possible to simulate satellite motion in orbit within a large speed range and high angular position accuracy."

STAYING RELEVANT

Since its inception, the LSS testing facilities have hosted many high-profile projects, including Envisat, Rosetta, the Automated Transfer Vehicle (ATV), Herschel, Planck, Goce, BepiColombo and Sentinel-2B. At present the team is preparing a test for a part for the Juice (Jupiter icy moons) satellite. This mission aims to travel to the moons of Jupiter in 2022 to make detailed observations of them over a three year period starting in 2029.

6.2M
Diameter of the largest TVAC at the IABG Test Centre, Munich, Germany

Besides its large size compared to other space simulators, Wagner believes that the key benefit of using the LSS is its ability to very accurately simulate in-orbit environmental conditions. This enables "a broad range of tests to be carried out in support of design optimization and verification for spacecraft and payloads", he says.

The ESTEC team is "very close to the ESA project teams, as well as to the specialist engineers in the various engineering domains," he adds. Furthermore, Wagner believes that ESTEC is well positioned to stay relevant to aerospace research in the future, because it is always updating the LSS and its other aerospace test equipment.

"We are directly involved from the beginning in the project lifecycle. This allows us to anticipate future needs and possible required facility modifications and developments," says Wagner.

"For instance, last year we installed an additional cryopump that enabled us to keep the vacuum level constant even during the release of gas through electrical thrusters on the specimen.

"This summer we are planning to put in place a new motion system that enables more movement of a specimen and can simulate virtually any attitude. Our other planned improvements include temperature homogeneity in the chamber, which is already very good but will be further improved to facilitate analytical model correlation."

PLUM BROOK STATION

Although Europe undoubtedly boasts a wide-ranging and sophisticated TVAC capability, the largest facility of its kind in the world is the Space Simulation Vacuum Chamber in the Space Power Facility (SPF) at NASA's Plum Brook Station in Ohio. The SPF also hosts the Reverberant Acoustic Test Facility (RATF), the world's most powerful spacecraft acoustic test chamber, and the Mechanical Vibration Facility (MVF), the world's highest capacity and most powerful spacecraft shaker system.

As David Stringer, director of the NASA Plum Brook Station, explains, the vacuum chamber at the site works by removing the air from a cylinder that measures 100ft wide by 122ft high (30 x 37m) "to establish the heating and cooling processes spacecraft experience".

The interior of the chamber can be cooled to -156°C (-250°F), while the radiant heat of the sun can be simulated with 600kW electric heaters. The chamber can lower pressure down to six-millionths of a millibar.

"It usually takes much longer to prepare the test articles for testing than it does to conduct the actual tests," says Stringer. "Then, once the tests are complete, the articles are disassembled and shipped elsewhere. The testing process is unique for each test. The facility is being updated continually to improve its functions as well as its data collection."

Recent high-profile tests carried out at the site include those for the SpaceX Falcon 9 payload fairing, the Lockheed Martin Orion backshell, and the ESA Orion service module structural test article. "We can save time and money if we realistically test spacecraft and launch vehicles before we fly them," says Stringer. \\

5

4 // The Large Space Simulator's main vertical chamber is decoupled from the rest of the building *(Photo: ESA)*

5 // The latest vacuum chamber is installed at RAL Space in Oxfordshire, UK *(Photo: STFC RAL Space)*

TESTING RESEARCH
// BEN SAMPSON

Risk & r

1 // Inside the Autonomy Laboratory at the AIRC

Can a university research center change the way the industry develops and tests aircraft?

eward

2 // The £35m (US$48m) Aerospace Integration Research Centre

RESEARCH SET TO SLASH ROTOR BLADE MAINTENANCE COST BY 40%

The £2.2m (US$3m) BladeSense project promises to reduce the maintenance costs of helicopter rotor blades by up to 40%. The project at the AIRC is Airbus Helicopters UK's first research and technology project and it has embedded a researcher within the project team. Other industrial partners include BHR Group and Helitune.

Researchers are developing fiber-optic instrumentation to measure deformation in rotating rotor blades, as well as working out how to transfer the data obtained and incorporate the instrumentation into vehicle health-monitoring systems.

Savings will be made by reducing the number of blade inspections and improving the design of rotor blades, say the researchers. Dr Mudassir Lone, principal investigator and technology expert on the project, believes that in the long-term companies could offer a monitoring-based maintenance service for helicopter rotor blades, similar to the service package Rolls-Royce offers for its jet engines. Flight safety would also be improved, because blade damage could be flagged up instantly to pilots.

"Our technology measures the blade deformation directly and at a very high frequency."

The fiber-optic-based instrumentation will have its first flight test in July. The results will be used initially to improve and validate rotor designs.

The Aerospace Integration Research Centre (AIRC) at Cranfield University in the UK has been open barely three months and already has a purposeful, work-focused atmosphere. The modern steel and glass building, which is positioned next to the university's airfield, looks conspicuously more commercial than the red brick buildings that make up the rest of the academic campus.

The center represents a £35m (US$48m) investment. Around £10m (US$14m) of the funding is from government, with the remaining funds coming from Airbus and Rolls-Royce, which will invest in research projects there over the next five years, and the university. After its formal opening in October 2017, the center's laboratories, workshops and conference rooms are steadily filling with exciting projects and researchers.

One of the ideas behind the AIRC is to merge design and testing into one shared cycle and thereby reduce the investment risk in aircraft development. This is achieved best, the backers of the AIRC believe, in a single building, using pooled expertise, with the latest design and engineering simulation software and hardware, and a comprehensive capability to develop a research concept all the way through to flight tests.

Tim Mackley, head of the AIRC, says the building was designed from the ground up with its industrial collaborators to be a place that can progress projects to higher technology readiness level (TRL) than are normally associated with a university. "It's about getting a very effective TRL 6 argument so that a chief engineer can take research output and use it in current development programs," he says.

20%
Amount of weight the Agile Wing Integration research project aims to remove from the current A320 wing

The AIRC's building has three levels. There are several laboratories and a hangar on the first floor, computer simulation and visualization facilities on the second floor, and office and meeting facilities on the third.

HIGH BAY LABORATORY

The heart of the building is the 1,500m² (16,150ft²) High Bay Laboratory. This large hangar area has the height of all three levels, with 18 x 6m (59 x 20ft) doors at the front. Attached to the roof is a large yellow Demag crane, which Mackley claims is the widest in the UK and the second widest in Europe, weighing more than 30 metric tons and able to lift 16 tons.

There are Airbus projects on one side of the hangar and Rolls-Royce projects on the other, "with no wall in the middle", Mackley proudly says. One of the projects is testing engine-on-wing configurations, including a full-sized A320 wing. Another A320 wing is being used to research automated assembly processes as part of the Airbus Wing of Tomorrow program. This program includes the Agile Wing project (see box above), which is developing a next-generation wing for eventual use on an A320 successor.

1946
The year Cranfield opened its airfield and College of Aeronautics. It remains the only university in Europe with a runway

3 // An Airbus A320 wing in the AIRC's High Bay area

The AIRC has access to Cranfield's fleet of aircraft, which includes a 19-seater BAE Systems Jetstream 31, Scottish Aviation Bulldog, Slingsby T6M260 and Pitt S2C. Cranfield Aerospace Solutions is also on the campus, to fully approve modifications and flight test experimental aircraft and research projects.

"The key thing here is airside access," says Mackley. "We can take test equipment and modifications from the labs, install them onto aircraft and take them onto the runway and into the air."

EXPERIMENTAL WORK

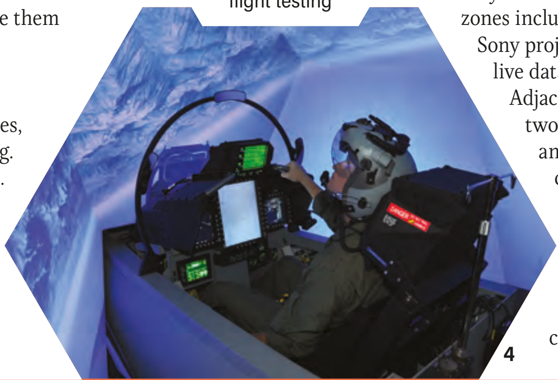
Behind the High Bay are several laboratories, for different areas of aerospace engineering. Eventually each will contain several projects.

In the UAV laboratory, drones are developed from scratch and are used as test vehicles for other experiments. One experiment is researching thermoelectric generation solutions for aircraft. A heat exchanger on a test bench, encased in a white insulating material, demonstrates technology that has been developed to withstand up to 300°C (572°F) and produce 3.5kW of power. The exchanger is being tested on the Demon UAV, a drone developed with BAE Systems and other universities.

Other projects in the laboratory are looking at novel flight control concepts such as a UAV quadcopter that is resilient to failures, able to fly autonomously despite failure of up to two of its rotors.

Meanwhile, elsewhere in the aeroelastics laboratory, a helicopter rotor blade spans almost the entire width of the room. The blade has a slender fiber-optic thread running down its length to measure load and strain. The blade is part of a project called BladeSense (see *Wing of tomorrow*, below), which is developing instrumentation to slash maintenance costs for helicopter rotor blades.

4 // Simulators are a key part of virtual flight testing



VIRTUAL BIRDS

The first floor of the AIRC is dominated by a large conference room, arranged like a mission control center, called the Integration Demonstration Engineering Analysis and Simulation (IDEAS) area. It has four zones including widescreens employing dual Sony projectors to display multiple simultaneous live data feeds from other parts of the lab.

Adjacent to the IDEAS room are the AIRC's two large flight simulators, including a *g*-seat and a room equipped with many large computers and servers for air traffic management simulation.

Engineers create pilot-in-the-loop simulations in the IDEAS area, merging data from other experiments and sources with flight physics so that it can be viewed live with the results via the

WING OF TOMORROW

One of the first major projects for the AIRC is research work for the £16m (US$22m) Agile Wing Integration (AWI) project, part of Airbus's Wing of Tomorrow program. The four-year project is developing the wing design to be slenderer and more glider-like, reducing its weight by up to 20% to improve fuel efficiency. The design is expected to be used on a future version of the Airbus A320 between 2030 and 2040.

The project used the first complete test-run of the integrated simulation capability at the AIRC in November 2017. A novel aircraft wing design, developed by Airbus, Cranfield and the University of Bristol, was put through the design processes and simulated flight testing by a team of 20 researchers in just five days.

Information about the wing and the aircraft's performance was transmitted in real-time to screens in the AIRC's IDEAS area, to watching engineers, developers and researchers, as the concept was iterated through various design loops.

The first day was spent discussing data processes and exchange and what was needed; day two, modeling the entire aircraft and its dynamics; day three involved test pilot flights with the new designs and identifying issues and performance problems, and looking at how to resolve them; day four on further test flights with revised and refined designs; and the final day was used for the whole team in reflecting on the process and reporting on the progress made as a basis for moving to a higher stage of development.

Dr Mudassir Lone, principal investigator on the AWI project at the AIRC, says that developing the models to be used in the simulator is a complex and data-intensive process, but the results can save massive amounts of development time. "We focus on the wing and use our understanding of wing structures and dynamics to ensure we comprehensively capture the flight physics," he says.

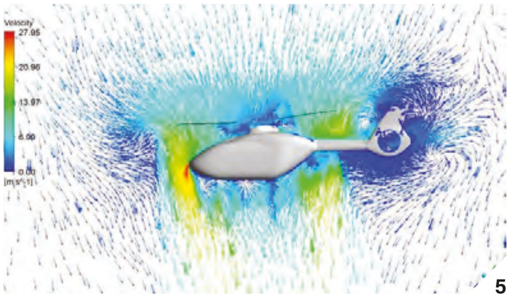
"Typically a design loop takes over six months because of the large number of people and the work involved. At the AIRC, because we have the specialists all in one place with the simulation tools, you can do one design iteration in three days and two more in five days."

The comprehensive and detailed information obtained can replace physical testing for aerodynamics in wind tunnels and loading and strain in laboratories, says Lone. "Previously, the fidelity of the simulations between the materials and structures was very low. But now we have the technology and expertise to do these simulations at a much higher fidelity.

"When it's implemented in industry, it will have a massive impact on development timescales," says Lone.

6 // A FANUC robot is used for research into cobots in the Intelligent Automation Laboratory

5 // Downwash of the H135 helicopter in hover condition at 1,000ft



5

6

projectors. It's with tools such as this that the AIRC aims to reduce design time and investment risk, by feeding back simulation and testing data as early and quickly as possible in the design process. Mackley says, "Simulation is key to integration. It fills the gaps between research and testing. There is an iron bird, a copper bird, and this equipment is for a virtual bird."

VIRTUALLY EQUIPPED

The research being done is at the system level, so a lot of the equipment is virtualized, although there are plans to develop and acquire more equipment, such as a thermal-management facility and a structures rig that will accommodate test pieces of up to 22m (72ft) long.

The AIRC is also acting as a gateway to Cranfield University's other facilities, such as the wind tunnel, high-performance computing and even the management school. "Many of the projects involve university expertise outside of the center," says Mackley. "In many ways challenges are going to be as much about soft issues as hard technical problems – such as supply chain issues and intellectual property. The AIRC acts as a focal point to pull everything together."

GRAND CHALLENGES

The AIRC exists to increase integration through optimizing at the system level, with the close partnership of Airbus and Rolls-Royce, but is still aiming to involve many industrial and academic players in the field. "We're investigating future concepts in aviation, new materials and components. Areas like hybrid electric propelled aircraft for example,"says Mackley.

"We are also responding to a recognition from companies that they want research to be done in areas where they know there is future value. A single facility enables you to focus on these areas and to bring together the best experts from different universities."

53
inspections of a helicopter rotor blade during its lifetime using BladeSense technology, down from 100 inspections today

The AIRC has proposed a set of grand challenges with Airbus and Rolls-Royce for the center. One is to improve the efficiency and effectiveness of aircraft. Another is to halve integration times for new products so that the companies can be more agile.

Mackley, who started his career as an engineer at missile manufacturer MBDA, is well aware of the demands of aerospace research projects. He remembers being told that a missile development program will always take seven years. "If you use the same architecture, and the same tools and processes, it will always take that long," he says. "To halve integration times you have to do something really radical, change the way you think, and that's what we intend to do here."

However, he admits that the increasingly integrated nature of aircraft tends to increase the development time of projects. "That's not a criticism; it's just more difficult. To have our grand challenge to reduce development timescales at the same time as increasing integration is a difficult task," he says.

1,500
The size of the AIRC's High Bay Laboratory (in m²)

"But it's being driven by these grand challenges that enables us to be unique in the world of aerospace research and development."

The AIRC is aiming to get the most benefit possible out of a system-level approach to design and testing. The center's success will be measured by the success of the projects within it. Although far from guaranteed, a close focus on industrial applications and partnerships, and an approach that focuses on the commercial value of research at an early stage, should yield results. \\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1 // Deliver took a look at small vertical take-off and landing vehicles, including air taxis like the CityAirbus

Test & liver

NASA is testing small unmanned aerial vehicles to validate the design tools that will be used to develop commercial drones and urban air taxis

The companies behind plans to develop airborne package delivery drones and passenger-carrying air taxis are developing multicopters and other vertical flyers that are very different from today's helicopters and tilt rotors. NASA's Ames Research Center ran the Deliver (Design Environment for Novel Vertical Lift Vehicles) project to validate proven computer design tools to be used for this emerging category of new, small unmanned aerial vehicles (sUAVs). Deliver pooled experimental and analytical expertise from three NASA Centers – Ames in California, Langley in Virginia, and Glenn in Ohio.

The principal investigator on Deliver, Colin Theodore, says, "We have tools that have been validated for larger vehicles – traditional helicopters, tilt rotors – for decades, so we know they're reliable. The goal of Deliver was to demonstrate the applicability of our tools for these new concepts and vehicles."

The two-year Deliver project ran until September 2017. The research investigated sUAV aerodynamics, propulsion and acoustics, with wind tunnel and flight tests as well as computer modeling. "We definitely put an emphasis on going out there and testing," says Theodore. "To better align our tools with these new vehicles and new markets, what we need is experimental data."

SWITCHING TO SMALLER UAVs

The Deliver project's results are now part of NASA's ongoing Revolutionary Vertical Lift Technology (RVLT) project, which is led by the Langley Research Center. Theodore is also the RVLT associate project manager. "Most of the work, or at least a significant part of it, is being transitioned to RVLT, rolling it into more of a research project."

However, RVLT has so far focused on full-sized helicopters and tilt rotors. Deliver provided a first look at small vertical take-off and landing (VTOL) vehicles for package delivery and two- to four-passenger urban air taxis.

As part of Deliver, researchers formulated a test program for the 60 lb GL-10 Greased Lightning electr tilt-wing built at NASA Langley. Other test vehicles included four quadcopters and one octocopter weighin from 3.3 to 12.8 lb, plus a 20 lb twin-rotor tilt-wing. Aerospace engineer Carl Russell, at the Ames Rotorcraft Aeromechanics Branch, says, "This size is above the small toy aircraft but below the manned aircraft we've studied in the past with our design tools.

3
year project to validate computer design tools on small UAVs

"From the start there was a focus on electric or hybrid electric vehicles, because most of the small vehicles on the market are electric and because that took us out of our traditional comfort zone of turbine-powered rotorcraft."

FORCES AND MOMENTS

Near-term RVLT work is focused on propulsion efficiency and noise acceptance for helicopters and tilt rotors. However, the multicopters considered by Deliver researchers pose new questions. "The aerodynamic interactions between the props in hover and forward flight definitely create some challenges in terms of modeling," says Theodore. "Typically the props are a lot closer to the airframe than you've got with

INDUSTRY DELIVERS INVOLVEMENT

Deliver's research program also involved small, non-traditional aerospace manufacturers. Straight-Up Imaging (SUI) in San Diego, California, is primarily an engineering company serving the NASA Jet Propulsion Laboratory. SUI loaned its Endurance commercial UAS to Deliver researchers to measure flight forces, moments and noise characteristics of the quadcopter. In return it received valuable aerodynamic data for the entire vehicle at a range of speeds and angles of attack.

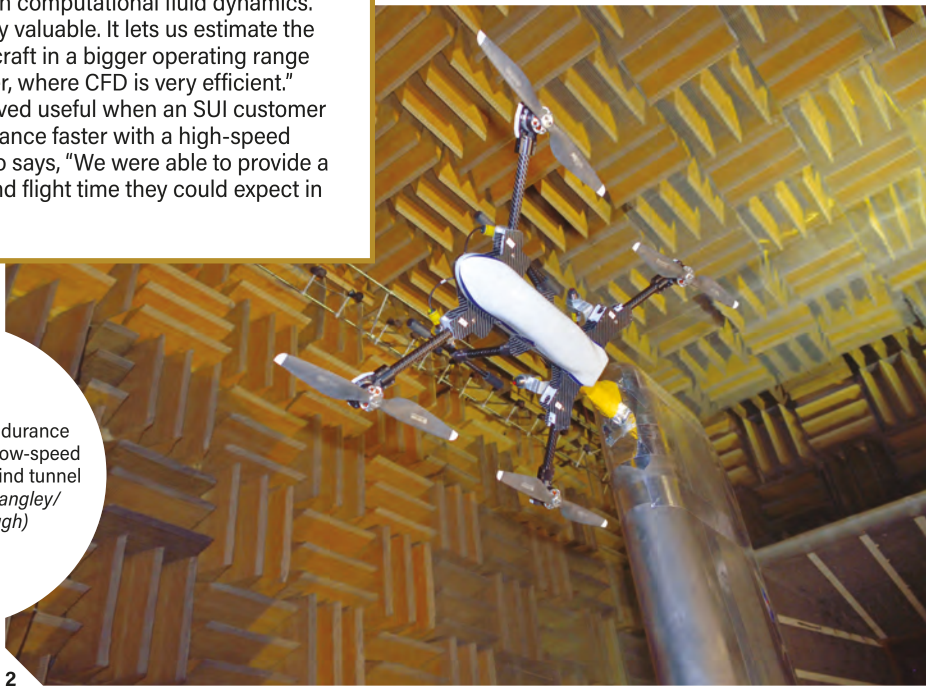
SUI's chief technical officer, Eric Maglio, says, "We had a lot of data on power system performance. We didn't have much on the vehicle's aerodynamics.

"It's difficult to do with computational fluid dynamics. Wind tunnel data is very valuable. It lets us estimate the performance of our aircraft in a bigger operating range than low speed or hover, where CFD is very efficient."

Deliver data also proved useful when an SUI customer wanted to fly the Endurance faster with a high-speed camera payload. Maglio says, "We were able to provide a chart with the speed and flight time they could expect in different conditions."

1

1 // The SUI Endurance on a quick-change fixture in the wind tunnel *(NASA Ames)*



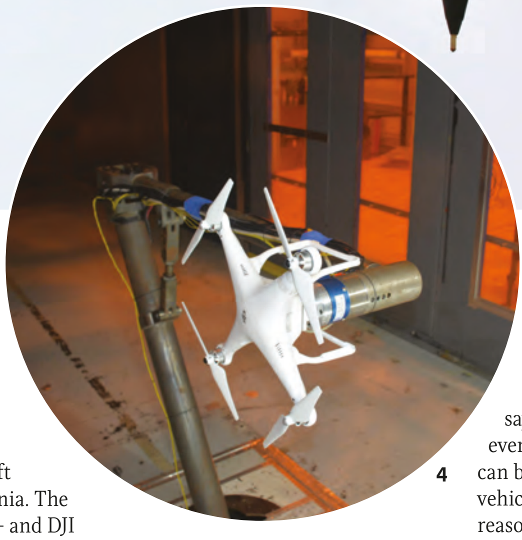
2

2 // The SUI Endurance in the Langley low-speed aeroacoustic wind tunnel *(Photo: NASA Langley/ John Swartzbaugh)*

3 // Deliver researchers formed a test plan for the GL-10 Greased Lightning UAV *(Photo: NASA Langley)*

20
researchers contributed to the Deliver projects' aerodynamic, acoustic and propulsion tests

helicopters, which creates interactions that are hard to predict. One of the keys is to predict those interactions and minimize their negative effect."



