SEPTEMBER 2018

Aerospace TESTING INTERNATIONAL

Inside this issue

G500 goes for gold

Discover how Gulfstream engineers pushed the limits of its latest jet and proved performance beyond its original design goals

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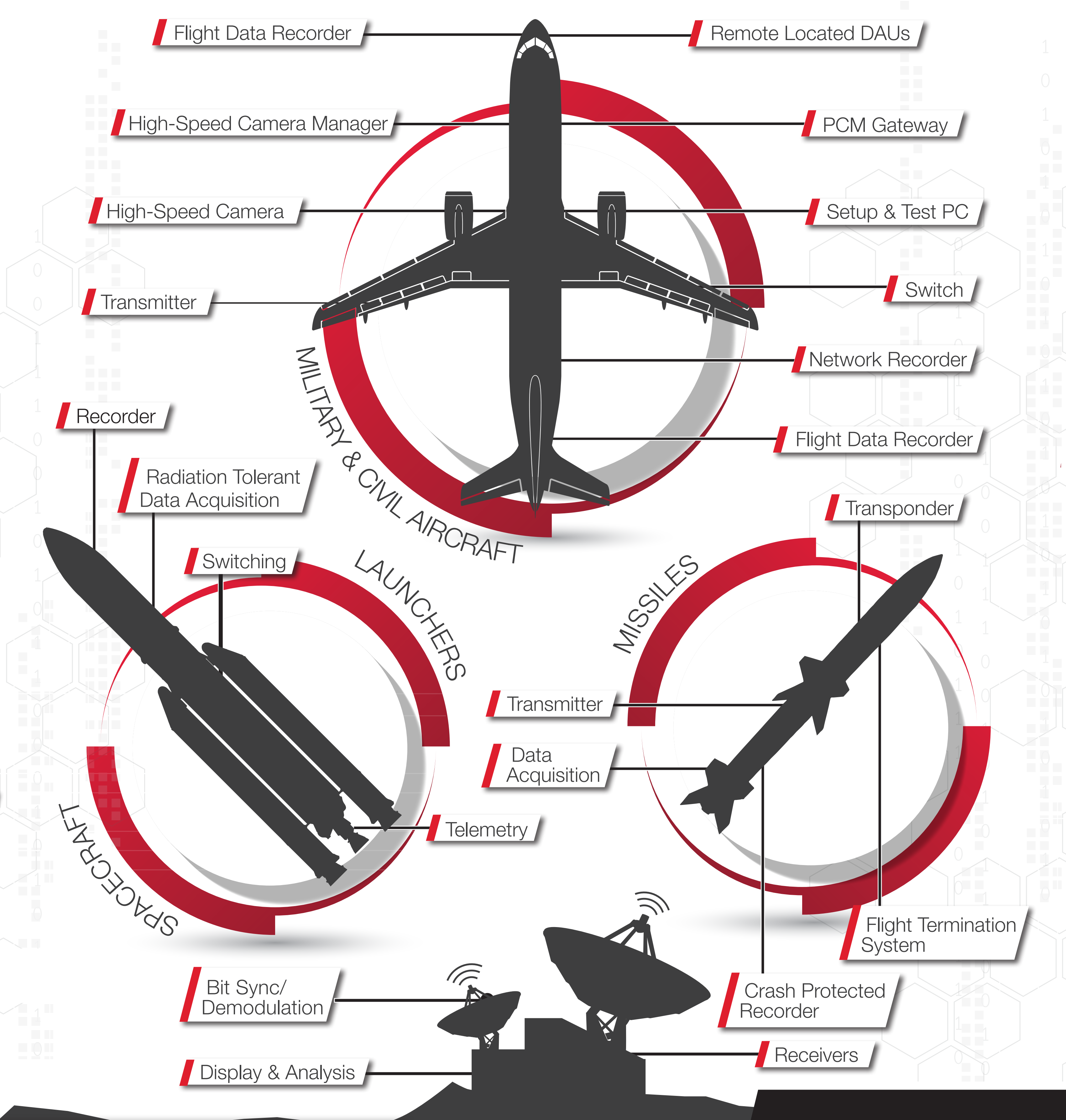
TOTAL DATA ACQUISITION SYSTEMS