4 // The DJI Phantom III was one of five commercial multicopters tested in the US Army wind tunnel at Moffett Field, California *(Photo: NASA Ames)*

EFFICIENT WIND TUNNEL TESTS

NASA Ames researchers tested five multicopters in the US Army's 7 x 10ft wind tunnel at Moffett Field, California. The SUI Endurance, 3DR SOLO, 3DR Iris+ and DJI Phantom 3 vehicles were quadcopters. The Drone America X8 was an octocopter. All the sUAVs were stripped of camera payloads to hold the custom-built tunnel fixture. For experimental simplicity, the electric motors in all five drones were controlled by an off-the-shelf electronic speed controller. "With all of the interchangeable mounting hardware and instrumentation plugs, we could change from one vehicle to the next in about a half hour," explains Russell. "Wind tunnel time isn't cheap; the ability to be quick and do five vehicles in quick succession was key."

Each of the multicopters was tested to gauge forces, moments and electrical power consumption as a function of wind speed, rotor speed and vehicle attitude. Bare airframes were tested to gauge drag coefficients of the vehicle bodies. Bare rotors were used to measure the lift generated in different flight conditions.

According to Russell, "We'd sweep through variables like wind speed, vehicle pitch and yaw angle, and rotor RPM in a methodical way to cover a wide range of possible flight conditions. The only difference from vehicle to vehicle would be the baseline hover RPM, which we'd determine by spinning up the rotors until the rotor thrust matched the vehicle weight." A two-rotor tilt-wing, built by Elytron Aircraft (now VTOL Aerospace) was also tested with variable wing tilt and elevator deflection.

Loads on the fixtured air vehicles were measured with a six-axis load cell. Test data was collected by a Basic Data Acquisition System (BDAS) based on National Instruments' LabView systems engineering software. The BDAS recorded tunnel conditions and vehicle signals. Another LabView-based data system tracked motor and rotor RPM.

3
NASA Research Centers – Ames, Langley and Glenn – teamed with non-traditional aerospace manufacturers to collect small UAV data

Unlike typical rotorcraft modeling, Theodore says that a clear advantage of small vehicles is that everything is tested at full size. "The data we collected can be directly translated in free-flow into these vehicles," he says, "We were able to use off-the-shelf, reasonably cheap, readily available hardware and instruments to get really good-quality data. It showed we don't have to go through an expensive, time-consuming process to build models and expensive test rigs to get good-quality data we can use for calibration."

NOISE MEASURES

"Noise is probably the biggest barrier to increased use of helicopters and rotorcraft around urban areas," says

"Wind tunnel time isn't cheap; the ability to be quick was key"

Theodore. Unlike full-size helicopters with internal combustion engines, small multicopters are widely expected to use electric propulsion. "The perception is they'll be quiet. The reality is that noise will be a factor. There may be different qualities or characteristics of the noise compared with what we think of with helicopters, but noise will still be one of the biggest factors in operations."

Deliver started to characterize the noise of small vehicles that vary rotor speed for all control axes. Theodore observes, "You have multiple time-varying frequencies, all adding up to create the noise characteristics of the vehicle." Vehicle configuration also impacts interactional noise. "Putting the props really close to the aircraft is a really big source of noise," observes Theodore.

"Once you start hybridizing you get a more complex vehicle"

To build an acoustic database, researchers at the NASA Langley Structural Acoustics and Aeroacoustics Branches took anechoic chamber measurements with multicopters fixtured in a hemispherical microphone array to characterize sUAV propulsion. Aeroacoustics Branch research engineer Nikolas Zawodny says, "We would do isolated rotor tests – mainly static because hover is an important flight condition for these vehicles." The low-speed aeroacoustic wind tunnel at Langley was originally used for jet noise studies, housed in a 17 x 17 x 34ft anechoic chamber. Deliver introduced a larger inlet to provide lower flow-speed capabilities more suitable for sUAVs. The modifications also prepared the tunnel for testing small aircraft and full-scale propellers for studies of distributed electric propulsion.

Propeller blades were laser-scanned blades for high-fidelity CFD models. Noise tests then introduced selected sUAV airframes. "We kind of picked a few different ones that were a cross-cut of different sizes and payload capabilities – different weight ranges," says Zawodny. Subsequent tests in Langley's low-speed acoustic wind tunnel measured noise in hovering and forward flight conditions.

Flight test data recorded noise frequency content and tone variations with time and frequency variations under different flight conditions. Ran Cabell, Langley Structural Acoustics Branch head, says, "We did outdoor measurements just to understand what noise these vehicles made flying over someone or hovering – the total noise."

NASA Langley has an exterior effects room with surrounding speakers to characterize three-dimensional noise with human observers. "We compared the noise from a small UAV with ground vehicles – delivery trucks and cars," says Cabell. "For a similar sound level, the multicopter was more annoying than the ground-level vehicles. We did not seek out the reason."

PLUG-IN PROPULSION

Electric flight visionaries typically foresee the use of battery-powered aircraft for short trips. Deliver researchers at the NASA Glenn Research Center also considered the performance of hybrid electric propulsion for air taxis big enough to carry two to four passengers over 20 to 50 miles.

Such vehicles might take off vertically but cruise on lifting wings, with distributed electric propulsion drawing on internal combustion engines burning diesel fuel or cryogenically cooled power systems using liquefied natural gas.

Theodore says, "What does adding hybrid electric do to your mission performance, your ability to perform the mission on one fueling and increase functionality? You get much greater endurance."

Data for accurate hybrid propulsion trade studies was not collected under Deliver, but NASA engineers did build high-power rotating components for cryogenic propulsion systems. According to Theodore, "We designed hardware. We went through all the safety reviews. We built hardware and we ran out of funding."

NASA is updating the NPSS – the Numerical Propulsion Systems Simulator code – to accommodate electric motors and propulsion. Theodore says, "For most of the hybrid electric vehicles, we just used what was available and made assumptions about efficiencies."

Hybrid electric propulsion remains intriguing for innovative vertical lift. Theodore concludes, "However, once you start hybridizing, you get fuel on board, more complex electronics and a more complex vehicle. In return, you get a lot more endurance. But, electric remains the easiest one to get to flight soonest.

"Then, as operators of urban air taxi networks increase their vehicle fleet sizes and start to raise productivity, you'll need to get beyond the capability of batteries and electric propulsion with hybridization." \\

5
different multicopters were tested to provide data on the small UAV class of vehicles

DRONES TO CARRY LARGER LOADS

Earlier this year Boeing revealed the unmanned cargo air vehicle that will be used to test and develop its autonomy technology for future aerospace vehicles.

The electric vertical take-off and landing (eVTOL) prototype can carry a payload of up to 500 lb (227kg) for the testing and development of possible future cargo and logistics applications.

The cargo air vehicle prototype is powered by an electric propulsion system and outfitted with eight counter-rotating blades allowing for vertical flight. It measures 15ft long (4.6m), 18ft wide (5.5m) and 4ft tall (1.2m), and weighs 747 lb (339kg).

The UAV recently successfully completed initial flight tests at Boeing's Research and Technology's Collaborative Autonomous Systems Laboratory in Missouri. Engineers now plan to use the prototype as a flying testbed to mature the building blocks of autonomous technology for future cargo air vehicle applications.

5

5 // The octocopter provided another configuration to measure control forces and performance in the wind tunnel *(Photo: NASA Ames)*

Ships

// Merlins land on the aircraft carrier HMS Queen Elizabeth *(Photo: MoD/Crown)*

shape

The aircraft used by the Royal Navy are monitored and inspected by a dedicated team of NDT specialists

1 // X-ray scans help analyze internal faults after incidents and failures

2 // The Squadron performs upgrades and modifications to equipment

The deck of a naval vessel at sea, pitching and rolling in the waves with rain lashing down, is not the most conducive place to perform inspections and tests on aircraft. But regardless of whether it's freezing in the North Sea or searing heat in the Middle East, if there are Royal Navy aircraft present, there will likely be a member of 1710 Squadron on hand to ensure that the aircraft are airworthy.

There has been aeronautical engineering support in the Royal Navy ever since the service started to fly aircraft in the 1910s. Today that support is just as necessary, from the Merlin helicopters that remain the mainstay of much of the Royal Navy's operational aircraft, to the new generation of F-35 Lightning II's that are expected to start flying from the UK's aircraft carriers this summer. The NDT engineers that inspect and monitor those aircraft are an integral part of keeping them in the sky.

UNDER ONE ROOF

1710 Squadron primarily provides support to Royal Navy and Joint Helicopter Command aircraft and supplies. The squadron works according to three main principles – to recover, sustain and enhance equipment. It is organized into four departments: repair, materials, monitoring and modifications.

Repair manager and executive officer at 1710 Squadron Darren Jones, says, "We have these functions all under one roof, so we can rely on engineers and scientists with world-leading expertise in NDT, materials, forensics and chemistry. It enables us to be coherent and comprehensive in what we do."

Jes Dugard is 1710 Squadron's NDT Lead and manages a team of eight engineers and technicians. He says, "NDT is fully integrated into 1710 Squadron. Anything that a repair team does will inevitably need a structural examination of some kind prior to the repair and potentially afterward as well.

"On the materials side, they are primarily looking at things from a failure investigation standpoint. We provide advice on potential solutions.

"We operate in some very strange environments compared with the civilian world. All of our equipment and processes have to cope with that. The knowledge and expertise we have built up and can access enables that to happen. Sometimes we have to come up with robust and innovative solutions for NDT."

103
repairs were carried out by 1710 Squadron in 2017

40,000
samples are analyzed by 1710 Squadron's Wear Debris team every year

ROUTINE INSPECTIONS

The NDT team provides monitoring and testing for routine maintenance and inspections. NDT inspections will be more frequent when a new aircraft first comes in, because engineers are getting to know it. Then the number of inspections falls to a steady level until age means fatigue and cracking starts to occur and the number of inspections has to rise again. "It's a bathtub curve," says Dugard.

"Each aircraft platform has a review of its NDT at least every two years to ensure the NDT is still valid – it may have been modified. Or you may have carried out inspections a number of times and not found anything. So perhaps you use that data to reduce the maintenance burden, or you have to assess if the NDT you are doing is still valid."

Inspections and projects are always conducted under a time constraint. "If you have an aircraft on the ground the requirement is to get it back in the air. From an NDT perspective that is seen as everyday maintenance. You've got to get it done. That's where our deployable teams are important – they have a maximum 48 hours attendance to a task, but normally they are there within a few hours."

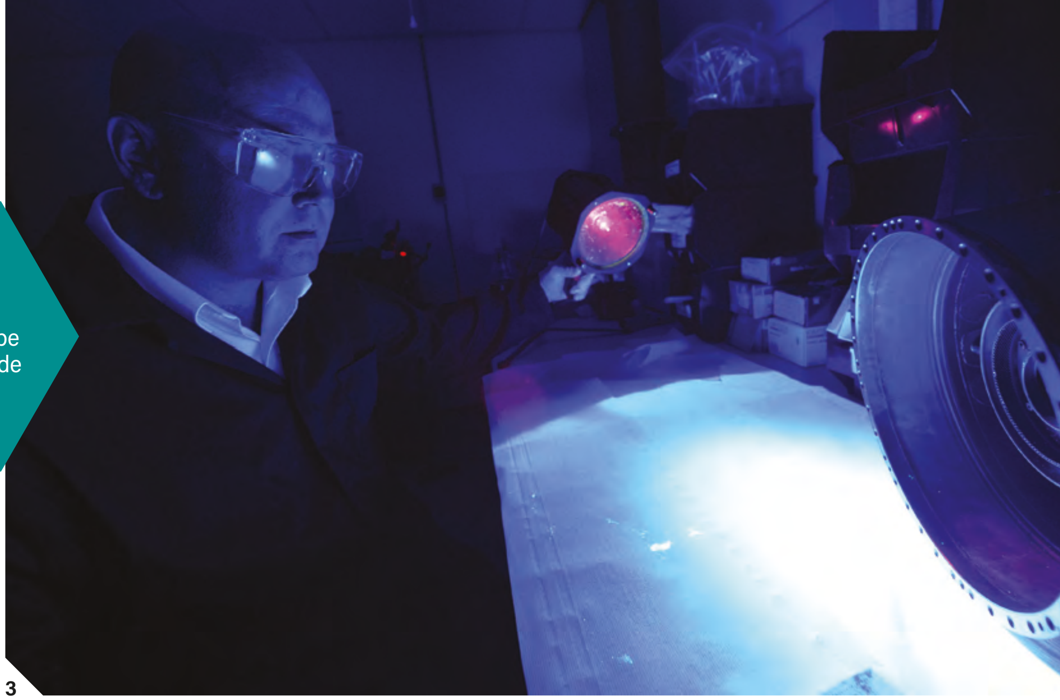
The Royal Navy's and Joint Helicopter Command's NDT technicians and engineers are trained to three levels. Level 1s are stationed at bases and on vessels to carry out inspections according to go/no-go instructions. Level 2s are deployed around the world and have the ability to interpret the results of tests and inspections and support the level 1s. Level 3s are based at Portsmouth and provide technical support to the Level 2s and ensure mandated certification processes are complied with. The teams are made up of service personnel and civilians.

The two and three-man NDT teams are based at several locations in the UK and can be deployed anywhere in the world. They have recently been sent to the USA, Norway and the Middle East. "Because of where we operate, we can't train everyone up to Level 2 standards. It's more practical to have serving personnel trained to Level 1," says Dugard.

FAILURE INVESTIGATION

Typical examples of NDT investigations include flange failures on driveshafts, cracks in landing gear, and

14
repair teams can be deployed worldwide



3 // Penetrant dyes and UV lights are commonly used to detect flaws

fatigue and cracks that occur in pistons and gearboxes.

At 1710's Portsmouth base, the NDT team shares the same office space as chemists, materials engineers and scientists. They can use this expertise to help solve engineering problems. "If we have any questions on applying NDT techniques, or the mode of failure of a fault, we can ask," says Dugard.

"Mode of failure has an impact on what NDT we are going to do and how we are going to do it, and if the crack is likely to propagate – whether it's a time-based or usage-based crack. The materials knowledge is essential when developing the NDT inspection."

After an NDT team has completed a report examining a problem, it will liaise with a repair team to repair or replace the aircraft's structure or component. However, when an issue keeps on appearing, fixes and inspections have to be developed that are more innovative. The NDT team has developed bespoke inspection equipment to keep aircraft in service while suppliers have rolled out fixes to the entire fleet. One such time involved cracking in the ring gear of a gearbox. The cracking was seen to start from the locating ring, so an easy-to-use ultrasonic probe was developed to examine that area of the gearbox quickly. This helped to keep aircraft in service while the fix was rolled out. Another time saw the team develop different probe sizes to inspect different sized holes for fasteners on main lift frames.

3,000
samples, such as oil and hydraulic fluids, are analyzed by 1710 Squadron's chemists every year

1710 SQUADRON REPAIRS

The Squadron is headquartered at Portsmouth and has bases at Yeovilton, Wyton, Wattisham and Benson. There are around 165 people in the squadron, with a mix of civilian and military personnel.

1710 Squadron's repair manager and executive officer, Darren Jones, says, "There are 14 repair teams that can be deployed anywhere in the world to repair damage. They are trained to assess aircraft and perform repairs using different equipment in different environments.

"You have to understand the operational context, to understand what it's like to carry out tests and repairs on a flight deck while you are at sea. It's about ensuring that people are using kits safely and with the right information."

Recent examples of repairs include bullet damage to Chinooks and heat damage to Apache helicopters. The main types of helicopters maintained are Merlins and Gazelles. The most common issues causing repairs across all aircraft are corrosion due to the marine environment and fatigue and cracking from vibration.

TOOLS OF THE TRADE

1710 Squadron's NDT teams use a range of technologies and techniques, ranging from tap hammers to CT scanners to inspect aircraft structures and components for flaws.

The NDT specialist can use visual and visual assisted techniques, including video probes for access to tight internal spaces. Relatively simple tap hammers are used to find defects in materials. Training is still necessary for this, as is a certain standard of hearing. Other 'old school' methods such as dye penetration and magnetic particle flows are also commonly used to detect flaws during quality assurance checks and fault investigations.

Eddy current kits are used to detect surface or subcutaneous damage. "It's reliable, sensitive, accurate and probably the most frequently used method, although the depth of penetration is limited," says Dugard.

The teams also use mobile kits for on-site inspections. The use of high-frequency sound waves reflected back from surfaces and flaws is well established. Low-frequency ultrasonics are also used routinely with composites to detect delamination.

X-RAYS

X-ray imaging is used extensively to find cracks and fatigue in aircraft. There is a requirement for x-rays as part of a routine inspection or if an aircraft has suffered a failure. "X-rays are the last resort. If you can do it by another means and it is as effective, cheaper and faster, then the other method wins," says Dugard.

One of the squadron's more recently acquired bits of kit is a Nikon Metrology x-ray scanner with CT software upgrade from VG Studio Graphics. The machine has a 160kV x-ray set and a flat-panel detector to look inside test pieces down at least 0.06mm.

The machine is used primarily for aviation accident investigation work, a function that the Squadron also performs for the UK's civil Air Accident Investigation Branch. Conventional x-rays are 2D and cannot be obtained as quickly as using the Nikon Metrology machine.

"The x-ray scanner and CT allow us to gather evidence before the scientists start pulling things apart," says Dugard. "We've used it with computer memory and SD memory cards to help recover data by showing where power can be applied to the chip.

"Another time there was an aircraft that was found to be off its flight path due to a navigation computer failure. Using the scanner, we found that a break in the insulation of the computer's power lead was causing intermittent power supply.

"The intermittence was compounding the error, but it was all down to one dodgy cable."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ROYAL NAVY AIRCRAFT

The Royal Navy uses a mix of rotary and fixed wing aircraft in its Fleet Air Arm:

∇ F-35 Lightning II Joint Strike Fighter

Expected to enter service on its two new aircraft carriers this summer, the Royal Navy is to using two versions of the F-35, the short take-off and vertical landing B variant and the carrier (C) variant. It has a top speed of 1,200mph (1,930km/h), a range of 1,200 nautical miles and a wingspan of 10.7m (35ft).

∇ Hawk

This twin-seat fast jet is used primarily for simulated ship attack and airborne intercept training. It has a top speed of 638mph (1,028km/h), a range of 1,360 nautical miles and a wingspan of 9.39m (30.8ft).

∇ Grob 115E Tutor

This training aircraft is known for its docile handling. It has a top speed of 213mph (343km/h), a range of 500 nautical miles and a wingspan of 10m (32.8ft).

∇ Merlin

The Royal Navy flies three variants of the Merlin helicopter. The Mk2 entered service in 2014 and is a submarine hunter. The Mk3 transports the Royal Marines.

∇ Sea King

The eyes in the sky of the Royal Navy, this helicopter searches the skies for aerial threats. It is 22m (72ft) long with a 19m-diameter (62ft) main rotor and has a top speed of 103mph (166km/h).

∇ Wildcat

An attack helicopter with a top speed of 180mph (290km/h) and a range of 420 nautical miles, it operates from frigates and destroyers and entered service in 2014.

4 & 5 // The detailed analysis of wear debris from aircraft involves the use of electron microscopy

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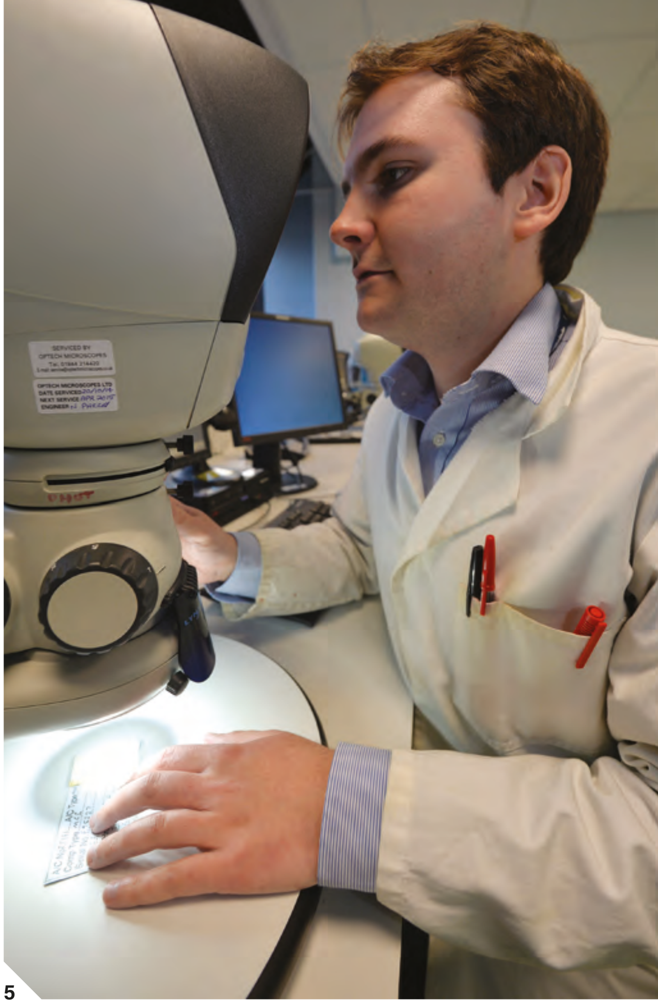

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The real-time radiography provided by the scanner is impressive. Equally impressive is the CT software, which builds a 3D image of both the outside and inside of a test piece. The software will be used to examine 3D-printed parts in the future. "There's a big drive in the NDT community to understand the mechanics of failure for 3D-printed components," says Dugard. "There's a lot of research going on using CT, looking at the structures and the way they come together. A lot of 3D-printed parts are made as one whole component, but you don't get to look inside it.

"If 3D-printed parts start failing on aircraft, this technology will be used to look at them. Exotic materials are more of a challenge than conventional ones."

As well as the Nikon Metrology machine at Portsmouth, there is a larger x-ray machine in a lead-lined cabin outside the main building. The Squadron's NDT team also uses mobile x-ray kits on-site for inspections. The imaging process for x-ray imaging was digitized in 2014. "We've lost all the large equipment associated with processing wet film, as well as all the chemicals and screens," says Dugard. "The digital images have a greater latitude. You can more easily vary the density of the radiograph."

LATEST TECHNOLOGY

The NDT team is constantly acquiring and upgrading kit and has strong links with the NDT community and commercial sector, so it can stay abreast of the latest developments. Team members attend conferences and closely work with partner suppliers. For example, the team is rolling out phased-array ultrasonic cameras – an array probe designed for use with carbon composites. The cameras can create high-resolution 2D and 3D images of areas where damage is suspected, which enable technicians to examine composites faster.

Further into the future, the Squadron is looking at ways of using data to more efficiently and effectively carry out its mission. Jones says, "We're looking closely at things like data exploitation, how we can combine, for example, vibration and structural health monitoring with usage data."

This may involve the linking of NDT data with wear debris analysis results, to see how the wear debris complies to inspection schedules and how the combined data interacts with recorded vibration signatures in aircraft components.

The other place where new technology may be present is in the aircraft themselves. New aircraft present new challenges, but the introduction of aircraft such as the F-35 does not worry Jones. "Most of the aircraft is engineering and technology we've handled before," he says. "It's metal, wetted oil systems and other materials we are familiar with."

Dugard believes modern aircraft withstand the rigors of military use and marine environments better than older designs. "But the requirement for NDT is always there," he says. "Some of the older aircraft weren't designed as rigorously as aircraft are today, and the materials knowledge we had and was used in the older aircraft meant they were more susceptible to stress and cracking. Those aircraft would have had greater failure rates than modern aircraft.

"NDT is seen in some areas as not adding value, because you are looking for cracks in components. But it should be seen as providing assurance that there aren't cracks. It should be regarded as high-value inspection." \\

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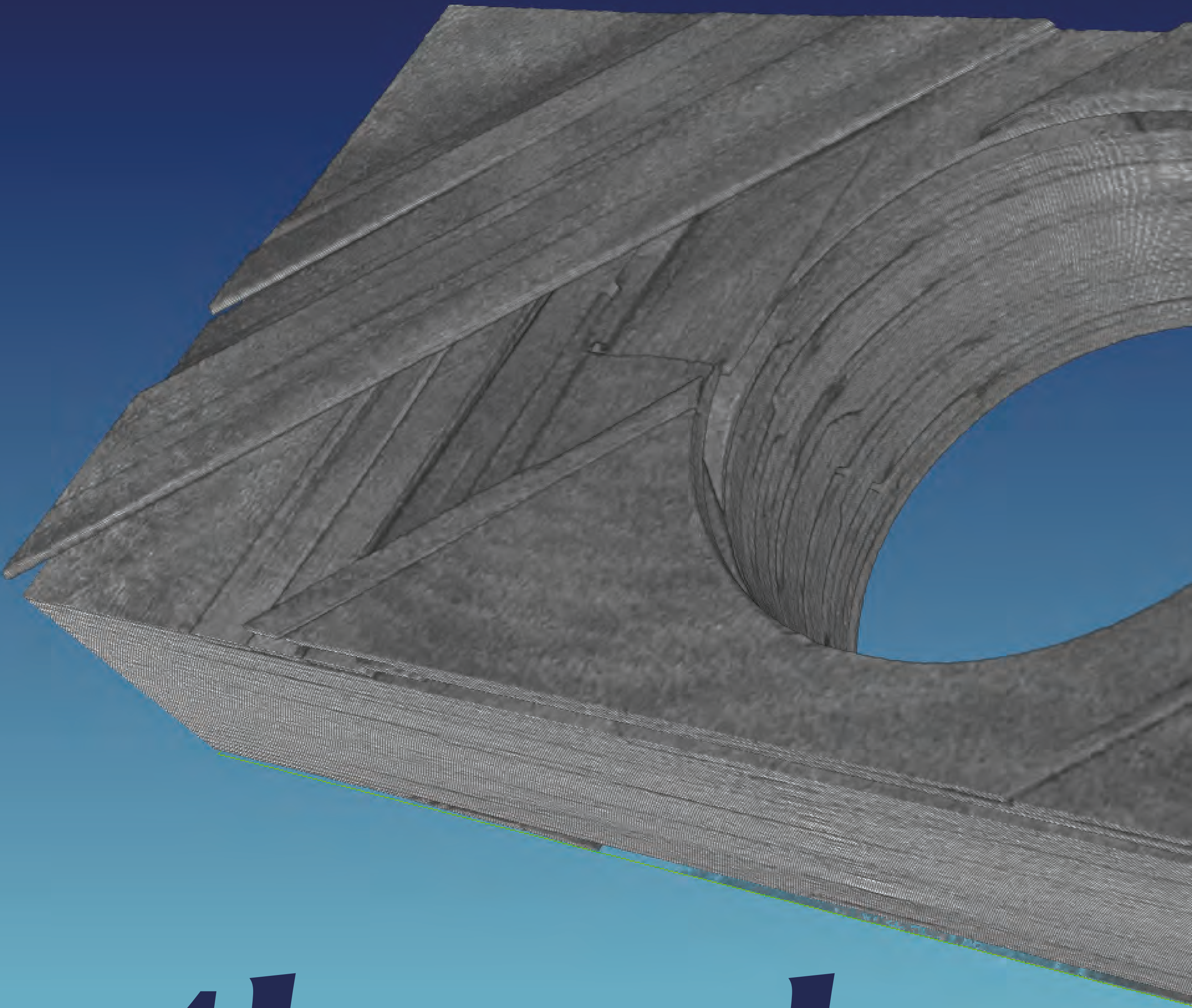

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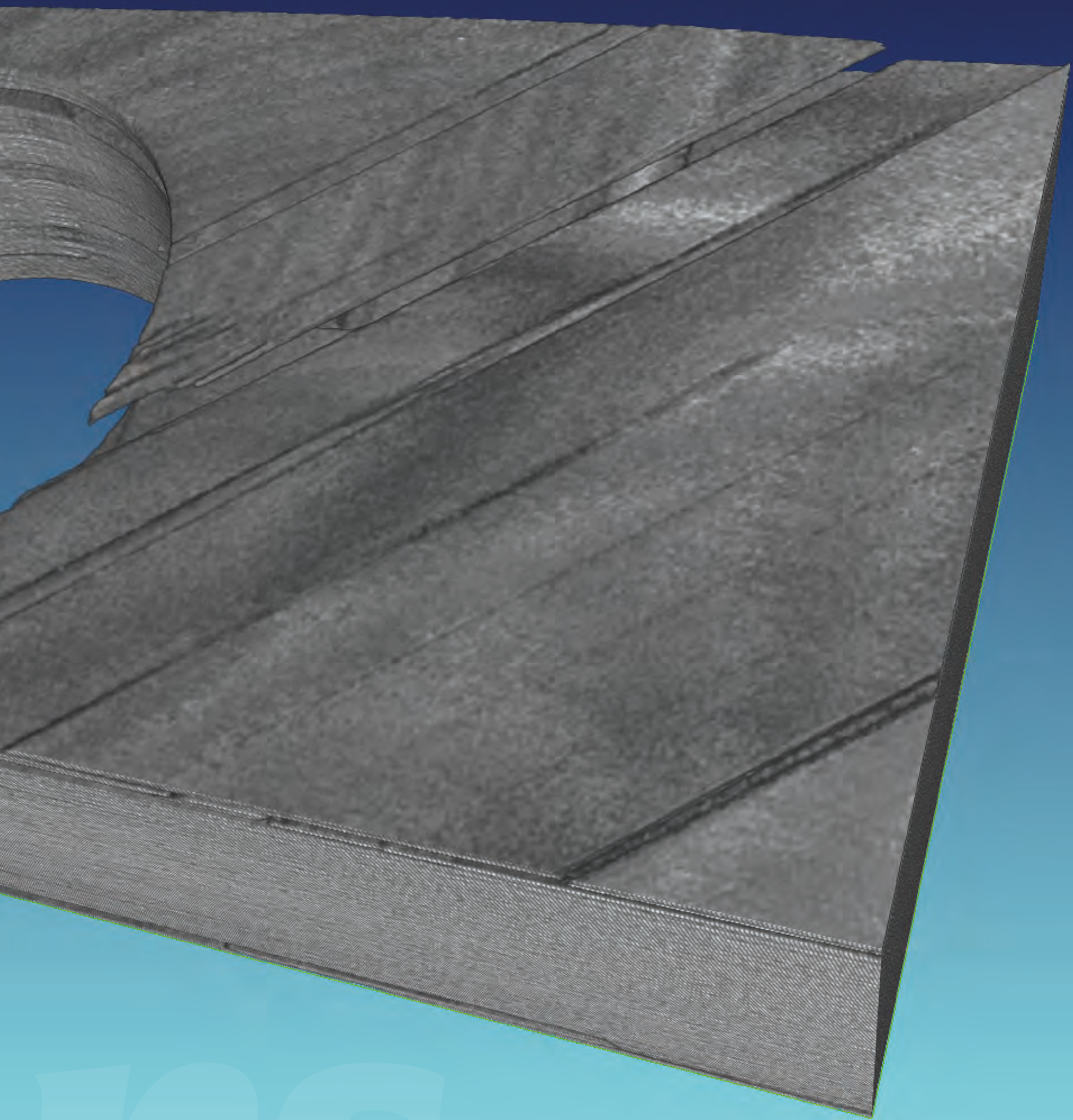


X-ray computed tomography is increasing the size and sophistication of the parts it can investigate, expanding its potential aerospace applications

// 3D scans at high resolutions can reveal details about damage and wear in composites *(Photo: National Institute for Aviation Research)*

The ability to look inside objects is understandably of great attraction for an engineer. But increasingly it is not just those looking for defects that benefit from developments being made in the technology.

"Having more information about an aircraft's inner structure enables you to make it lighter," says Johann Kastner, computed tomography (CT) group head at the University of Applied Sciences Upper Austria. "You can simulate the behavior of the materials of the component better. CT is being used in the aerospace industry for the development of new parts and materials and in production."

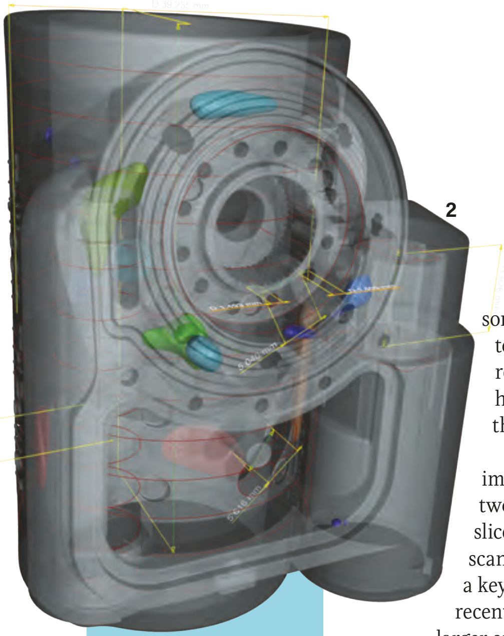
To see the inner structure of parts and materials, CT uses x-ray source, sometimes called the x-ray tube, and a detector to capture images. Electrons are fired at a target metal, typically tungsten, to generate the x-rays, which then pass through the sample to the detector. The target metal and the detector are in fixed positions while the sample is rotated.

This method, known as x-ray CT (XCT), can be used on any part of an aircraft, but its effectiveness varies according to the thickness of the structure and the materials it contains. Dense metals are resistant to XCT, but there are no better alternatives. Ultrasound, which requires a sample to be placed in a medium such as water for the sound waves to penetrate the surface, does not provide better image resolution.

Nor can ultrasound penetrate as deeply into a sample as XCT. Kastner says: "Sometimes you can see that something is not okay with ultrasonic testing, but you cannot interpret the results. So you use CT to see what is happening, what the problem is with the inner structure."

CT constructs a three-dimensional image of the internal structure from the two-dimensional images of sections and slices of the sample generated by the x-ray scans. The speed of computation has been a key factor in the development of CT in recent years, enabling more complex and larger samples to be analyzed effectively.

"When I started in 3D image reconstruction in 2005 you would hit 'go' and it could be several hours before you knew the result," explains inspection services firm North Star Imaging's product manager, Nick Brinkhoff. "Generally now it takes a matter of minutes or seconds, depending on your sample, to reconstruct the 3D image. It's pretty fast." He adds that a scan of an object can produce tens of gigabytes of data.



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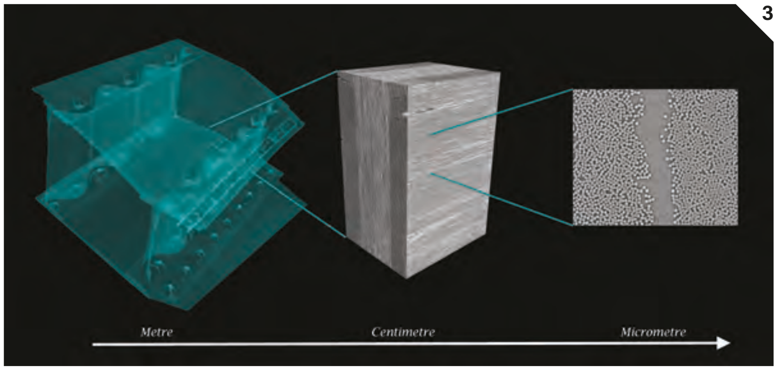
2 // A 3D image of a sample from an x-ray computed tomography machine *(Photo: North Star Imaging)*



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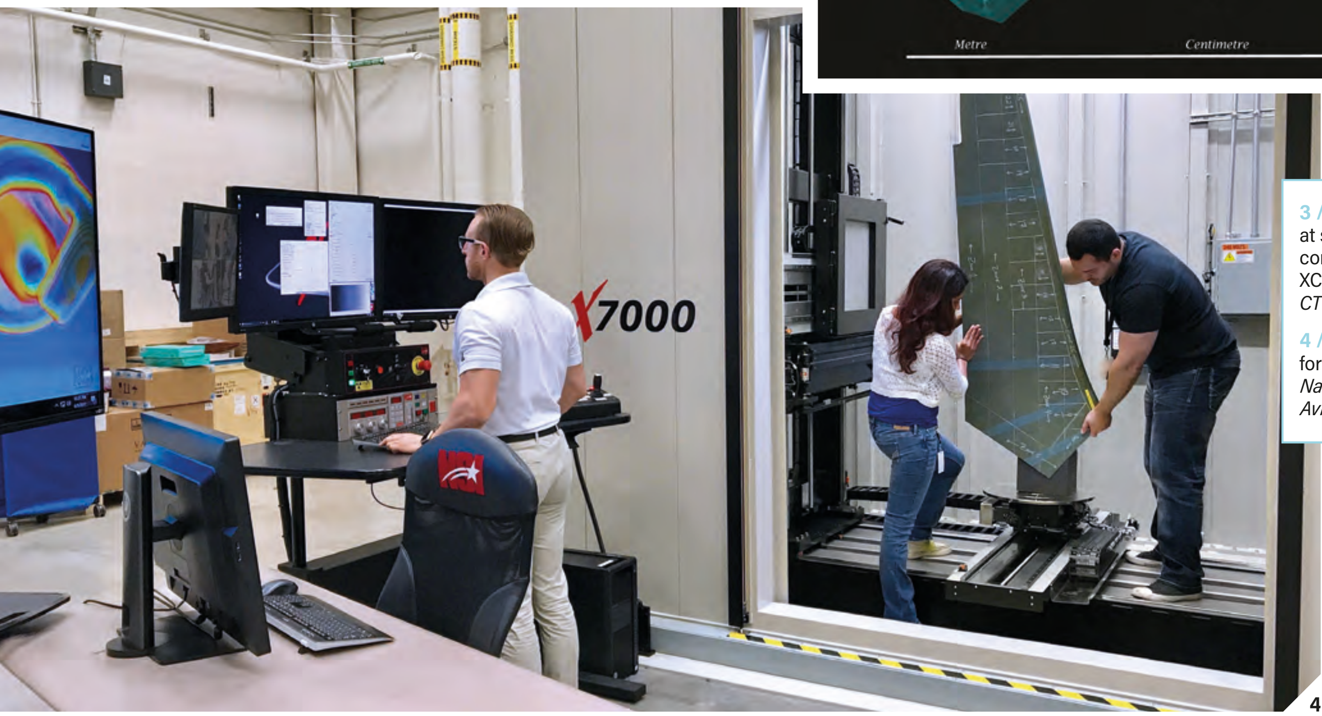

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3 // Engineers can look at structures inside components using XCT *(Photo: µ-VIS CT Imaging Centre)*

4 // A part is prepared for scanning *(Photo: National Institute for Aviation Research)*

5

5 // The X7000 XCT is used for scanning aircraft parts up to 5ft (1.5m) long at the National Institute for Aviation Research at Wichita State University *(Photo: NIAR)*

The development of graphical processing units (GPU) for computer gaming is behind the dramatic improvement in reconstruction performance.

"A lot of people are using GPUs for computing power now and that has really changed the landscape of computed tomography," says Brinkhoff.

Mark Mavrogordato, director of commercial operations at the University of Southampton's μ-VIS CT Imaging Centre, UK, which uses XCT for inspections in engineering research and development projects and accident investigation, says: "Advances in computing technology have enabled larger, higher-resolution data sets to be acquired, handled and processed with an ease and timeliness that has made CT a realistic option as a technique for more routine inspection."

FAST PHENOMENA

Another application for XCT that requires fast computation and generates huge amounts of data is high-speed imaging for transient phenomena. This is made possible with a more powerful x-ray, which enables more frequent imaging to take place so that images of very fast-occurring phenomena can be recorded. For example, a research project led by NASA investigating lithium-ion battery fires in aerospace applications recently used the European Synchrotron Radiation Facility in France, alongside laboratory-based XCT. A synchrotron is a particle accelerator that produces highly charged electrons, which, when they hit the target material, generate brighter, more powerful x-rays. A series of experiments captured 20,200 images a second during a lithium-ion battery fire's ignition and propagation, allowing engineers to develop safer battery designs for lithium-ion batteries.

Chemical engineer Donal Finegan works at the USA's National Renewable Energy Laboratory and was involved with the battery study. "NASA had a battery failure on an all-terrain Mars robot it was testing at the Jet Propulsion Laboratory. It caught fire and caused a scare," Finegan says.

It isn't just NASA that is concerned about lithium-ion batteries. High-profile incidents in 2013 involving the battery packs on board Boeing's 787 Dreamliner and fires in consumer smartphone batteries have raised awareness of the issue. Despite the risks, lithium-ion batteries are the most energy-dense form of battery available. They are being used in most hybrid and fully electric aircraft currently in development throughout the world.

ELECTRIC AIRLINERS

With the use of XCT and high-speed imaging, Finegan and his colleagues on the project have been able to develop a battery design that will not fail in a catastrophic way. "The aim now is to get a battery module that can easily be scaled… and then scale it up for whatever application we need," he says, whether that application involves planetary rovers or a commercial passenger airliner.

The batteries for electric airliners will be large and it is likely that in future robots will be used with XCT to scan especially large aerospace parts. "There are ongoing research activities where you have two robots. One has the x-ray tube and the other has the detector," says Kastner of the University of Applied Sciences Upper Austria. "With these two robots you can scan almost an entire airplane. However, the resolution is still not very good and you have a lot of restrictions concerning the technology. It will only work in some applications."

ROBOTIC SAMPLING

Robotics are already being used to automate the setting-up of samples for scanning in CT machines. A rack of parts to be examined can be left inside a machine's x-ray enclosure and the robot places the component to be tested onto the rotating platform. "Our Robotix part loader and manipulator can move the part and enables real-time inspection of components," says Brinkhoff. "It allows for autonomous operation of the system."