Seamless Integration



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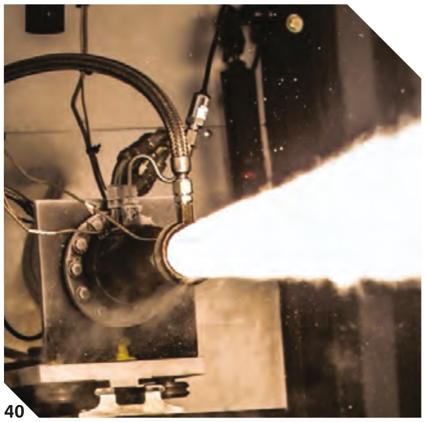
32
24

Global briefing



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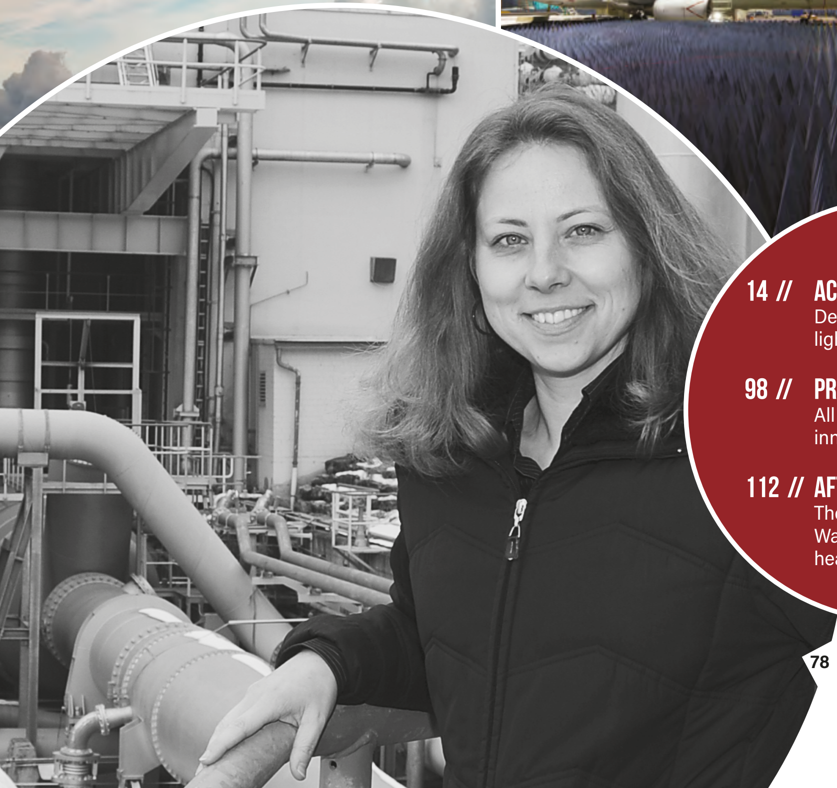

78

Inside this issue

// Electric chatter

An odd atmosphere permeated the Farnborough Air Show as the week-long event progressed in July.

Analysts and the media began to realize that even though the total number of orders was rising to close to 1,000, many of them had previously been announced or were far from done deals. Indeed, one analyst estimated after the event that firm deals accounted for just 20% of the total orders announced at 2018's show, compared with an average of 50% at previous shows held over the past decade.

Yet while there may have been disappointment about the number of deals done at the show, there was plenty of new technology and projects to get excited about. BAE Systems displayed the development work for the UK's next-generation fighter, named the Tempest; Airbus displayed real progress on the Zephyr drone, which subsequently broke the world record for continuous flight (see page 6); and Rolls-Royce demonstrated several innovative inspection and monitoring technologies for its engines.

All these stories and many more are on our website – AerospaceTestingInternational.com – which has recently been revamped and is updated daily. The website's new look and systems have been designed to make it easier to find and view the latest news, features, jobs and products for aerospace testing. Check it out and please also sign up to our free, weekly email newsletter.

Rolls-Royce also used this year's air show to unveil an electric flying taxi, which it said would be ready in 18 months. By far the most chatter at the show was about electric and hybrid aircraft, particularly electric vertical take-off and landing (eVTOL) vehicles. Boeing for example, announced a new division, Boeing Next, to head up eVTOL development and the crafts' introduction into urban airspaces.