Once placed on its rotating table, by hand or by robot, the sample can also be put under stress. Images are then captured in real time to see exactly how the stressed sample's internal structure is

ACCIDENT INVESTIGATION

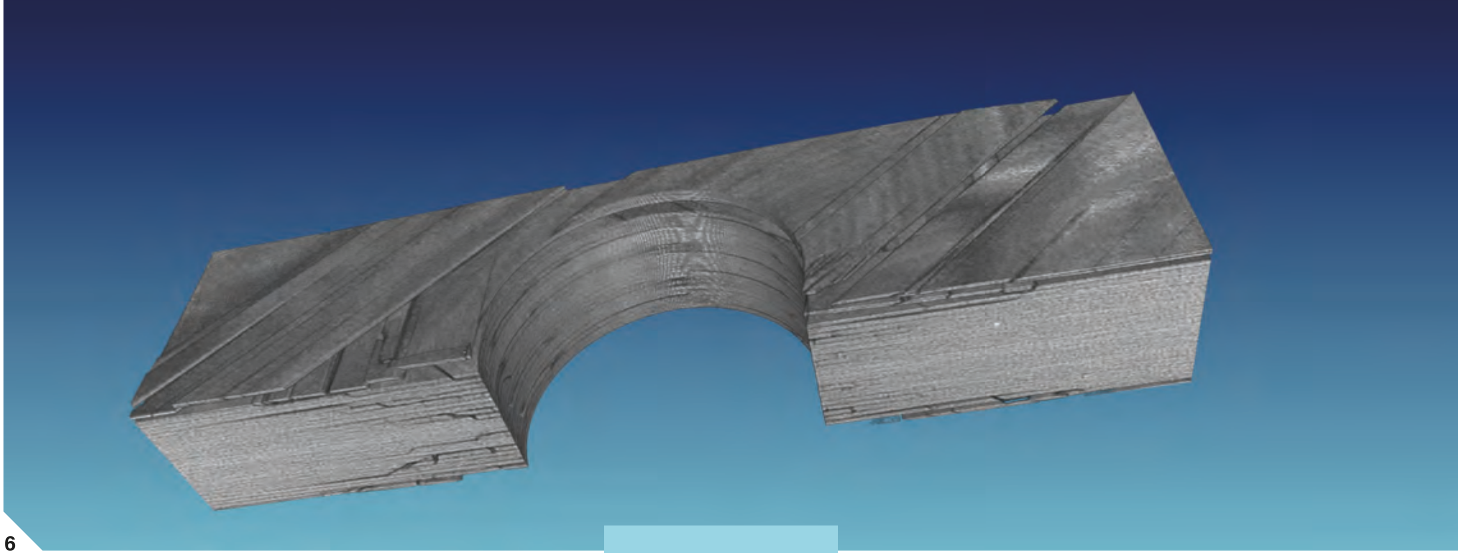
Mechanical failure is often at the root of an aircraft crash. However, the cause of a crash can be difficult to determine when landing gear, wing parts or the fuselage is deformed and possibly burned.

The University of Southampton's μ-VIS CT Imaging Centre recently carried out CT analysis for Norway's Air Accident Investigation Board (AIBN) as part of an investigation into the crash of an Airbus Helicopters EC225 Super Puma helicopter. The main rotor head of the helicopter had suddenly detached from the rotorcraft in mid-flight as it traveled from Bergen Airport, Flesland on April 29, 2016. All 13 people on board were killed.

The center's equipment enabled a detailed non-destructive examination of key components. The investigation revealed that the accident was the result of a fatigue fracture in one of the eight second-stage planetary gears in the epicyclic module of the main rotor gearbox.

Director of commercial operations at the μ-VIS CT Imaging Centre Mark Mavrogordato explains that from the outset of an investigation, the customer's expectations have to be managed in line with the limitations of XCT technology. For example, customers are told that it is difficult to see inside a dense metal object, that the debris from a crash may be larger than an XCT system can handle.

Although XCT can reveal clues to the reasons a crash happened, it should not be expected to reveal all the answers.



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6 // The detection of cracks using x-ray computed tomography is enabled by slicing through the 3D image *(Photo: NIAR)*

affected. The University of Southampton's μ-VIS CT Imaging Centre conducts this *in situ* testing for customers. The testing can involve a part being repeatedly loaded, with greater stresses, and scanned at each stage.

The Fraunhofer Institute for Structural Durability and System Reliability, Darmstadt, Germany also provides such a service. Previously the approach was to scan a sample, take it away for load testing, and then bring it back for another scan, to see the difference. The Fraunhofer Institute can induce up to 250kN while conducting XCT. It cites carbon-fiber aerospace structures as a particularly relevant use case.

DIGITAL TWINS AND 3D PRINTING

With the increased digitization of industry, the large amounts of data generated by XCT can be used to produce a digital twin. This is a virtual model of the product or part under test. The results from *in situ* testing and post-test examination can help improve the accuracy of the digital twin, which can be used for virtual testing, reducing certification testing and cutting costs.

Another industry development that needs XCT is additive manufacturing (3D printing). This can use materials and fabrication processes that are not fully understood. "We're heavily involved with the 3D printing industry already. We're working with major aerospace companies. They see the value of XCT," says Brinkhoff of North Star Imaging.

XCT is able to provide an insight into the internal structures of the more complex geometries that are possible with 3D printing. "XCT is the only way engineers can perform a comprehensive inspection of those things," Brinkhoff adds.

While some dense, thick, metal parts will never be able to be fully imaged by XCT and will have to undergo destructive testing and examination, advances in computational power have already improved 3D image reconstruction. Further progress with the detector and x-ray source will provide new capabilities and uses.

Mavrogordato, from the University of Southampton, says, "We can expect to see the employment of more elaborate acquisition and analysis methods, reduced scan times, increased applicability to larger, denser or more awkward components, more widespread integration into production lines, and increased system portability and convenience with x-ray computed tomography."

Today a standard CT machine costs around US$500,000 and can scan parts up to around 3ft (1m) wide. A machine capable of scanning a part that is 10ft (3m) across will cost between US$1m and US$1.5m.

For large aerospace companies such as Airbus, Boeing and Rolls-Royce, the analysis benefits of these machines outweigh the costs now. With the continued development of the technology and engineers' efforts to push the envelope of what it can be used for, an increased range of applications and a broader user-base for XCT looks more than likely. \\

MAJOR US AVIATION INSTITUTE BENEFITS FROM XCT

The National Institute for Aviation Research (NIAR) at Wichita State University, Kansas successfully expanded its NDT capabilities with the delivery of a North Star Imaging X7000 CT system in July 2017.

The industrial-scale digital x-ray and 3D computed tomography system is capable of both internal and external inspection of components as well as metrology. The X7000 CT is the first machine at NIAR to offer such capabilities and has proved a valuable resource since its installation last year.

The X7000 CT is a multisource (225/450kV) and multidetector system that can inspect objects up to 5ft (1.5m) in length without sectioning. It is suitable for use in the inspection of composite aircraft sections for applications such as void detection, as well as the inspection of additively manufactured metal structures to look for features like porosity, un-melted powder and also perform dimensional inspection.

"Our NSI X7000 system has the capability to inspect large components without sectioning them," says Waruna Seneviratne, technical director and senior research scientist at the NIAR. "This helps troubleshooting manufacturing issues during the early stage of a product development cycle, as well as during production, to quickly resolve issues.

"We are inspecting composite parts that have ply waviness, wrinkles and porosity to produce CAD models using software packages like Materialise Mimics. We then develop finite element models using the CAD models to determine the effects of such defects on the performance of these parts.

"Similarly, we use the machine to inspect the internal surfaces of additive manufactured parts to non-destructively integrate the surface quality. We also use the system to characterize the damage growth of advanced materials with complex failure modes, under quasi-static and cyclic loading."

Engineers at the NIAR have also built a load frame that can be placed inside of the x-ray CT system so that the internal damage to materials under load can be visualized.

"The system is vital for what we do in failure analysis. We are currently using it post-test, for failure characterization as well as to support accident investigations, thanks mainly to the capability to inspect large parts without sectioning," adds Seneviratne.

// PAUL E EDEN

A winter's work

Airbus Helicopters' chief test pilot, Olivier Gensse, gives his take on the H160 test and certification program and the demands of testing helicopters in tough environments

// Caught in the H160's main rotor downwash, Yellowknife's hard, granular snow behaves similarly to sand *(Photo: Airbus Helicopters)*

1 // Airbus Helicopters saved time and money with H160 trials in a Vienna climate chamber

Helicopter pilots really do go places others can't reach, posing an interesting set of challenges for those testing rotary-wing environmental performance. Currently working on the H160 program as it nears certification, Airbus Helicopters' chief test pilot, Olivier Gensse, believes that finding the correct weather is perhaps the most difficult task of all. He also says the manufacturer takes its environmental testing beyond the certification requirements that are considered a minimum specification by Airbus Helicopters.

Most of Gensse's flying is normally done out of Airbus Helicopters' Marignane facility in the south of France, which the pilot believes is ideal for helicopter testing.

Gensse says, "In Europe we can easily find temperatures between -10°C and 40°C [14°F to 104°F], and in winter, temperatures of -20°C to -25°C [-4°F to -13°F] are just an hour's flying time away in the Alps.

"We consider the normal range for H160 operations as down to around -20°C, with no real upper limit. Colder than that and you need to understand specific phenomena, with composites, elastomeric parts and hydraulic systems, for example. There's no specific limit for high temperatures, except for carefully monitoring parameters, including oil temperature."

Gensse also notes that Marignane is frequently windy, which helps develop crosswind capability and, he says, tongue firmly in cheek, "Perhaps it means Airbus Helicopters aircraft are the best in windy conditions?"

ON THE ROAD

Marignane is well placed for temperature and wind, but for extreme trials the test team packs its bags, equipment and aircraft and flies to foreign climes. Gensse acknowledges these campaigns as necessary yet complex,

-10 TO +40°C
Typical temperature range in Europe

-25 TO -20°C
Typical Alpine celsius temperatures in winter

2 // Avionics work best at moderate temperatures, but Gensse reports no problems with the H160's Helionix

3 // Yellowknife provided plenty of opportunity to test the H160's recovery mode *(Photo: Airbus Helicopters)*

ANTI-ICING

The H160 is not equipped for anti-icing and although Olivier Gensse says a system could be installed quickly and certified relatively easily, the helicopter's initial certification will be suitable "for around 95% of the flying our customers do".

Having trialled anti-icing systems on other types of helicopter, he says that neither the Vienna chamber nor Yellowknife provide the conditions needed.

"Icing doesn't occur at -40°C/F. It's a particular problem between 0°C and -10°C [32-14°F]. So anti-icing is subject to another campaign, it can't be done in the same region as the cold-weather trial. There is no icing in Yellowknife – it's too arid and cold – and the snow is very frozen, more like sand. The worst thing for helicopters is wet snow.

"We've done some development flying in icing conditions, though, especially looking at the performance of the H160's new Blue Edge rotor blades."

costly undertakings and ruefully considers the particular challenges of testing helicopters.

"When I speak with my friends in Airbus fixed-wing, they tell me that for their cold-weather campaigns they fly to an airport, stay a few nights and then go home. For us it's completely different. For a start, we can't fly direct from Marignane to Yellowknife [capital of Canada's Northwest Territories] for our cold-weather trials. Usually we take the aircraft in an Antonov, plus a team of between 10 and 15 people," says Gensse.

"I keep the team quite small because we're working in extreme conditions and it helps reduce risk. We chose Yellowknife for its climate and because it's a city, with medical and support facilities.

"We could go somewhere more extreme, but without a population center nearby, our risk increases. Typically we need around two months to achieve all our test points and we'll deploy in January and February.

"Hot-weather trials, low- and high-level, are usually completed in two or three weeks because the summer weather tends to be more predictable and stable. But it's still a major undertaking, involving aircraft, specialist equipment and people. Sometimes we visit places so small we struggle to find accommodation for our team!"

A team usually includes four engineers for airframe, engine and avionics maintenance; two flight test installation specialists; two analysts who perform the preliminary analysis after each flight, ensuring test points have been met and that it's safe to continue; and the flight crew comprising pilots and flight test engineers. Sorties are generally flown by a single pilot and two flight test engineers.

2
Clicks on the cyclic push button to activate recovery mode

-10 TO 0°C
Temperature range for the most extreme icing conditions

VIENNA INTERLUDE

The Yellowknife trials were actually conducted more as a proving exercise than a step into the unknown, thanks to time spent closer to home at a test facility in Vienna, Austria.

"It's like a hangar built for trains, with its temperature controlled from -50°C to 50°C [-58°F to 122°F]," says Gensse. "We put the helicopter inside and tested it at all the temperatures we needed for the real cold-weather trials, so when we got to Canada we were very confident and there were no surprises.

"It's a very precise facility. If you want to perform a check at -38°C [-36.4°F], for example, you adjust the temperature as you would on your thermostat at home, wait a few hours and it's exactly right.

"At Yellowknife we might wait a week and still not achieve precisely

"I keep the team quite small because it helps to reduce risk"

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the conditions we need, which means we have to have a conversation and decide how best to proceed.

"Even using the Vienna chamber, in my experience one winter is not enough to satisfy our certification requirements fully – we need two or three.

"The campaigns are long and we might wait several weeks for the correct conditions, using a dedicated aircraft that's then not available for other tests."

CABIN COMFORT

The H160 is a multirole aircraft and introduces new levels of passenger comfort to the medium-twin class. While much of the cold-weather flying is performed with only the test crew aboard, there are times where Airbus wants to work the cabin systems hard, meaning that a full cabin is required.

Gensse says, "Once we asked seven mechanics to run around and get hot. We started the aircraft, then loaded them in the cabin – we wanted to test the windshield demisting system.

-50 TO +50°C
Temperature range of Vienna chamber

50
Temperature trials planned for 2018

"We were confident it would work well because we developed a really good heating and ventilation system for the larger H175 and applied exactly the same equipment to the H160. A few times we took off for other trials from Yellowknife at -40°C/F and after a few minutes decided to reduce the cabin temperature because we were too hot!"

Surprisingly, reusing the H175 system didn't reduce the test workload for the H160. As well as assessing its efficiency in operation, Gensse says component parts were tested again, while some ducts and other parts were new for the H160 and also extensively trialled.

"I think that in the past we didn't spend enough time testing the cabin. Airbus has always spent lots of time on its airplane cabins, but 10 years ago we weren't doing that with the helicopters. Now we pay lots of attention to the cabin, even though much of the time only the cockpit of the helicopter is occupied. We've checked cabin vibration, individual seat

4

5

4 // The majority of environmental test sorties involve a pilot and two flight test engineers *(Photo: Airbus Helicopters)*

5 // Setting up a helicopter, an environmental trials team and its infrastructure so far away from France is a major undertaking *(Photo: J Deulin /Airbus Helicopters)*

"Snow ingestion can be an issue, because too much can cause a flameout"

6

7

6 // The cold soak trial involves parking cooling the helicopter to ambient temperature before starting its engines and systems *(Photo: Airbus Helicopters)*

7 // Yellowknife is very cold, posing challenges for human and helicopter alike *(Photo: Airbus Helicopters)*

comfort and more, with seven passengers on board."

HOT TEST

Summer 2017 provided the opportunity to test the H160 at 40°C (104°F) in Marignane, and a US trip is scheduled for this June and July, for desert operations at 50°C (122°F) and low altitude, and for hot-and-high work. "We have to assess hot-and-high performance because we can only extrapolate a little from the low-level, high-temperature trial. We used the 40°C work to de-risk the process and inform necessary changes, giving us time to complete them before the US campaign," says Gensse.

"We examine the effects of dust and sand, most importantly on the engines. Snow ingestion can be an issue, because too much water entering the engine can cause a flameout, but these tests are separate from the temperature trials.

"We also look at our Airbus Helicopters' safety modes, including the recovery mode that was introduced for the H175 and included in the H160. It provides safe flight in brownout conditions, or if the crew has lost outside reference. The pilot double-clicks a cyclic push button, takes his or her hands and feet off the controls, and the aircraft enters a precise hover. I pushed hard to have it included on the H160 and used it a lot at Yellowknife in its sand-like snow, when reference is easily lost. I'd already tested it in France and was confident it would work well, but it was great to use it in real conditions."

10 TO 15
People in a test team

2
months required to complete a cold-weather campaign

According to Gensse, the most difficult aspect of the H160 environmental trials has been waiting for the correct conditions: "Using the cold-weather chamber in Vienna saved us a lot of money. We could even start the engines inside and we gathered lots of data that we only had to go and prove in Canada. In Yellowknife we additionally checked on aerodynamics, vibration and so on, parameters we couldn't assess in the chamber.

"We were lucky because there were few issues, although it wasn't terribly exciting for the crew with everything working well. We were effectively ticking the boxes for certification." \\

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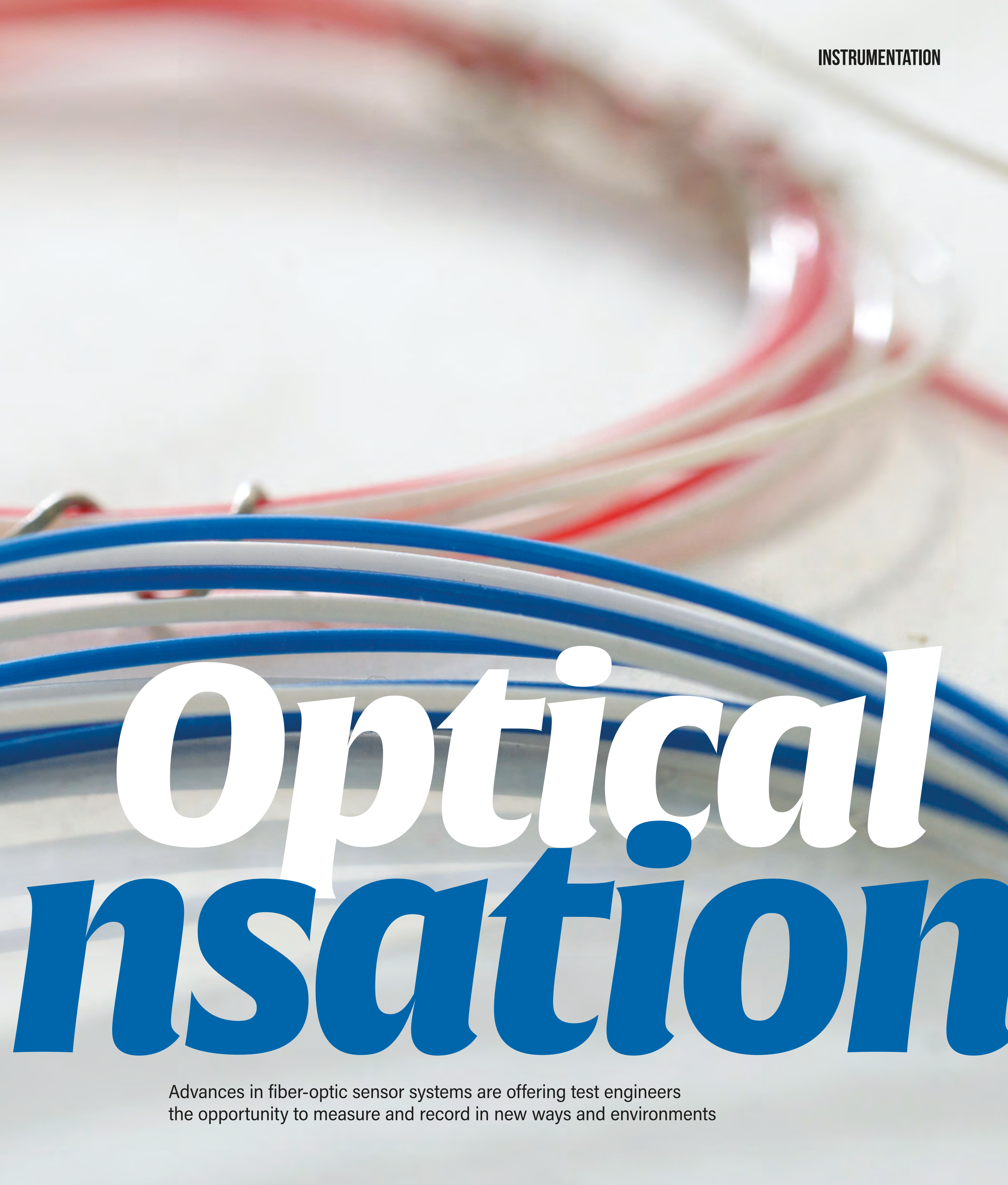
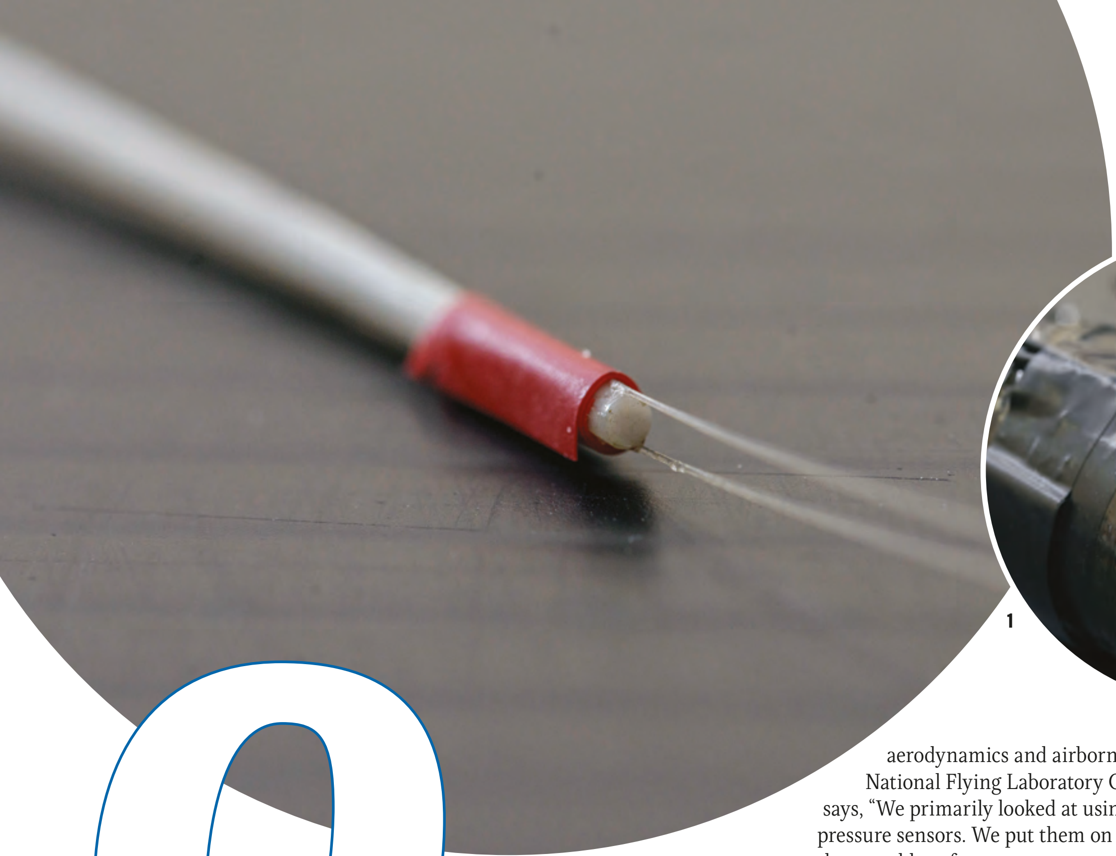


Optical nsation

Advances in fiber-optic sensor systems are offering test engineers the opportunity to measure and record in new ways and environments



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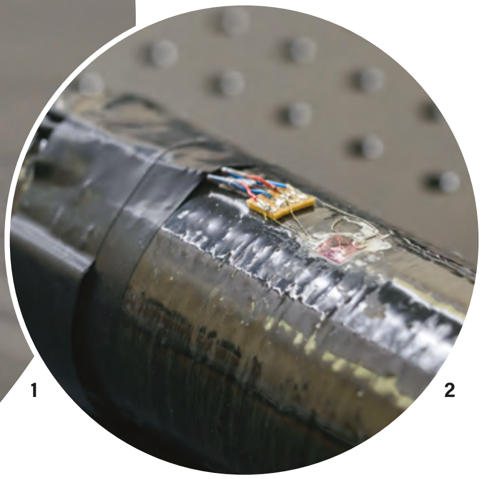

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1 // Researchers used 150µm diameter fibers to measure pressure and strain on aircraft

2 // Fiber-optic sensors have a small footprint and no electromagnetic limitations *(Photos: Cranfield University)*

Optical fibers, which can be thinner than a human hair, have clear benefits for the aerospace industry, helping to reduce weight and providing more bandwidth for communication systems and avionics. But aerospace engineers are only just realizing the benefits of using fiber-optic sensing systems (FOSS) to measure a raft of variables that include strain, pressure and temperature.

"Fiber Bragg grating sensing systems are used in load, pressure and temperature monitoring in aerospace," explains José María Álvarez, partner manager at Smart Fibres, which produces Fiber Bragg grating (FBG) sensing systems for a number of industries.

The FBG sensor is a type of reflector constructed in a segment of optical fiber that reflects particular wavelengths of light and transmits all others. "You can think of it as a series of mirrors inscribed in the core of an optical fiber by modulation of its refractive index so that all wavelengths pass through it, except for one, which is reflected," says Álvarez. "So pretty much anything that changes the refractive index or the grating period can be monitored."

125µM
Diameter of a fiber-optic sensor, around the same thickness as a human hair

STRAIN AND PRESSURE

A FOSS involves three components: the FBG grating, which is a series of thousands of minute stripes over 5-10mm (0.2-0.4in) of the optical fiber core; an interrogation unit, which sends pulses of UV light down the fiber and measures the wavelengths of the light reflected back; and the interconnecting optical fibers that are used to link the system together.

So far much of the adoption of FOSS has been in military and research aircraft. One such project was the AIM research project conducted at Cranfield University in the UK from 2006-2014. Nicholas Lawson, professor in aerodynamics and airborne measurement for the National Flying Laboratory Centre at Cranfield, says, "We primarily looked at using fibers as strain and pressure sensors. We put them on an aircraft to see how they would perform.

"The main issues we found were strong temperature sensitivity, but there are a lot of ways to correct it," he says. "You could, for instance, have one fiber sensor to measure the pressure and one to measure the temperature, to eliminate the sensitivity."

SMART WINGS

What benefits can the use of FOSS bring to the aerospace industry? One of the most exciting areas is in measuring structural shape.

"In aerodynamics at the moment the gains are plateauing," says Lawson. "The only way to get any significant gains now is with more sensors. There are a lot more composites on aircraft and fibers can be put into the manufacturing process quite easily."

By preloading composites with fiber sensors, the shape of wing structures can be monitored and adjusted to maximize efficiency – so-called smart wings.

"The structure of new aircraft wings is very flexible, so with a combination of fiber sensors and actuators that adjust the shape of the wings, you can get the best aerodynamic position of the wing at any given time and condition," explains Lawson. "All the pieces of the jigsaw are there to achieve this now."

This idea of smart wings is something being explored by NASA's Armstrong Flight Research Center in California on the unmanned X-56 aircraft.

Developed by Lockheed Martin, the X-56 is used by engineers at Armstrong who are developing flexible wings to improve safety, efficiency and ride quality. FOSS is enabling researchers to see the dynamic changes in the condition of the wings. "You can have hundreds, even thousands of sensors along a length of fiber," explains Allen Parker, NASA Armstrong's FOSS research lead. "We can use the strain measurements to extract the

1/100,000TH
of an atmosphere: the level of pressure to which a fiber-optic sensor can measure


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3 // Fiber-optic sensors ensure the more complete analysis of new materials at Delft University in the Netherlands *(Photo: Delft)*

shape of the wing by using it as feedback to resurface and change the active parts of the wing, enabling you to keep the wing at maximum efficiency."

He says FOSS technology could have huge benefits for the aerospace industry. "When we talk to people in aerospace, this seems to be the way it is going. There is a big drive toward efficiency and FOSS can play a major part in that," he claims.

Researchers have conducted three flights with the X-56 so far and have another 20 scheduled.

FIBER-OPTIC GAME-CHANGER

"Before we put FOSS on an airplane, we have to be confident it will work," says Parker. "The next generation of this technology will also help to decrease the complexity of aircraft systems. FOSS technology can be seen as a game-changer."

He says FOSS has many benefits over comparable measurement technologies such as metallic strain gauges, including being lightweight, flexible, non-intrusive, rugged and environmentally friendly.

FOSS is also immune to electromagnetic interference and potentially has many applications. These include real-time structural monitoring for inflight aircraft; monitoring temperature, strain and load; monitoring the thermal and structural health of satellites; UAV flight refueling; aeroelastic feedback control; and end-of-life decision making for aircraft.

Indeed, Armstrong is using the sensing properties of fiber optics to measure rockets' cryogenic fuel levels in the latest space launch vehicles. FBG sensors along a single fiber-optic cable provide measurements at 0.25in (6mm) intervals within a tank. The fiber-optic sensor system is able to actively discern between the liquid and gas states of the cryogenic fuel to pinpoint the liquid level more accurately.

40FT

The length (12m) of a fiber strand being developed by NASA researchers, who aim to push the sample rate to 20kHz

THE COMMERCIAL CHALLENGE

While the military is embracing the use of fiber-optic sensing systems in operational aircraft, commercial airlines are being far more reluctant to adopt the technology. With so many inherent advantages, what is stopping them from adopting the technology?

"Commercial aircraft are flown well within their flight design envelope, so the only threat is from damage, such as bird strikes," says Dr Roger Groves from Delft University's NDT laboratory.

Dr Roger Groves

"Military aircraft will often operate right up to the limit of their flight design envelope, and sometimes beyond, so they need different levels of health monitoring."

Others believe the uptake in defense applications is because the military has more freedom to experiment than commercial airlines.

"The military can do a lot more R&D, tests and projects than the commercial world, where everything just takes that little bit longer," says Smart Fibres' José María Álvarez.

José María Álvarez

But it is not only FOSS applications that have taken time to be embraced by the commercial airline industry. Fiber-optic technologies as a whole have taken a while to gain a foothold, as Russell Graves from TE Connectivity explains. "Commercial aviation has 50 years of experience dealing with copper wiring. Glass fiber is more sensitive to damage during installation and maintenance than copper, and you need to train people to maintain and clean it," he says.

Russell Graves

But this is changing. Airbus and Rolls-Royce are both looking at FOSS technologies, although the applications may start off small. "We are starting to see interest from commercial aircraft, not for measuring loads, but as overheating sensors," says Álvarez.

"Launch vehicles are complicated, but the benefit of FOSS is that you can have a whole sensor suite giving multiple parameters. You can reduce the number of sensors on the vehicle," says Parker.

STRUCTURAL HEALTH MONITORIING

Another area in which FOSS is being used is in measuring the structural integrity of aircraft. Dr Roger Groves leads the Structural Integrity and Composites group at the Aerospace NDT (non-destructive testing) Laboratory at Delft University of Technology in the Netherlands. He says that when planes used to be made out of aluminum, dents and cracks were visible on the surface, but with modern composites things are not so easy.

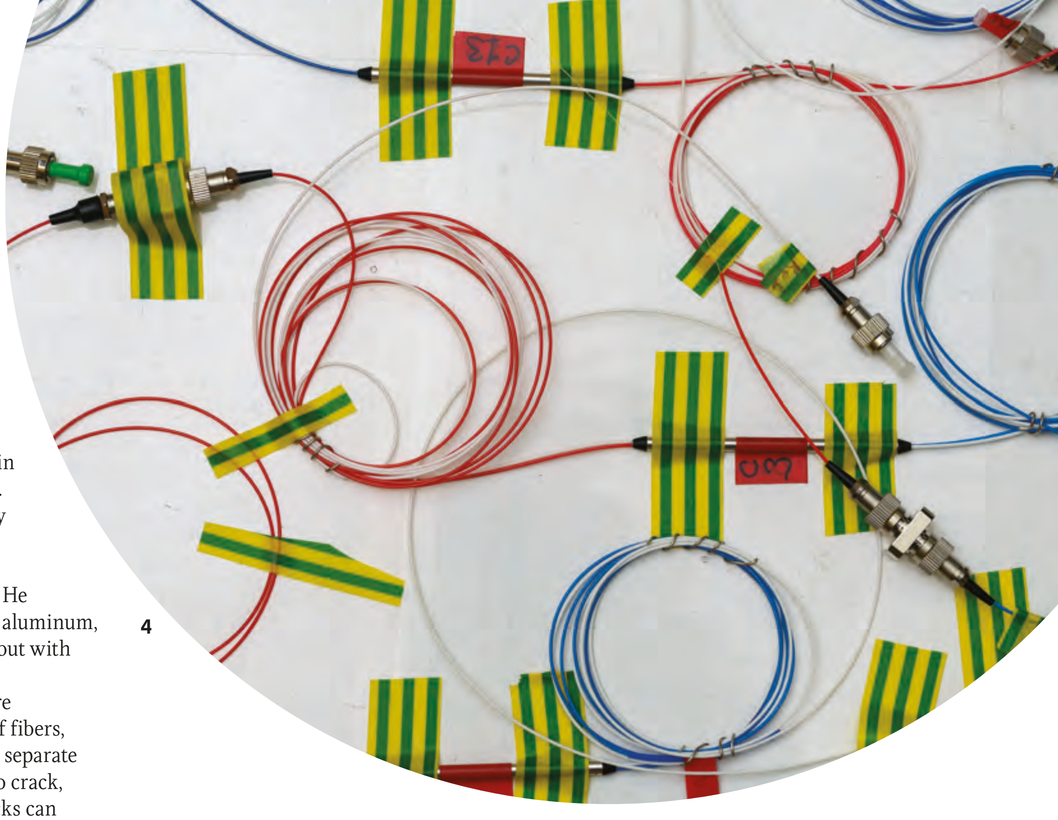
"Composites have more complicated failure mechanisms," he explains. "Different mixes of fibers, both fiberglass and carbon fiber, can crack or separate from each other. The matrix material can also crack, impact damage can be barely visible, and cracks can appear in the back layer and not be visible on the surface of the material."

As new composite materials are being developed for aerospace applications, testing using FOSS is set to become more crucial.

"Currently there are two types of sensors for structural health monitoring: ultrasonic piezoelectric sensors that monitor the sound of impacts or cracks, and FBG fiber sensors. The current ratio in structural health monitoring is that about 70% is piezoelectric and 25% fiber, with the rest made up of a few other solutions. But FBG is certainly catching up," he says.

"Piezoelectric sensors require two wires for each sensor, so if you have 50 sensors you will need 100 wires coming off them. With fiber optics you can have 50 or 100 sensors with one connection, so for this reason alone I see them taking more of the market sector," he says.

Indeed, in the past four years, according to data from market research firm ReportsWeb, the market for fiber-optic sensors in aerospace maintained an average annual growth rate of 15.56%, from US$11bn in 2013 to US$17bn in 2016, and it is expected that by 2021 the market will reach US$28bn.



4

4 // Fiber-optic sensors do not have to be fixed into place with lots of adhesive like other strain gauges *(Photo: Cranfield)*

NOVEL APPLICATIONS

Part of this growth is due to the number of application areas being explored. Roger Caesley, director of Epsilon Optics Aerospace, which provides FOSS to military customers, says, "One of our major activities is monitoring the condition of landing gear, mostly on military rotary wing aircraft. The key thing for them is to get away from having to remove the landing gear after so many landings.

"We've also done some work with Bell Helicopters and the US Army. We've not flown with the sensors on but have used them to monitor the rotors.

"Metallic strain gauges are very stiff, so they experience high shear load, but with fiber in a patch that runs down the length of the rotor you can separate the shear load so that it is very low."

A low shear load enables greater measurement accuracy and makes it easier to adhere an instrument to the helicopter's rotor.

The technology is also being used in wind tunnels. Groves says, "You can get far more sensors on a model using fiber optics, and therefore get much more data. Fiber-optic sensors are going to make structural health monitoring much more accessible for more aircraft," he concludes.

However, FOSS does have some drawbacks. "FBGs are more expensive than other types of strain gauges," admits Caesley. "They are also susceptible to high temperatures – anything over 1,000°C (1,830°F) and the glass characteristics can change. But if you want extended measuring, there is no comparison." \\\\

1,800°F
Temperature (980°C) to which a fiber-optic sensor can measure strain on NASA's X37 re-entry vehicle

FIBER AND THE BANDWIDTH BENEFIT

Optical fiber has been used in communication systems in aircraft for more than two decades, for a number of functions, but its use could be set to explode.

"In commercial aerospace, fiber is mainly used in avionics systems, computers and in-flight entertainment systems," says Russell Graves, global aerospace business development manager at TE Connectivity, which supplies cabling and connectivity to the aerospace sector.

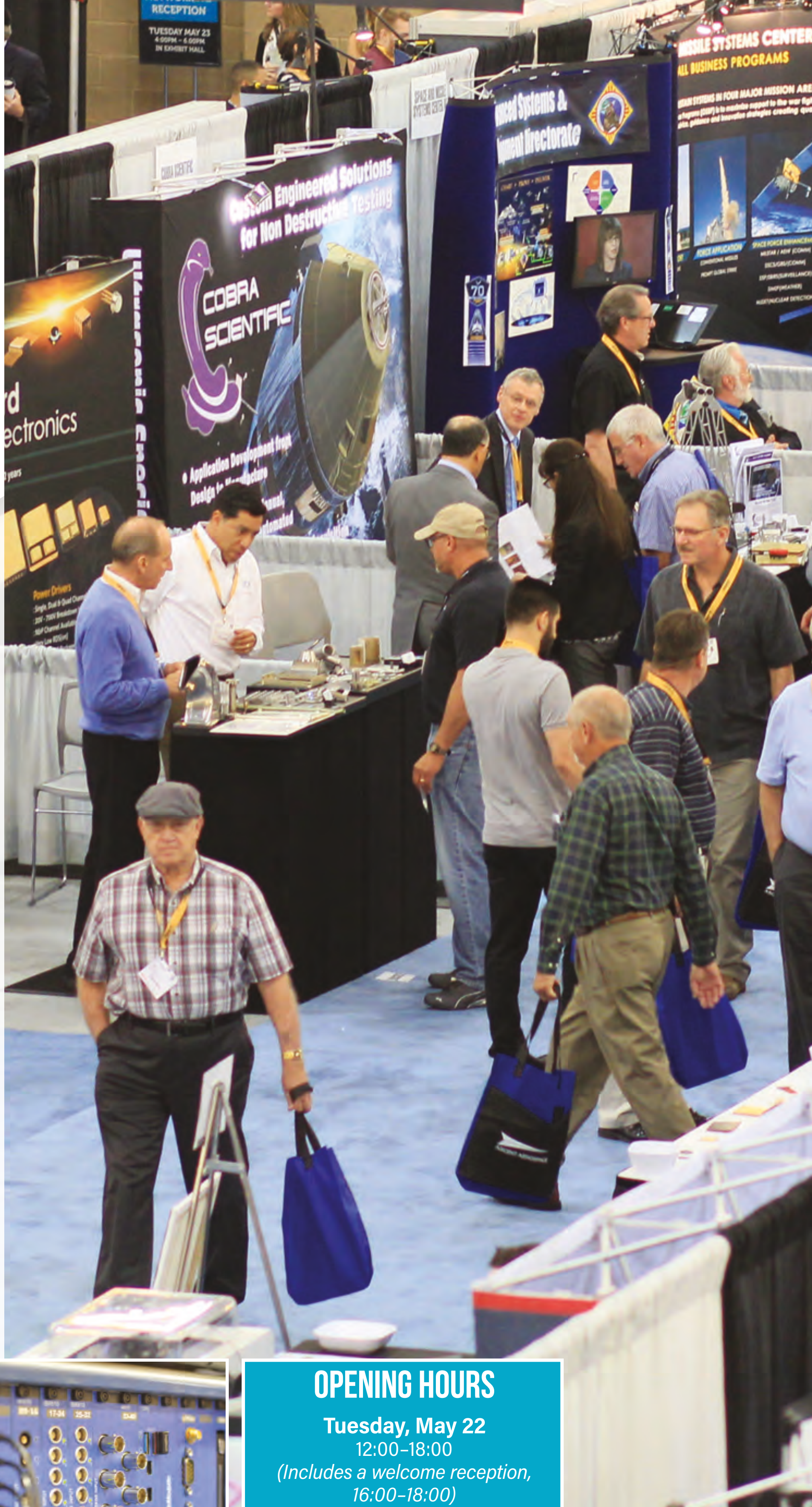
"We first started seeing fiber optics in avionics in the early 1990s. The first deployment was in a Boeing 777, and Boeing has been developing fiber optics ever since. Compared with copper systems you get a weight saving, almost unlimited bandwidth and it's not susceptible to electromagnetic interference," he says.

"The ultimate aim is to replace all copper wiring with fiber optics. Its inherent advantages over copper will come to the fore because more digital information systems are required in aircraft and that means we are fast running out of bandwidth using copper systems," he adds.

However, fiber optics is not the only technology that could replace copper.

"Wireless could replace some copper systems, but has disadvantages," says Graves. "Signals could be intercepted. We will see wireless used in some systems, but fiber optics will become more widespread in aircraft."

SPACE ON SHOW



In its seventh year, Space Tech Expo & Conference 2018 continues to grow at its Pasadena, California, venue

May 22-24, 2018

VENUE DETAILS

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

Space Tech Expo is a global event. Next year it returns to Europe (Bremen, Germany), November 19-21. Find out more about Space Tech Expo Europe at **www.spacetechexpo.eu**

OPENING HOURS

Tuesday, May 22
12:00–18:00
(Includes a welcome reception, 16:00–18:00)

Wednesday, May 23
09:00–17:00

Thursday, May 24
09:00am–15:00
(Includes an engineers' networking breakfast ,09:00–10:00)

Can you afford to miss Space Tech Expo? As the space technology industry grows at an unprecedented rate, so does the competition.

This is the seventh year that Space Tech Expo USA is running and it is going to be the biggest and boldest event yet! Providing a platform to 3,500 industry professionals including primes, systems integrators, technical engineers and buyers, Space Tech Expo is your gateway to this expanding market.

Last year saw the event grow exponentially and, building on an extremely successful 2017, this year's expo is set to grow further with a strong portfolio of specialist suppliers from right across the supply chain.

The exhibition attracts thousands of industry leaders, decision makers, engineers, specifiers and buyers who attend to meet manufacturers and the supply chain for civil, military and commercial space. The expo is the place to do business. With customer meetings arranged through B2B Matchmaking for exhibitors, a co-located JPL Business Opportunity Fair and new engineer-targeted networking events, everyone is welcome.

More than 150 exhibitors have already booked to participate in Space Tech Expo, including: Element Materials Technology, Boeing Technology Services, Hioki USA Corp., National Technical Systems, Weetech, DEWESoft, Q-Plus Labs, Tenney Environmental, Oneida Research Labs, Dayton T Brown, Durr NDT, Weiss Technik, Vibration Research, Thermotron, Russells Technical Products and Circuit Check.

SPACE TECH CONFERENCE

Space Tech Conference returns to Pasadena in 2018 with a three-day agenda packed with powerful insights. Commercial, military, government and academic organizations will be able to share knowledge and network alongside the largest supply chain exhibition of its kind, while discovering who is driving innovation and where business opportunities lie.

The conference's keynotes, panels and interactive discussion sessions include...

- Day one, Launch Systems Day, starts with a panel consisting of, among others, Dan Hart, CEO at **Virgin Orbit**, and Joshua Brost, senior director, governmental business development, at **SpaceX**. Attendees will have an insight into what type of launch vehicle is most feasible for commercial, civil, military and crewed missions.

- Mike Laidley, VP of the next-generation launch program at **Orbital ATK,** and Bradley Schneider, executive vice president, USA, at **Rocket Lab,** will participate in the second panel of the day, discussing a tech roadmap: Outlining the industry and government requirements for next-generation launchers.

- Satellite Systems Day on day two kicks off with a keynote discussion led by Lisa Kuo, director of commercial programs at **The Aerospace Corporation**, who will address the rapid development of the satellite industry.

- Later in the day the show focuses on space situational awareness. Led by speaker Mark Dickinson, vice president, satellite operations, **Inmarsat** and chairman and executive director, **Space Data Association**. The session will explore the role of individual operators and their need to implement operational best practices for collision avoidance.