Despite these and similar announcements, I failed to notice any flying taxis in the air at Farnborough. This reflects the early stage of development of most electric aircraft projects. Engineers are still getting to grips with hybrid propulsion and the electrical subsystems required to put fully electric and hybrid aircraft in the sky. But the pace of development is fast.

If you want to be brought up-to-date with the latest battery and motor technologies, best design practice and safety regulations for electric and hybrid aircraft, the place to do so is at the Electric & Hybrid Aerospace Technology Symposium, November 8-9, in Cologne, Germany.

The comprehensive agenda for the event (see page 86), which is now available online, features more than 45 presentations by speakers from organizations such as NASA, Safran, DLR, Airbus and GE Aviation. Now in its fourth year, the Symposium grows in size and popularity every year. An early-bird discount can be obtained from links on the magazine's website.

Finally, this month's magazine contains some great articles, including features on software testing and avionics. There's also valuable insight about flight test instrumentation from Boeing's instrumentation solutions architect, Rick Stiers, and coverage of how new entrants to the space industry are testing their launch platforms. Enjoy!

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WORLD
test update

// MITSUBISHI FLIES REGIONAL JET

The Mitsubishi Regional Jet was flown at an air show for the first time during Farnborough 2018 and has so far logged more than 2,000 hours of flight testing.

Flight test aircraft three, an MRJ 90, conducted the display at the air show in July.

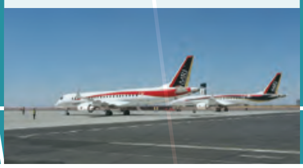
The 90-seater aircraft is on target to enter service in 2020 with All Nippon Airways, said Mitsubishi Aircraft.

Development of the MRJ started more than a decade ago and its entry into service will be seven years later than initially planned. The latest delay, which was announced in January 2017, was because of problems with the aircraft's wiring.

Mitsubishi Aircraft has 213 orders for the MRJ.

Speaking at the Farnborough Air Show in July, Alex Bellamy, chief development officer for the MRJ, said, "Advanced aerodynamics and the geared turbofan engine make it the quietest aircraft in its class. It has an extremely spacious cabin with the bags at the back of the aircraft, enabling us to optimize the shape of the fuselage."

Farnborough, UK



// NASA DRONE FLIES IN NATIONAL AIRSPACE

NASA's remotely piloted Ikhana aircraft has flown its first mission in the USA's National Airspace System without a safety chase aircraft.

Ikhana, which is based at the agency's Armstrong Flight Research Center in Edwards, California, demonstrated a suite of detect-and-avoid technologies during the test flight.

Ed Waggoner, NASA's integrated aviation systems program director, said, "This is a huge milestone for the team on our Unmanned Aircraft Systems Integration in the National Airspace System project. We worked closely with our FAA colleagues for several months to ensure we met all their requirements to make this initial flight happen."

READ MORE ONLINE

The Ikhana is a MQ-9 Predator B drone acquired by NASA in November 2006 to support Earth science missions and to act as a testbed to develop capabilities and technologies to improve the utility of unmanned drones.

According to NASA, the technology being trialled in the Ikhana could be scaled down for use in other general aviation aircraft in the future.

California, USA

// ROYAL NAVY SET TO START F-35 SEA TRIALS

The UK's Royal Navy is starting a four-month period of flight tests for the F-35B off the Eastern Seaboard of the USA to develop its operating envelope.

The flight tests, which will see the first deck landing of the F-35B performed on the HMS Queen Elizabeth aircraft carrier, will determine the parameters for the safe operation of the carrier-variant of the F-35.

The tests are being supported by the 820 Naval Air Squadron, which flies Merlin Mk2 helicopters and will provide force protection and search and rescue capabilities during the four months of testing. Merlin Force Commander Mike Currie said, "The focus since the completion of the first deck landing with a Merlin last year has been very much centred around the first of class flying trials with F-35B."

New Mexico, USA

// NORWAY TO LAUNCH HYBRID ROCKET

Norwegian firm Nammo has completed ground testing of a hybrid rocket and confirmed it will launch from Northern Norway in September.

The Nucleus will be the first European hybrid rocket ever to reach space.