- The final day is the conference's Future Programs Day, which features an opening keynote from James Reuter, deputy associate administrator, of the Space Technology Mission Directorate, **NASA**.

- There will also be a panel discussing the evolution of an exploration tech roadmap: Delving into advanced transportation vehicle technology requirements and innovations. With speakers from **Lockheed Martin**, **Moon Express, Euroconsult, JAXA, The Planetary Society** and **ESA**, this is one not to miss.

CONFERENCE PASSES START AT US$395. BOOK YOURS AT WWW.SPACETECHEXPO.COM

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VISIT DNB ENGINEERING AT BOOTH 6026

Environmental to EMC test excellence

DNB Engineering offers world-class environmental and product safety test capabilities for high intensity radiating fields (HIRF), lightning and EMC, and will be demonstrating its capabilities and services at Space Tech Expo in May.

The company is dedicated to solving customers' problems for the aerospace, commercial and military industries. Customers can find the solution for all qualification needs under one roof – designing, engineering, building and testing.

DNB's capabilities in HIRF testing include the supply of custom-built hardware and proprietary software systems for fully automated RS testing using the mode tuned (RTCA DO-160F, MIL-STD-461) or mode stirred (RTCA DO-160G) methods. DNB's three reverberation chambers provide peak field strength level up to 25kV/m and average field strength up to 2kV/m.

The indoor lightning test facility features a large ground plane for high voltage attachment testing that measures 32 x 36ft (9.8 x 11m). The direct-effect lightning lab features custom-built equipment designed and constructed by DNB. It is able to generate all of the waveforms necessary to meet typical test standards as well as the exclusive requirements of customers.

DNB has six locations in three states across the USA to support all testing needs.

VISIT TENNEY ENVIRONMENTAL AT BOOTH 3012

Spacious vacuum chambers

Tenney thermal vacuum chambers or space chambers are designed to simulate various different types of pressure and altitude conditions.

These thermal vacuum chambers are suitable for testing products used in space travel, satellites and other equipment for the space industry. Tenney space test chamber designs vary from 1.0ft^3 to 226ft^3 (0.03m^3 to 6.4m^3) or more, large enough to fit almost any piece of equipment. They offer a temperature range of -184°C to +150°C (-300°F to +302°F) and a tolerance of ±1.0°C after stabilization. For vacuum simulation a site level to 1×10^{-7} Torr is achievable and the chamber can attain 5.0×10^{-6} Torr within four hours if required.

Tenney space chambers are constructed with a stainless steel vacuum vessel and temperature conditioned internal platen and shroud to simulate outer space conditions. The chamber, machinery and instrumentation are manufactured as one unit and meet the OSHA, NEC and ASME codes for unfired pressure vessels. Safety interlocks and features are provided for the space chambers and operating personnel.

Tenney offers mechanical and liquid nitrogen fluid cooling systems as well as gaseous nitrogen recirculating with an LN2 flooded system to meet the extreme temperature ranges required in modern space vehicle and components testing.

VISIT HIOKI AT BOOTH 1019

Power measurement professionals

Electrical power measurement solutions from Hioki range from the trustworthy DMM to highly accurate engineering instruments.

Electrical measuring instruments are the mother tools of the industry and used in R&D, manufacturing, maintenance and service. They also continue to contribute to social progress, mirroring developments in technology as their designers anticipate the changing needs of the times.

Hioki designs, manufactures and distributes over 300 electrical measurement solutions. The range includes everything from basic voltage, current and insulation testers, to multichannel memory recorders and data loggers, to LCR/impedance analyzers, power meters, power analyzers, hi-pot, resistance and battery testers.

Whether your work is in design, manufacturing or Quality Assurance/Quality Control, or you are at a test bench, taking field measurements or using automated test systems, Hioki can support all measurement requirements.

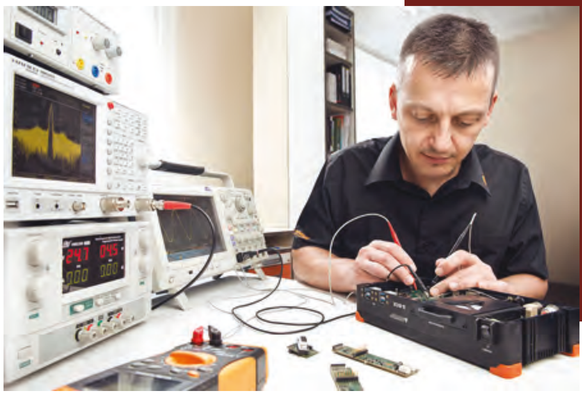
Data acquisition instrumentation

VISIT DEWESOFT AT BOOTH 7013

DEWESoft offers a full suite of hardware for in-vehicle and lab data acquisition applications. Scalable from four to thousands of channels, its instruments are available as small USB and EtherCat devices, standalone battery-powered systems, rack-mounted configurations and ruggedized field-ready solutions.

Powered by the latest DEWESoft X software, DEWESoft acquires and controls many multidomain test sets that include analog in/out, digital in/out, video, CAN, FlexRay, XCP, GPS and much more. DEWESoft is designed to handle a variety of applications including ride handling, brake testing, durability testing, road load, e-mobility, power quality, combustion analysis, pass-by-noise, NVH testing, order tracking, torsional vibration, balancing, real-time kinematics, ACC, ISO lane change and much more.

DEWESoft hardware and software are used around the world in a variety of fields ranging from auto manufacturer and construction equipment to aeronautical development and telemetry. And with the dynamic signal analysis capabilities users will be able do more, all on one computer.



FREE SESSIONS

Space Tech Expo is also proud of the educational aspect of its event.

Each year the free-to-attend Open Tech Forum includes more than 40 unmissable presentations exploring aerospace manufacturing and design, propulsion, thermal management, additive manufacturing, materials, electronics and testing innovations:

- Additive manufacturing, thermal management, and materials and design on Tuesday, May 22 – with speakers from DLR, Virgin Galactic and Curtiss Wright
- An Electronics and Testing day on Wednesday, May 23 – with speakers from Zuken USA Inc., Vorago Technologies and Vibration Research, among others
- Advanced propulsion systems and propellants will be addressed on Thursday, May 24 – with speakers from organizations including Alameda Sciences Corporation, BluHaptics, Inc. and Space Generation Advisory Council

Speaking about last year's free sessions, Matthew Sipek, mechanical engineer at Northrop Grumman, commented, "The free sessions have been interesting – they're definitely value added, I think you might even need to add a few more seats!" \\

VISIT ELEMENT AT BOOTH 5010

Materials testing

Element is a global platform of more than 200 laboratories with 6,200 engaged materials and product qualification experts. As one of the largest independent testers of materials in the world, it is able to test a diverse range of materials, including metals, polymers, elastomers, composites and ceramics, to make certain they are safe, high quality, compliant and fit for purpose in their end application.

Element provides critical compliance, reliability and qualification testing of parts, components, and systems for clients in the aerospace industry. Other services include infrastructure, environmental testing and EMC testing for a variety of industries. The company also offers highly specialized simulation testing programs for fuel systems, hydraulic and pneumatic components and systems, spin testing and thermal vacuum testing for simulation of space and upper atmosphere conditions, including temperature and altitude.

At its booth, Element will have multiple samples of small copper coupons that have been exposed to a mixed flowing gas corrosive test simulating acid rain, as well as multiple samples with a control that show parts that have been subjected to both a salt fog and sand/dust testing.

EXPLOSION-PROOF NDT

Aerospace companies are using explosion-proof non-destructive testing equipment to minimize operational risk

UV lights are used when performing inspections in non-destructive testing, more specifically in magnetic particle inspections and liquid penetrant inspections. Every day thousands of aircraft components, new and used, made from ferromagnetic materials, are tested at production sites and maintenance shops to detect surface or slight subsurface discontinuities. Faulty components are identified and removed and accidents are avoided by engineers and technicians performing non-destructive testing.

Inspections are often made near sites that are classified as hazardous locations. These can be areas such as close to a refueling station, on a military aircraft carrier, or on an offshore oil rig platform where helicopters are stationed. Typically such locations are classified as Zone I, Zone II or Zone III, depending on how high the risk of explosion is considered. Explosions at hazardous locations have on many occasions caused loss of life and destruction of physical assets.

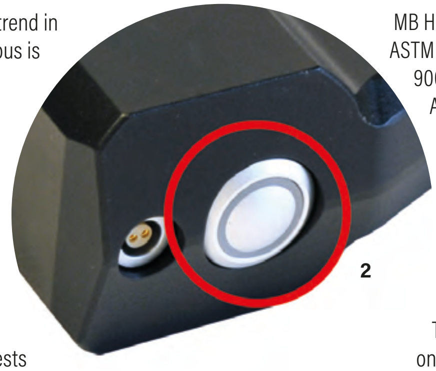
UV lights without an explosion-proof classification are used today in hazardous locations around the world, causing expensive shutdowns of operations. Performing a required inspection with an explosion-proof product, which fulfills the requirements of the area where the inspection take place, ensures that the UV light used will not be the cause of an explosion, even when used close to the assets which are operational.

The cost of replacing or repairing an oil rig, a refinery, a fueling station, or ceasing operations so that maintenance can be conducted, is potentially massive compared to the small investment that is made in an explosion-proof UV light.

Asset owners and operators with locations in their operations classified as hazardous, as well as insurance companies, are paying more and more attention to the prevention of accidents and safety. The current trend in all areas that are considered hazardous is the use of explosion-proof products. Many organizations worldwide, including armed forces, have adopted this requirement in their own specifications.

The MB Hercules Ex is an explosion-proof handheld UV inspection light, and an extremely durable and safe product. It has successfully completed several very tough tests, among them stringent tests for thermal conditioning, impact tests, drop tests and ingress protection tests. The tests have enabled the MB Hercules EX to be ATEX certificated for Group II, Zone II (Certificate: ITS17ATEX402144X). The product is also suitable for use in extreme weather conditions, operating in temperatures varying from 104°F (40°C) to -4°F (-20°C).

Furthermore, Hercules Ex has successfully completed all tests and audits, leading to its certification for IECEx (Certificate: IECEx ITS 17.0056X), NFPA 70 Article 500 for Class I (division II locations) and the US military tests, salt fog test and explosive atmosphere test. In addition, the Hercules Ex has an ingress protection rating of IP66.



1 // The full MB Hercules Ex package

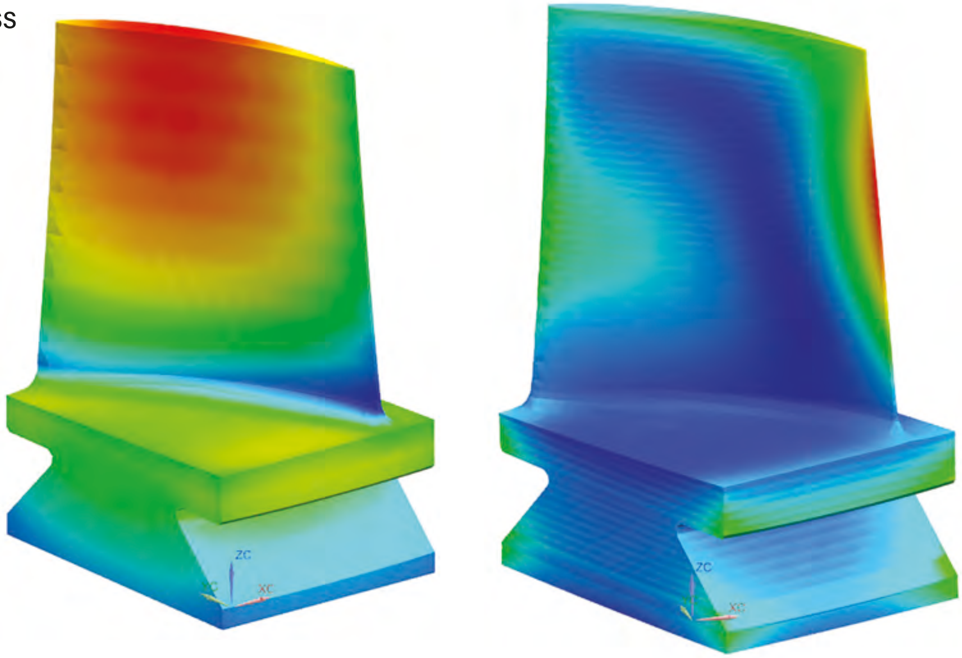
2 // Close-up of the MB Hercules Ex light

MB Hercules Ex is in compliance with ASTM E3022-15 standard, Rolls-Royce RRES 90061 engineering specification and Airbus AITM6-1001 (issue 11) testing methods. These are the primary standards followed by the manufacturers of LED UV lights in non-destructive testing and ensure the quality of the unit as well as the uniformity of the UV output and the stability of the wavelength (365nm). These are critical elements required on a UV light to perform inspections.

This unique inspection UV light is battery powered, has four UV LEDs and generates an intensity of 4,000µw/cm^2 with a beam size of 19cm (7.5in). It is a portable device, extremely light and compact, that weighs just 888g (2.0 lb). It can be carried without any inconvenience, even in the most remote locations. The overall running time of the battery is six hours and the device can be recharged either from wall power outlets or a car charger. \\

SIMULATING ADDITIVE PRODUCTION

Siemens' Simcenter 3D is accelerating the industrialization of additive manufacturing by using process simulation in an integrated end-to-end process



1

2

Additive manufacturing (AM) and specifically powder bed fusion technology is maturing fast. The aerospace and energy industries began to use AM several years ago, specifically to produce high-end components from specific alloys. It is used to make, for example, complex compression blades with internal cooling channels.

One of the challenges of producing such a blade using AM is to ensure the part's dimensional accuracy. AM is a severe thermomechanical process that induces material deformation because of residual stress accumulation.

Siemens PLM Software has developed a methodology for use with Simcenter 3D that ensures dimensional accuracy using distortion prediction and geometry compensation, helping to accelerate the industrialization of AM. The company has been looking at AM for more than 20 years. One of the major bottlenecks is its high cost, a critical component of which is low production yield. Defects generated due to the thermomechanical process, such as distortions, cracks and porosities are very common. Additionally, machine instabilities have also been reported as a factor. The stochastic aspect of the AM process also makes repeatability challenging.

The new methodology in Simcenter 3D creates for the first time a fully automated end-to-end process simulation. By the addition of the ability to predict the thermomechanical processing and the resulting defect before the build operation, Siemens PLM Software has achieved a major step in offering a full digital twin, enhancing the robustness and increasing the AM production yield.

Simcenter 3D AM is based on an original physics-based and multi-scale approach. The simulation tool provides a flexible methodology offering.

The first proposed methodology is the well-know inherent strain approach, where a standardized experiment is usd to calculate the inherent strain.

The second is a Siemens-patented method that is based on an inherent strain function.

Finally, Simcenter 3D AM proposes a fully computational method based on the meso-scale calculation where the physics at the meltpool level is analyzed.

The simulation of the blade is completed in a very short time in this example. The integration of manufacturing and simulation technology in the software means the initial and boundary condition are imported systematically from the manufacturing part.

1 // Predicted distortion and global temperature in the last increment

2 // Fully integrated end-to-end process between NX and Simcenter

The seamless integration of the Simcenter simulation technology in the Siemens NX technology is an important milestone in the journey to AM industrialization. This unique workflow makes Siemens PLM Software offering the most powerful in the market. This new product is used today by privileged customers in different industries including aerospace, automotive and energy.

Written by Omar Fergani, additive manufacturing product manager, Siemens

Aerospace TESTING INTERNATIONAL

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*ABC audited circulation, average net figure Jan-Dec 2017

2018 publishing schedule

MARCH 2018
NDT • Vibration • Environmental testing

JUNE 2018
Data acquisition • Fatigue testing
Engine testing

SEPTEMBER 2018
Avionics testing • EMC testing
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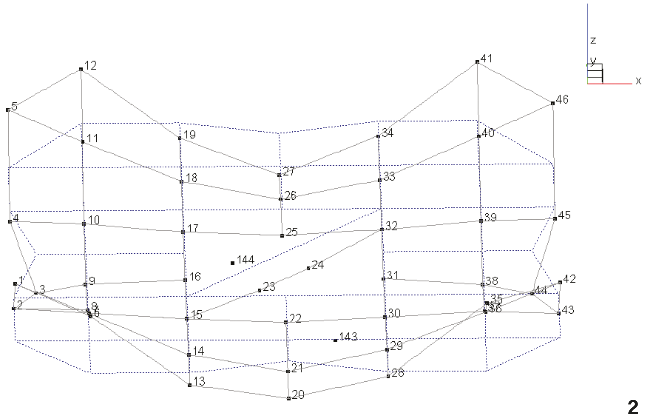
GAIN VALUABLE INSIGHTS

Determining operational deflection shapes in vibration testing can result in additional information from sine tests

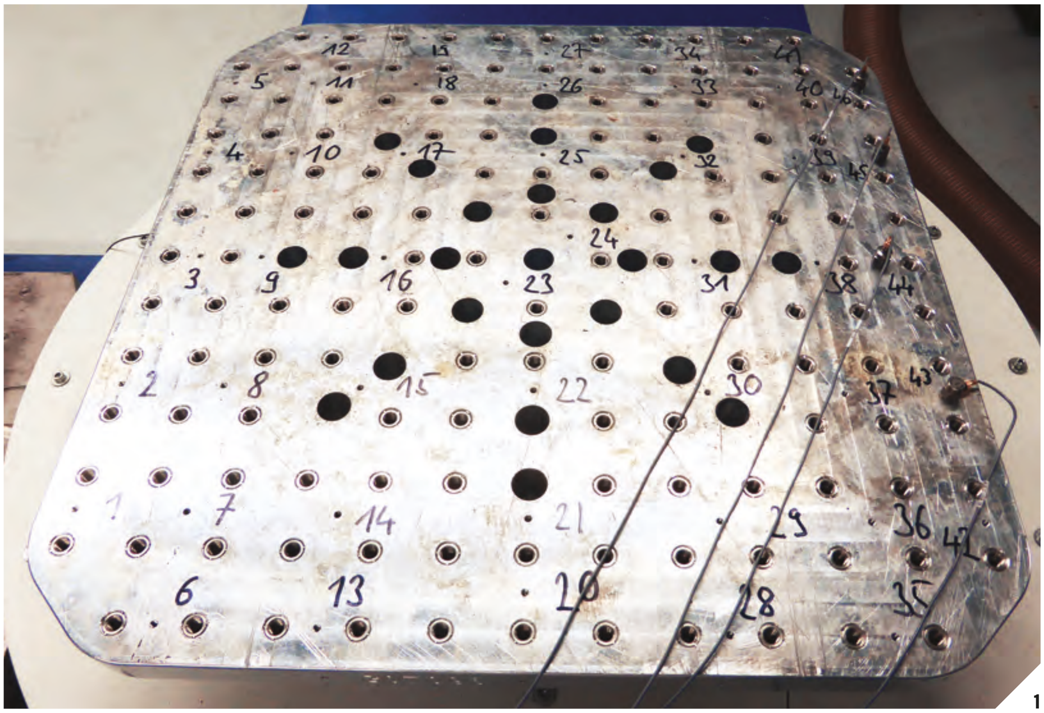


2

Vibration testing to international and laboratory standards is an important aspect of product qualification and approval, especially in the aerospace sector. Typical test procedures require random, sine or shock excitation performed by electrodynamic shakers. The test results will then simply confirm compliance to the given appropriate standard.

However, additional information such as operational deflection shapes of the system under test is often neglected, despite being easily established directly from the measurements at hand. This additional information enables engineers to further identify the source of vibration induced failures, optimize test fixtures or provide a comparison with real-world deflection shapes to finite element results.

To extract operational deflection shapes, a comprehensive and representative set of phase-referenced spectra is key. Measurement positions should be evenly distributed among the test specimen, in order to receive an accurate spatial resolution for the operational deflection shapes.



1

For most applications in the aerospace industry, this is already the case, as the vibration level of the specimen is monitored at many locations during a test. Thus, measurement at all relevant positions may be acquired during a single test run. However, this requires a high number of measurement channels and sensors, which may introduce a mass-loading effect in the case of a light-weight test specimen. In those cases, repeated test runs with a low sensor count are preferable, but require manual relocation of individual sensors between test runs.

Finally, the results are loaded into modal analysis software. Within the software, a geometry is created and each measurement is mapped to a single geometry node. The operational deflection shapes for individual frequencies are then reviewed and analyzed.

The following example illustrates the results of a test campaign at a customer site, where operational deflection shapes of a head expander were acquired.

The images show the head expander without any additional test specimen (Figure 1) and the extracted deflection shape at 1,954Hz (Figure 2).

This result, when considered with additional lower frequency operational deflection shapes, verified the preliminary finite element calculation. It also confirmed that the placement of the reference sensor in a gap between the head expander and the armature was the correct position. It was determined that a placement directly on the head expander could result in over- or under-testing.

The example shows that by utilizing the acquired data from a sweep test it is possible to create a model of a test specimen or fixture and to easily visualize the operational deflection shapes encountered during a vibration test. The results can give engineers additional valuable insights into the vibration's characteristics. They can also help engineesr to improve test methods, as well as identify the source of the vibration induced failure.

The whole process of data acquisition and operational deflection shape calculation is an integral part of m+p international's software solutions, m+p VibControl and m+p Analyzer. With the use of this software, all relevant data types are fully compatible and geometry generation and measurement mapping is easily done.\\

1 // Head expander without test specimen

2 // Diagram showing the deflection shape extracted from the head expander

SOLVING AEROSPACE ANALYSIS CHALLENGES

High-speed cameras are combining data processing and improved sensor capabilities

1

Vision Research, a manufacturer of digital high-speed cameras, recently introduced an ultra-high-speed 4MPx camera, the v2640. It uses a proprietary 4MPx CMOS sensor (2048x1952 pixels) and addresses many of the challenges found in aerospace high-speed imaging analyses, including research concerns with detailed imaging, light sensitivity, dark area visibility and experiment versatility.

Detailed imaging is a combination of data processing and sensor capabilities. The v2640 achieves up to 26,000MPx/s throughput while reaching 6,600fps at full 4MPx resolution, 11,750fps at 1920x1080, and higher frame rates at reduced resolutions. While such frame rates are typical with 1MPx cameras, the 4MPx sensors are advantageous because a larger number of pixels sample the object being imaged more finely, giving significantly more detail. High levels of detail are critical in aerospace applications, such as material measurement studies, including digital image correlation or the analyzing of minute particles.

Sensitivity is heavily impacted by pixel size, as smaller pixels capture less light than larger ones. The ultra-high speed 12 Series line of 1MPx cameras from Vision Research has very large pixels and very high corresponding light sensitivity, with an ISO rating of 32,000D for monochrome cameras. 3MPx and 4MPx sensors have smaller pixels and are not as light-sensitive. However, the v2640 was specifically designed for maximum sensitivity, with an ISO rating of 16,000D for monochrome cameras. Put in perspective, this rating is higher than many 1MPx cameras that offer the same frame rate.

Researchers will occasionally add gain to an image to see the data in a dark region. This can show the fixed pattern noise inherent in digital high-speed sensors, which can obscure the critical data being imaged. The v2640 works to solve this issue.

2

1 // The v2640 digital high-speed camera

2 // A balloon popping recorded by the v2640 high-speed camera at 17,000fps

Its standard operating mode incorporates correlated double sampling (CDS). CDS compares the two images, canceling out the fixed pattern noise that often plagues studies.

The standard CDS operating mode has a read-out noise measurement of only 7.2e-. Most camera manufacturers do not provide this measurement, but it is the lowest noise floor of any Phantom camera.

The v2640 also has a high dynamic range of 64dB that aids in high-contrast scenarios. Quite often critical details occur in the shades closest to black or white. The dynamic range is the ratio of the maximum detectable signal to the lowest detectable signal, which translates into a wide number of usable f-stops. The higher the dynamic range, the more shading definition the sensor detects from dark to near saturation.

For applications requiring higher throughput, the v2640 also has a binning mode. It employs 2 x 2 binning on monochrome cameras, effectively converting the camera into a 1MPx camera with increased light sensitivity and throughput. In binning mode, it is equivalent to Vision Research's v2512 ultra-high-speed camera, achieving 25,030fps at full 1MPx resolution, and almost the same sensitivity. Additionally, for applications that require extremely low exposure times, an export-controlled fast option can be applied, reaching as low as 142ns.

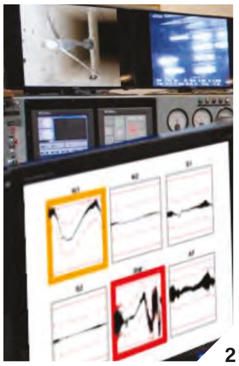
To increase flexibility in testing and experiments, the v2640 incorporates an internal pulse processor that supports programmable I/O, giving the ability to assign and define signals to manage camera activity. Signals that can be modified include F sync, strobe, event, pre-trigger, memgate, timecode-out, ready, aux and auto-trigger. In most cases the signal polarity, delay, pulse width and rising or falling edge can be set according to the needs of the application and interfacing equipment.

The ability to assign and define signals enables the camera to accommodate an application workflow more readily, giving better camera control and flexibility. \\

HIGH-LOAD STRAIN GAUGE BALANCE FOR WIND TUNNELS

A combination of a new balance design and the latest load-monitoring system is giving wind tunnel engineers the opportunity to maximize their test envelope, while maintaining balance safety

1



2

1 // The civil reference model used during verification tests for the HLB53 in the ARA TWT

2 // Real-time monitoring software has been developed that can distinguish between benign oscillations and high-frequency vibrations

3 // The HLB53 high load balance is for both low- and high-speed testing of aircraft and weapons in a wind tunnel

3

Wind tunnel test engineers are continuously driven to provide more data at the extremes of the flight envelope, while maintaining data measurement accuracy and repeatability at low load conditions. This is particularly the case for the latest generation of advanced manned and unmanned military aircraft, which can generate abruptly changing or high-frequency dynamic loads during certain conditions within the flight envelope.

A simple solution is to use two strain gauge balances to suit the different requirements for the tests. A sensitive balance with a reduced load capability is suitable for performance testing at low incidences. A high load range, less-sensitive balance is best suited for testing at high incidence and sideslip. However, while this may provide the optimum engineering solution, the increased costs and time required for repeating some parts of the test program make it impractical in most cases.

Wind tunnel model and high-speed testing company Aircraft Research Association (ARA) has developed a new design of high-load strain gauge balance, the HLB53, which is aimed at addressing the requirements for the testing of the next generation of manned and unmanned air vehicles. The HLB53's one-piece design provides a robust, fatigue-resistant solution for wind tunnel testing, while maintaining measurement accuracy and repeatability.

The 53mm diameter balance is the first of a family of strain gauge balances designed to meet the requirements of wind tunnel companies for low- and high-speed testing of aircraft and weapons, while encountering both low and high loads in steady and dynamic flow conditions.

The one-piece concept of the HLB53 means it is easy to modify the design to suit existing mounting systems and it is scalable for both load range and balance size. The HLB53 is capable of carrying a vertical load of up to 30,000N, while retaining axial load resolution and repeatability of less than ±2N.

The HLB53's performance has been verified during tests of the ARA Civil Reference Model in the ARA Transonic Wind Tunnel, during which it was subjected to variations in temperature and load for different model and test conditions. The data from these tests showed good agreement with that measured from previous tests of this model on a variety of balances. This provides ARA with confidence that the new balances will provide wind tunnel operators with reliable data accuracy and repeatability.

As part of an enhanced offering for wind tunnel testing, ARA has developed load-monitoring software that is able to distinguish between benign oscillations and the often-invisible high-frequency vibrations that can lead to unexpected balance failures. This new software affords the ability to limit a test envelope before damage occurs, and reduces the reliance on the test engineer's subjectivity.

ARA aims to provide this capability with each balance to ensure customers can maximize the test envelope, while maintaining balance integrity and safety. A reduced finite element approach is employed to monitor the total stress at any critical regions within the balance, including components that are not directly gauged, providing a real-time graphical output with an indication of how the limits alter with a change to the proportion of low- and high-frequency content. \\

MICROWAVES BRING CURING HOMOGENEITY

Efficient microwave technology offers short process times, low energy consumption and process automation of plastics and foams

The VHM Hephaistos microwave unit is an internationally patented system. The units are characterized by their extremely high field homogeneity. It is possible to cure high-quality fiber materials such as carbon fiber reinforced plastics in the Hephaistos. Carbon fiber reinforced plastics are often used in lightweight constructions and are therefore frequently employed in the aerospace, marine and the automotive industries.

In the Hephaistos system, microwaves selectively penetrate the material and heat the product, but the oven chamber and air inside it remains cold during this process. Energy consumption is reduced by up to 70%. The production cost of parts is thereby reduced through the shorter warm-up, processing and cooling times offered by the unit compared with conventional methods used in autoclaves.

The system is continuously being improved in terms of both its process and its system technology. Engineers are working toward functionality that enables the Hephaistos to be integrated into automated systems. A semi-automated slide door version is available. This allows the automated placement of large and heavy parts inside the microwave using a robot or transport mechanism.

The Hephaistos system can be designed either for a one-piece flow or according to a manufacturing cell layout that optimizes the process and available space.

The current system is distinguished by the hexagonal design of the heating chamber. The implementation of this structure was a first very successful step to obtain a high-quality uniform temperature distribution. The development of the structure is going on. The Vötsch and Weiss central Department of R&D Electronics/Software are now presenting promising results of an innovative control system. A Model Predictive Controller (MPC) was designed based on a thermodynamic model of heat generation within the volume of the material and heat losses at the surface of the material in combination with a Kalman filter. Detailed results will be published at the Sampe Conference in Southampton in the UK, on September 2018. The MPC will be available as an option for industrial applications soon.

The MPC independently controls 12 microwave antennas using the temperature feedback from fiber-optic temperature sensors and infrared cameras. Comprehensive measurements with two infrared cameras show the improvements made possible by the MPC.

The innovative VHM Hephaistos microwave system is produced by Voetsch Industrietechnik in Reiskirchen, Germany. It was developed as part of a technology transfer and an ongoing collaboration with researchers at the Karlsruher Institute of Technology (KIT) in Germany.

The modular Hephaistos system is safety tested with CE certification and is available immediately. The system is available in three capacities with an operating temperature up to 400°C (752°F). Laboratory scale units with a usable volume 750 liters to large-scale industrial systems with usable volumes of 4,200 liters and 7,000 liters are available.

Voetsch Industrietechnik offers a wide product portfolio in the field of heating technology. The company has an experienced team of engineers and designers that develops, plans and produces heating technology. Products include heating/drying ovens, clean room drying ovens, hot-air sterilizers, microwave systems and industrial ovens. The portfolio reaches from the technologically sophisticated standard versions to customized solutions for individual production operations.

As part of the Weiss Technik Companies, Voetsch Industrietechnik contributes to the solutions developed under the slogan -"Test it. Heat it. Cool it" and are deployed around the world in research and development as well as in the production and quality assurance of numerous products. With more than 21 companies at 15 locations, the company can provide support and high operational safety for systems. The products under the Weiss Technik brand include environmental simulation and air-conditioning as well as containment solutions. The Weiss Technik Companies are part of the Schunk Group based in Heuchelheim, Germany. \\

// The Vötsch VHM Hephaistos microwave oven is characterized by high field homogeneity

UAV FLIGHTS UNDER ICING CONDITIONS

A drive to improve weather forecasting has resulted in the development of drones able to operate in extremely icy weather

1

Weather conditions have an enormous impact on business. While large-scale weather conditions are already well captured by weather models, the prediction of small-scale systems such as inversions, low-level jets, fog and cloud layers are highly problematic. What is needed is better data from the planetary boundary layer – the lower 1.5-3km (0.9 to 1.8 miles) of the atmosphere – to enhance these regional weather models.

Meteomatics has developed and is operating its own Meteodrones to gather this data and has been awarded permission to fly beyond the visual line-of-sight and within regulated airspace in Switzerland.

The key variables of temperature, relative humidity, pressure, wind direction and speed can be accurately determined by measurements taken by the drones at heights of up to 3,000m (9,842ft). This information can then be immediately assimilated into very high-resolution weather models. This means that one single instrument can facilitate a detailed analysis of atmospheric conditions. The enhanced output of these high-resolution weather models can then be visualized or simply ingested into decision making systems.

A major challenge to the use of Meteodrones at altitude is flying under icing conditions. When there is high humidity and temperatures are below freezing, ice builds up on the rotor blades, rescue system and body of the Meteodrone, ultimately rendering the UAV unable to fly.

Initially, tests could only be performed under real icing conditions within the natural environment. High-humidity and temperatures below 0°C (32°F) caused ice to build up on the rotors, which ultimately triggered the rescue system as the Meteodrones were left unable to fly. A closer study of the circumstances surrounding such events was needed to develop a protection system that permitted UAVs to fly under icing conditions.

Therefore, various atmospheric conditions were simulated in the Vienna Climatic Wind Tunnel and the conditions under which different icing conditions occur were examined. Eight different weather conditions were tested: two stratiform and six cumuliform clouds, during different freezing temperature conditions.

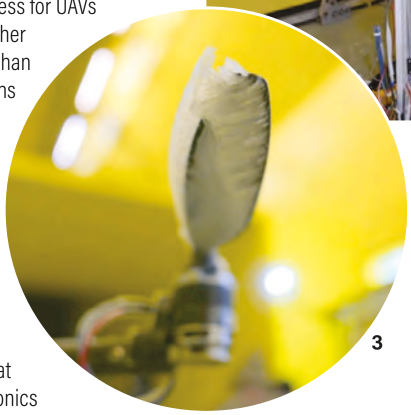
The tests showed that icing poses a serious threat for UAVs. Icing will lead to a loss of propulsion within a period of 100 seconds. The icing process for UAVs occurs faster during higher negative temperatures than under very cold conditions of below -10°C (14°F). Icing also occurs more quickly in cumuliform clouds than within stratiform clouds. In addition, more ice deposits on propellers in 'warmer' freezing air.

A positive outcome from these tests was that the Meteodrones electronics withstand the harsh icing conditions well, and that all the meteorological sensors stayed ice-free at all times, with the parachute cap only frosting from -20°C (-4°F).

There are three possible scenarios to protect the Meteodrones against icing conditions. The first would be to cancel flights to avoid damage. Another is that the UAV's body and propellers could be protected by a heating system or by using atomizing anti-icing agents during flights. A third could be to produce vibrations or dilatations to shake off or break away ice.

It was found that flight cancellation was not a suitable approach if the UAV is tasked to collect important data or transport time-sensitive material. It was also found that vibration was not sufficiently effective.

2



3

1 // Meteodrones gather data to improve regional weather forecast accuracy

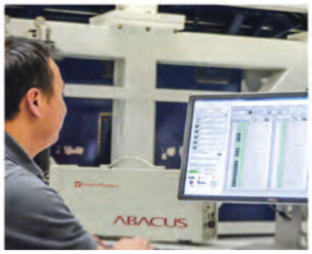
2 // Meteodrones being set up at the Vienna Climatic Wind Tunnel

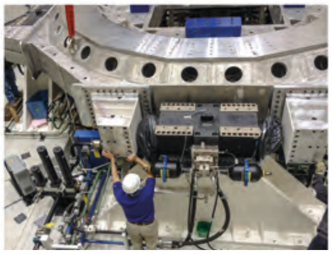
3 // Ice accumulation on a Meteodrone after four hours in the Vienna Climatic Wind Tunnel

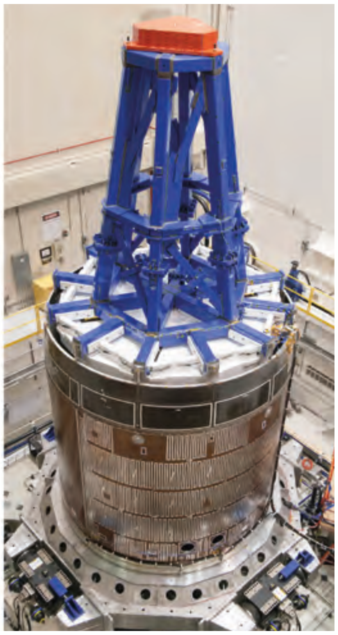
None of the anti-icing agents tested offered any considerable improvement. Due to the high rotational speeds of the rotors, application of de-icing agents in flight was also not feasible. It appeared that only a propeller heating system could help. However, using a heating system would reduce flight times by half.

In a second phase of the project, engineers plan to collect data to create an accurate icing forecast. This data will include the severity and intensity of ice forming when a UAV encounters these conditions. The effect of rotor size and the resulting rotational speed will be taken into account for the speed of icing development, with the goal of creating an icing forecast for any size of drone. The current propeller heating system will also be tested and improved using different procedures to decrease the system's power consumption. \\

MEETING THE CHALLENGE OF SPACECRAFT VIBRATION TESTING





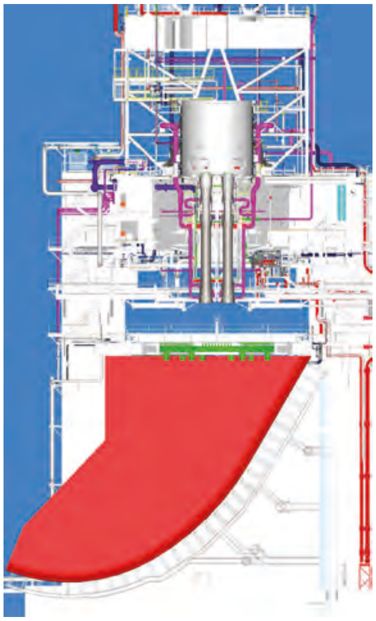


Vibration testing of large payloads can require multiple shakers to achieve required force and acceleration levels. This presents a considerable challenge for the vibration controller and vibration table, which must not only support the load, but deliver controlled vibration for up to 6DOF. The controller and shaker table arrangement must also minimize angular and cross-axis motion.

Data Physics and Team Corporation recently paired up to meet this challenge at NASA's Mechanical Vibration Facility (MVF) at Plum Brook Station in Ohio. Designed for qualification testing of the Orion spacecraft, the MVF shaker table is the highest capacity and most powerful shaker built for spacecraft testing. The 22ft-diameter (6.7m) vibration table from Team Corporation is capable of testing articles up to 75,000 lb (34,000kg).

Sixteen hydraulic shakers drive the table vertically and four horizontally. Special hydrostatic couplings and bearings allow the table to be driven simultaneously in 6DOF.

The Data Physics Matrix multishaker controller was used to generate vibration signals per test profile specifications. The Matrix controller system has eight output channels with an additional Constant Output Level Adapter. The Orion testing required swept sine testing from 5-150Hz at sweep rates from 1-4 octaves per minute. Both force and acceleration limiting were used to control response levels at key locations on the structure. \\



STENNIS CENTER MODIFIED FOR SPACE LAUNCH SYSTEM TESTS

NASA Stennis Space Center (SSC) will be testing the Exploration Upper Stage (EUS) at the B-2 Test Stand to support the Space Launch System (SLS) program.

The EUS and its four RL10 engines are all flight assets that will launch subsequent to the green run test series. To test engine start and full mission operations at altitude conditions, each engine will be attached to a passively pumped diffuser by a clamshell and seal on the B-2 Test Stand. The four diffusers will each be pumped down to altitude conditions prior to engine start using a facility steam ejector vacuum system.

Jacobs is working with NASA SSC to design the changes to the facility including the EUS diffuser systems. Jacobs has designed multiple full-scale and sub-scale diffuser systems in support of previous NASA White Sands Test Facility and SSC test programs.

As part of the diffuser system, Jacobs will also be designing, building and testing a full-scale liquid oxygen/gaseous hydrogen fueled steam generator. The steam generator will supply steam to the facility steam ejector vacuum system. \\

HIGH-PERFORMANCE ACCELEROMETER

The Endevco 7290 series has been helping flight test engineers gather valuable low-frequency data for more than 30 years. These variable capacitance accelerometers utilize trusted MEMS (microelectromechanical systems) sensing technology combined with signal conditioning for excellent accuracy and performance over temperature.

The gas-damped design of the Endevco 7290 ensures that the sensor can survive shocks of up to 10,000*g* and then quickly recover to make low-frequency measurements. The 7290G is available in ranges from 2*g* to 100*g* with a wide input voltage range from 8V DC to 40V DC.

For exceptional performance in outdoor applications, the Endevco Model 7290GM5 provides watertight performance to IP67. This accelerometer incorporates a PFA cable that won't wick in water as well as a reinforced cable-to-case connection, which improves ruggedness as well as eliminating water ingress.

If a triaxial measurement is needed, the Endevco 7298 has six different ranges from 2*g* to 100*g* and frequency response up to 1,500Hz. It has the tightest non-linearity specification as a percentage of full-scale output in the industry to provide end users with the most accurate vibration data. The 7298 has proven durability with the highest shock survivability and a hermetic package with a water-resistant connector.

The Endevco family of piezoelectric, piezoresistive, IEPE and variable capacitance accelerometers, piezoresistive pressure transducers, rate sensors, electronic instruments and calibration systems, ensure critical accuracy and reliability in aerospace, automotive, defense, industrial, medical, power generation, R&D, space and T&M applications. \\

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3D SCANNING BRINGS SURFACE INSPECTION BENEFITS

Being the part of the airplane that cracks the air, the leading edge is susceptible to the most damage.

In cases where many dents occur on the same surface area, it becomes difficult and time-consuming to be properly treated and analyzed. Scanning a wing can take up to a day and data may not even be accurate, because the technique leaves significant room for error. The probability of detection is greatly reduced and diminishes the efficiency of the straight-edge technique.

This technique involves positioning the pit gauge on even surfaces to measure the depth of the dent. If there is no reference point left on the damaged surface, the technique becomes less efficient and measurements become harder to analyze and less accurate and repeatable from one user to another.

How is this inspection issue solved? The 3D scanning of aircraft surfaces takes 30 minutes per wing to set up, scan, analyze and report.

A key part of the scanning solution is the surface inspection software, which enables the user to reduce inspection time, aircraft downtime and maintenance costs. It also offers other major benefits, such as a virtual pit gauge that can be extended up to 10m (32ft). This brings more stability and accuracy to the straight-edge technique, which in turn gives more surfaces to lean on to find the highest reference points on the part. \\

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COME FLY WITH ME

AIM's rugged ANET-MxAy-R Ethernet based interface for MIL-STD-1553, ARINC429 and mixed protocol applications has been qualified to MIL-810G standards for shock, vibration, humidity and altitude, for the most rugged applications.

This qualification now enables customers to use the ANET-MxAy-R for rugged and airborne requirements. Applications include data loading, data monitoring, simulation and protocol gateways. One real airborne application for which the ANET-MxAy-R will be deployed is on board a military aircraft, integrated into a pod, for real-time avionics databus monitoring.

Up to two dual redundant MIL-STD-1553 streams (BC, MRT, BM) and up to 12 ARINC429 channels configurations are available. Standard ANET features like IRIG-B I/O, discrete I/O, trigger I/O and a general purpose USB 2.0 port for hosting USB devices are available for the rugged ANET plus an Ethernet interface supporting 10/100/1000 Ethernet links. They have a wide range power input 9.36V DC and an optional MIL-STD-704-compliant power input 18.50V DC.