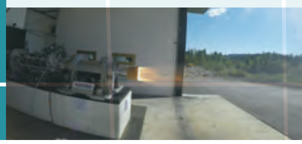
MORE NEWS ON OUR WEBSITE!

Nammo's hybrid engine uses both liquid and solid fuel and emits only water and CO_2. According to the company, the oxidizer, hydrogen peroxide, is safer than other liquid fuels and is non-poisonous. The engine can also be throttled, turned off and restarted.

The Nucleus rocket's motor was ignited and burned for 40 seconds, until full depletion of the oxidizer and gas tanks, for the first time during testing in June 2018.

Adrien Boiron, lead engineer on the Nucleus project, said, "This system test included all flight components for the propulsion system, the inflight electronics and data acquisition systems, and we also validated the controls and filling procedures, including ground support equipment."

Raufoss, Norway



// AIRBUS STARTS BELUGAXL FLIGHT TESTING

The BelugaXL has started its flight test program. The first of five BelugaXLs to enter service next year took off from Toulouse on July 19.

The crew in the cockpit on board this flight comprised Captain Christophe Cail, Co-Pilot Bernardo Saez-Benito Hernandez and Test Flight Engineer Jean Michel Pin.

The monitoring of the aircraft systems and performance in real time at the flight test engineer's station was conducted by Laurent Lapierre and Philippe Foucault.

The BelugaXL will gradually replace the BelugaST transporters. It was launched in November 2014 to address the transport and ramp-up capacity requirements for Airbus beyond 2019.

The new oversize air transporters are based on the A330-200 Freighter, with large reuse of existing components and equipment.

Toulouse, France

READ MORE ONLINE

// TEJAS FIGHTER STEPS TOWARD SEA TRIALS

The naval variant of India's Light Combat Aircraft, also known as the Tejas, has been landed successfully with an arrestor hook system for the first time.

The successful test was conducted on July 23, 2018, at the Shore Based Test Facility at Hansa, Goa. The LCA Naval Prototype 2 (NP2), piloted by Captain Shivnath Dahiya, safely used an arrestor hook system at moderate taxi-in speeds. The arrestor hook was designed and developed by Hindustan Aeronautics' (HAL) Aircraft Research and Design Centre.

The Carrier Compatibility trials being conducted by NP2 are the final tests before sea trials are carried out on an actual deck later this year.

The HAL Tejas is an indigenously developed single-seat, single-jet engine, multirole light fighter. Development started in 1984 and the Mark 1 version of the aircraft is planned to be delivered to the Indian Air Force by the end of this year.

Bengaluru, India

// CHINA TESTS FIRST HYPERSONIC AIRCRAFT

China has successfully tested a hypersonic aircraft, according to China's Academy of Aerospace Aerodynamics (CAAA).

The waverider, called the Starry Sky 2, was launched from a multistage rocket on August 3, and during flight performed extreme turning maneuvers while maintaining velocities of above Mach 5.5 for more than 400 seconds. According to a statement from the CAAA, it achieved a top speed of Mach 6, or 7,344km/h (4,563mph) and reached an altitude of 30km (19 miles).

Videos of the successful launch and test were posted and widely shared online.

A waverider is a hypersonic aircraft with a wedge-shaped fuselage that is designed to improve its supersonic lift-to-drag ratio by using the shock waves generated by its own flight as a lifting force.

Beijing, China

WATCH THE VIDEO ON OUR WEBSITE

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ZEPHYR DRONE BREAKS ENDURANCE RECORD

Airbus's Zephyr high-altitude drone has logged a maiden flight of 26 days and could fly for up to 100 days, according to the engineer in charge of the project. The solar-powered Zephyr S, which Airbus calls a High Altitude Pseudo-Satellite (HAPS), achieved the world record after taking off on July 11 from Arizona.

The test flight proved the system capabilities and achieved all the flight's engineering objectives. The previous record for the longest un-refueled flight – 14 days – had been held by a Zephyr prototype since 2010.