The API interface is compatible with the standard API of the AIM MIL-STD-1553 and ARINC429 ANET interfaces. Powerful ANET features such as the onboard Python scripting and a Customer Application Development Kit are offered.

The standard AIM PBA.pro test and analysis software for Windows and Linux is available as an option to control the rugged ANET from a networked host system. The optional PBA.pro Engine for execution in the ANET is also available. \\

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ÄLVDALEN RANGE READY FOR THE ARMED HELICOPTER COMMUNITY

Älvdalen Firing and Exercise Range has until recently been open only for the Swedish Armed Forces, but is now available for the international rotary wing, UAV and Electronic Warfare communities, with Airbus Helicopters as its launch customer.

The 540km² firing and exercise range is big enough to allow live firings with almost any helicopter weaponry, for example laser-guided rockets, Hellfire, Stinger and HOT. The remote location of Älvdalen permits the use of laser and the possibility for live navigation and communication jamming. During the cold and dark season, Älvdalen is an excellent range for NVG and cold climate trials.

Älvdalen Firing and Exercise Range is jointly operated by the Swedish Armed Forces and the Swedish Defence Materiel Administration Test & Evaluation division (FMV T&E), which operates several ranges in Sweden. The portfolio includes air, land and naval test and exercise ranges.

Airbus Helicopters took advantage of this new opportunity to perform the first live firing tests with 70mm (2.7in) FZ275 laser-guided rocket (LGR) from Thales Belgium, out of an H145M helicopter. The H145M was equipped with Airbus HForce system.

The Airbus Helicopters live firing campaign at Älvdalen was supported by the FMV T&E's Flight Test Centre (FTC), which supported with practical issues concerning the range, such as LGR target design, test management and laser safety. FMV FTC also assisted in the complex permit-to-fly process.

A joint effort by FMV FTC and Airbus Helicopters made the launch campaign a great success for both parties. \\

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FMV

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VALIDATION WITH HIGH-SPEED CAMERAS

In flight test instrumentation applications, high-speed cameras are essential for conducting photogrammetric studies to validate performance prediction models.

Validation of store separation prediction techniques is required to complete flight test instrumentation (FTI) studies for airborne certification programs. The use of photogrammetric high-speed camera missions enables the validation of store separation prediction models by capturing 6DOF motion data.

The FTI engineer correlates the quantitative data from the separation testing with the actual flight test results to validate the models. This data is measured when the stores are within a defined volume of analysis while on the test vehicle.

Typically, flight clearance authorities request measurement accuracy on the order of a few inches for proper correlation.

Photogrammetric techniques involve obtaining measurements from individual digital images to analyze the precise position and orientation of objects in three-dimensional space during a test flight. In many cases, wind tunnel experiments will be performed in advance to generate the prediction model, which helps to minimize program risk.

Typically, FTI requires a high-speed camera device capable of capturing moving images with exposure times for each image of less than 1/1,000 of a second or frame rates in excess of 200fps. After recording, these images can be played back in slow motion to examine the motion for scientific study of transient phenomena.

An example of a high-speed camera designed for FTI is Curtiss-Wright's recently introduced nHSC-36-S1-1 miniature camera. Designed to capture high-speed imagery and record data in the harsh environmental rugged conditions of aerospace test applications, this camera supports the high resolution (1280x1024 pixels) required for use in demanding airborne store separation testing and helicopter testing applications. The camera measures only 3.12in (8cm) wide by 3.42in (8.5cm) high by 2.87in (7cm) long and weighs only 3lb (1.4kg). \\

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WATER SEPARATOR AND HYDRAULIC PURIFIER

Hydraulic fluids are hygroscopic. They absorb water from the atmosphere rapidly. The higher the temperature, the faster the absorption. Acid control additives in modern hydraulic fluids can neutralize the product of this hydrolysis up to a water content of 0.4%. When the fluid has been in use for a certain time, the additives' effect fades and the hydraulic fluid does not stop altogether to collect water from the environment. Samples drawn often show a water content higher than the allowed maximum percentage by most aircraft manufacturers.

A Test-Fuchs pioneer project tackled the problem and delivered a perfect solution: The Water Separator and Hydraulic Purifier does not only lower the water concentration in an aircraft's fluids, it also eliminates particles from the fluids and dehydrates stationary and mobile hydraulic power units as well. The purification is done during routine maintenance checks.

While the hydraulic power unit and the hydraulic purifier are connected, the aircraft can perform hydraulic movements such as gear swings, incorporating contaminated hydraulic fluids back into the circulation that otherwise would remain untouched.

The purifying device is already Airbus certified on 3,000psi and 5,000psi aircraft, especially for the use on Airbus A350. It has also recently been awarded with an innovation award. Major airlines already profit from the numerous benefits, keeping their particle and water contamination within their limits, and avoiding the premature changes of hydraulic fluids and thereby saving a lot of costs and resources. \\

ENVIRONMENTAL TEST SOLUTIONS

ETS Solutions was founded 14 years ago and has grown to employ 180 people at an 8,000m^2 (86,000ft^2) site. The company offers high-quality environmental test solutions for aviation and aerospace applications.

ETS has ISO9001/14001 certificates and its equipment has the CE mark. The innovative range of vibration equipment it supplies is covered by 17 patents awarded by the Chinese government.

ETS Solutions has a highly skilled, technically qualified team able to use high-precision machine tools to provide customized engineering and solutions. The company also has local service teams and spare-parts storage to ensure that customer's machines are working as much as possible.

Products can be supplied to the USA, Europe and Asia from China. MIL-810 and other local standards can be met.

A highlight of ETS Solutions' range includes its vacuum chambers. These can be supplied with an internal useful capacity from 150 liters, with the capability to operate over a temperature range of -70°C to +120°C (-94°F to +248°F). Vacuum shock chambers can be supplied with internal capacities of 1,000, 2,000 or 2,600 liters, able to operate over a temperature range from -70°C to +120°C and provide shocks from 18.8kPa to 75.2kPa in less than 15 seconds.

ETS Solutions space simulator has an internal useful capacity of up to 12m^3. The test vessel can be used horizontally or vertically and is cooled by a compressor using either LN^2 or GN^2 with shroud and cold plate individual control and an ultra vacuum to 1 x 10^{-5} Pa. The company has installed a 1,000m^3 astronaut training vessel at China's astronaut research and training center in Beijing. \\

SIMPLER SOFTWARE FOR SOUND AND VIBRATION MEASUREMENT

Sound and vibration measurement company Brüel & Kjær has released its new flagship software – BK Connect. The software platform offers a fully integrated user-centric solution for multi-channel data acquisition with industry-leading LAN-XI hardware, alongside data processing, data management and reporting functions.

BK Connect's structure and concept is based on user-configurable workflows that reduce the risk of error and the need for customer-specific development, while maintaining the full feature richness of a modern analysis platform.

The core applications provide a comprehensive set of tools for real-time measurement and data processing in a range of engineering scenarios – from repetitive, standardized testing, to complex troubleshooting investigations. BK Connect also offers a wide range of specialized modules for structural dynamics, noise source location and angle domain analysis.

The BK Connect data concept is open, enabling full access to data – regardless of its original format, from legacy LabShop data to third-party, universal and finite element model formats. In addition, legacy LabShop functionality has been included to ensure that all existing capabilities are covered during the transition to BK Connect.

The user interface is easily configured, so it can be adapted to the needs of different users within organizations, enabling operators/test engineers, specialists, managers and requesters to work together with maximal efficiency and productivity.

Each of the applications is designed as a self-contained solution for a typical task or set of tasks within a more detailed test and analysis workflow. Users can then select the module or modules that will help them perform the task or combine applications to increase functionality and create tailored workflows for quick and easy completion of multiple steps in an established sound and vibration test process. \\

ACCELEROMETER FOR GAS TURBINE ENGINE TEST

PCB Piezotronics, a designer and manufacturer of microphones, vibration, pressure, force, torque, load, and strain sensors, has released Model 357A63, a very high temperature 900°F (482°C) charge output, case isolated accelerometer with a UHT-12 sensing element.

This miniature accelerometer was developed for use in aviation power generation, turbine research and development, and automotive powertrain noise, vibration and harshness applications.

The Model 357A63 accelerometer has a sensitivity of 0.5 pC/*g* (picocoulombs per *g*) a measurement range up to 5,000*g* and a high-frequency response to 10kHz (±10%.) The mature UHT-12 crystal technology has proven reliable performance in hundreds of installations for more than a decade. The advantages of this crystal include an absence of pyroelectric noise spikes and a sensitivity that remains more consistent over a wide temperature change.

The shear mode crystal design isolates the sensor from base strain to reduce transverse measurement errors.

This proprietary crystal technology comes sealed in a hermetic housing that prevents risk of contamination. It has also been designed with integral electrical case isolation that prevents noise issues without the added height or weight of an accessory isolation base. \\

ENGINE HEALTH MONITORING ON THE RUNWAY

Fan beam emission tomography is set to emerge as a new tool to monitor the health of an aircraft engine while the aircraft is idling on the runway.

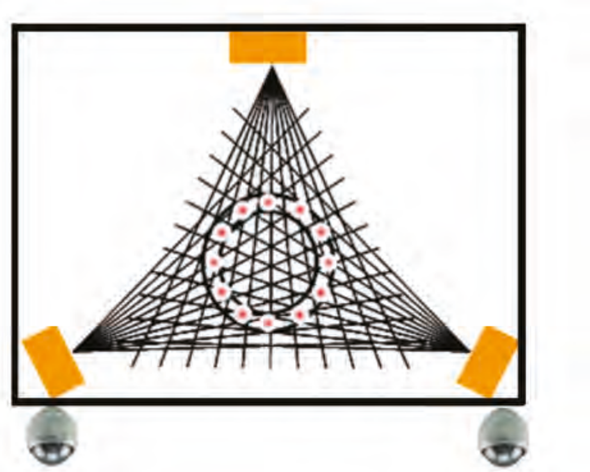
The aircraft engine monitoring system is based on high-speed infrared imaging and analysis of the engine plumes. There are two major drivers for having a monitoring system that can be rolled out onto the runway for testing the health of engines. The first is to ensure that the aircraft is flightworthy and that there are no current or impending problems with the engine.

Currently, aircraft engine performance monitoring is labor intensive, and therefore scheduled on a regular basis irrespective of the operational needs of the aircraft. For example, if one of the several nozzles inside the aircraft engine combustor is blocked, or if the coating of the thermal barrier coating is compromised, there is no reliable method of detecting it in time to prevent extensive corrosion due to an unbalanced combustion or wear and tear. Fan beam emission tomography will identify any potential problems with the state of the engine health at a very early stage.

The second driver for having an engine monitoring system is to reduce the downtime for expensive aircraft. The system is expected to improve fleet readiness, cut maintenance costs, and improve aircraft safety.

One of the key requirements for an engine monitoring system is that it can be easily moved to the end of the runway to monitor aircraft engines on a regular basis.

Scientists at En'Urga have developed such a system and are in the process of field testing it using full engines at the Aviation Technology School at Purdue University in Indiana. An artist rendition of the engine monitoring system is shown in the diagram. \\



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EN'URGA

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BRING THE TESTING TO THE PART

Stationary hardness testing methods waste time and effort by requiring users to move large parts to the testing machine, exposing both people and parts alike to the risk of injury and damage.

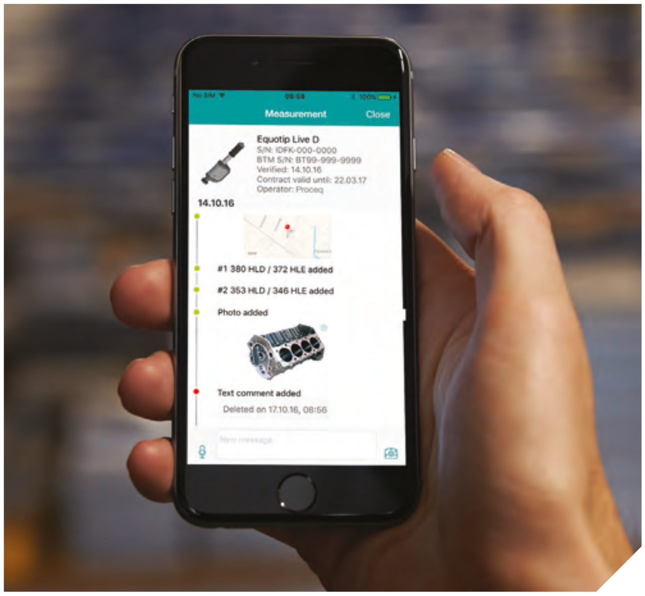
Since 1975, Proceq has offered Swiss-made solutions for Leeb Rebound, Portable Rockwell and ultrasonic contact impedance (UCI) testing by providing high-quality portable, reliable tools that can potentially replace stationary methods.

Proceq's Equotip Live platform for portable hardness testing features Leeb D and UCI up to HV10, and has been tested according to international standards. Testing showed how closely its performance matches that of a traditional stationary Brinell machine.

An Equotip Live probe connects to the Equotip Live app on the user's smartphone. There, a step-by-step wizard helps them to create a correlation curve, if necessary, and to verify its accuracy on metallic materials. These include advanced materials such as titanium and nickel alloys, which are increasingly used in aerospace engineering.

The Equotip Live app also allows the user to trace the entire procedure, including the history of their probe verifications. All of the measurement data and traceability information are stored remotely and securely on the cloud, enabling the generation and sharing of reports from the app or the web, anywhere, anytime.

If you already use UCI or Leeb, try out Equotip Live. If not, you'll find it's faster and easier to use than stationary methods, typically leaves a smaller indentation on the part, and reduces risk and costs. \\



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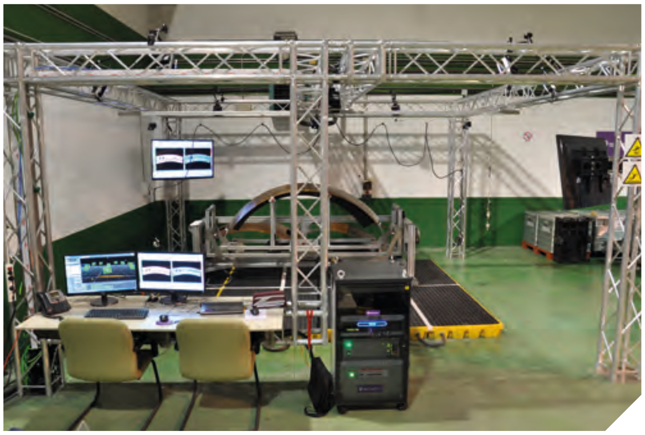
WIRELESS POSITIONING SYSTEM AIDS INSPECTION



The Wireless Positioning Inspection System (WiiPA) is a portable and semi-automatic system developed by Tecnatom for the manual inspection of sensitive areas in which a C-scan record is required.

This innovative equipment is intended to provide a low-budget solution to some NDT (non-destructive testing) applications traditionally addressed to high-end and costly automated systems, such as the testing of complex geometry components. To achieve this, WiiPA integrates technologies: artificial vision positioning and 3D inspection software. These technologies provide highly competitive advantages, but at the same time save costs for the customer.

The WiiPA system emulates a six-axis machine for multiple geometries and parts dimensions. The system is based on motion capture, which works using infrared cameras and markers for tracking the inspection probes with high accuracy and cadence.

Among its proven advantages for the aerospace sector are that the system provides position and spatial orientation of multiple probes (UT/ET); it is very productive thanks to the use of phased-array technology; it is easy to install; and it is suitable for multiple dimensions and geometries. WiiPA also offers reinspection possibility for uncovered areas in real time.

Tecnatom's portable system has already been acquired by some aerospace customers, such as Corse Composites Aéronautiques in France, the Turkish Aerospace Industry, and Aernnova-Coasa in Spain. These companies work with aero parts of different sizes and geometries that are part of the aerospace programs of Airbus, Boeing and Lockheed Martin. WiiPA will be at JEC World (Paris) in March and ECNDT (Gothenburg) in June. \\

EQUIPMENT BENEFITS FROM RESEARCH PARTNERSHIPS

Italian company Criotec Impianti supplies cryogenics, high-vacuum and turnkey equipment to some of the most important test and research centers in the world, such as CERN in Geneva, Switzerland. From the analysis and design of equipment, to the manufacturing, test, on-site installation and commissioning of cryogenic systems down to 1.8K, Criotec is able to manage the whole process.

During the past 30 years, Criotec's flexibility and capability have been appreciated by the market, enabling the company to grow in several different fields. In 2010, Criotec started a new business producing CICC (cable-in-conduit conductors) superconducting cables and it is now the main supplier of these cables to the experimental fusion reactor ITER.

Meanwhile in 2016, Criotec, leveraging its 10 years of experience producing Thermal Vacuum Chambers (TVAC), started a new activity in the aerospace business, making its own TVAC (3 x 4m) suitable for testing components at its premises in Chivasso, Italy.

Engineers and technicians from Criotec always work with clients' technicians and researchers. The exposure to constant technical progress and enterprise technology has a positive impact for industrial customers, who find Criotec an efficient partner for work on their plants. \\

SURVEY RESULTS

Results taken from our online polls
hosted in January, February and March 2018

WAS THE SPACE SHUTTLE PROGRAM A MISSTEP IN THE US SPACE PROGRAM?

► Readers overwhelmingly believe that despite its many critics, who say it was expensive and didn't meet its main goals, the space shuttle program was a success.

78% No
13% Yes
9% Don't know

IS YOUR COMPANY ADEQUATELY EQUIPPED, WITH TOOLS AND KNOWLEDGE, TO INSPECT AND TEST 3D-PRINTED PARTS?

► Many think they lack adequate capability to inspect 3D-printed parts and want to acquire more equipment to feel confident about the new materials being used.

33% Yes
67% No

DO YOU SEE STRONG DEMAND FOR FLIGHT TEST PILOTS AND ENGINEERS CURRENTLY?

68% Yes
32% No

► Respondents to our poll were positive about career prospects for flight test professionals at the moment.

DO YOU SPEND TOO MUCH OF YOUR TIME DEALING WITH DATA?

68% Yes
21% No
11% Don't know

► Most readers see that their jobs have changed to one where they spend too much time dealing with conflicting formats while they import and export data.

Most read on the web

1. Next SpaceX Falcon Heavy launch will carry NASA atomic clock test
2. Ehang performs first manned test flight of air taxi
3. Prototype aerial/underwater hybrid drone progresses through tests
4. Pentagon report reveals the F-35 faults found by test engineers
5. Saab invests millions in new aerospace R&D center

To join the debate and for the latest news, sign up to our weekly newsletter online at:

WWW.AEROSPACETESTINGINTERNATIONAL.COM

// BEN SAMPSON

STEALTHY RETIREMENT

The B-2 Spirit's phasing out from active service has been announced, but the impressive aircraft still represents the peak of the USA's technological and military prowess

The driver behind some of the most iconic and innovative designs in aviation is the gaining of military advantage over your enemies. Nowhere is this more evident than in the B-2 Spirit, which, with its stealth technology and distinctive bat-like shape, embodies superiority in military technology.

Last month marked 20 years since the B-2 Spirit was deployed overseas for the first time, and in December this year it will be 25 years since the aircraft entered service.

The multirole bomber, which was originally developed to deliver nuclear bombs, has reduced infrared, acoustic, electromagnetic, visual and radar signatures. How exactly this is achieved to a great extent remains classified, although it is known that the B-2's composite materials, special coatings and flying-wing design, which reduces its leading edge, are all factors in its low observability to radar.

Also known is that decades after its initial development, the aircraft pioneered and spurred major technology advances in several areas, including composites, 3D computer-aided design, avionics and digital navigation systems, GPS targeting systems and fly-by-wire flight controls.

When images of the B-2 first surfaced in the 1980s, it looked like an alien spacecraft had landed from the future. Unsurprisingly for such a technologically advanced bomber, the development of the B-2 was protracted. The aircraft's direct R&D lineage can be traced back to the 1970s, but the main development program started in 1981, with a design by a team from Northrop. The Tacit Blue technology demonstrator was key during this early design phase. Tacit Blue was flown 135 times between 1982 and 1985 to demonstrate the viability of "continuous curvature" and other design features that lower the B-2's radar signature.

By the mid-1980s the B-2's mission was changed from high-altitude to low-altitude bomber and the aircraft had to be redesigned. This delayed the project by almost two years and added another US$1bn to the cost.

Flight testing was conducted by the B-2 Combined Test Force at the Air Force Flight Test Center, Edwards Air Force Base, California. July 1989 saw the aircraft AV-1 undertake the first flight, lasting two hours and 20 minutes, from the manufacturing plant in Palmdale, California, to Edwards Air Force Base.

Two years later, when the Soviet Union collapsed, the initial order of 132 B-2s was reduced to 20, plus one test aircraft for validation of software and weapons upgrades. In December 1993, the first B-2, the Spirit of Missouri, entered service at Whiteman AFB. The last was delivered in November 1997.

In a neat case of historical symmetry, the US Air Force announced plans to retire its 20-strong B-2 Spirit fleet last month. The B-2s are to be phased out incrementally to make way for their successor, the B-21 Raider, in the mid-2020s. The B-2's continued usefulness in the 21st century, and its technological legacy, are a testament to the innovative work done by the many engineers behind this iconic aircraft. \\

JULY 17,1989
First flight

B-2
Model number

52M
wingspan

21M
long

170,600KG
gross weight

630MPH
top speed

560MPH
cruising speed

6,900 MILES
range at full load

15,200M
service ceiling

17,300LBF
thrust of each of four F118-GE-100 engines

18,000KG
payload limit in two internal bays

URL for B-2 flight test film:
WWW.YOUTUBE.COM/WATCH?V=L-F044A500Q


See beyond the surface
CT scan of a rotor spar
Control
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