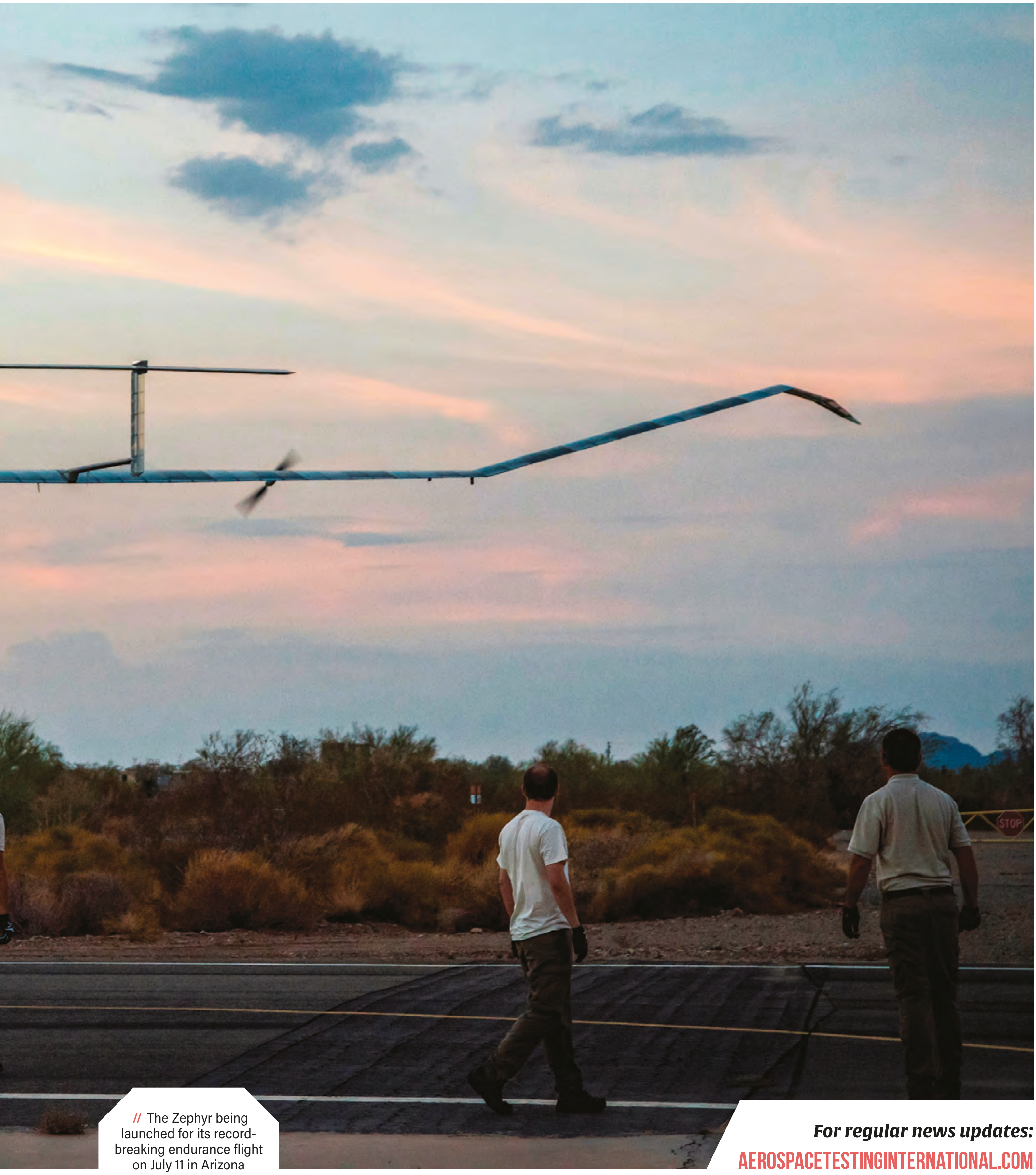
Jana Rosenmann, head of unmanned aerial systems at Airbus, said, "This successful maiden flight represents a significant milestone in the Zephyr program. In the coming days we will start the preparation of additional flights planned for the second half of this year from our new operating site at the Wyndham airfield in Western Australia."

Speaking at the Farnborough Airshow in July, Rosenmann said the drone could fly continuously for up to 100 days: "We are focused on altitude. It is important for Zephyr to fly in the stratosphere so that it is above air traffic and adverse weather. The other important aspect is proving the endurance. We think the design can do 100 days. The data we are getting from the tests so far is extremely positive."

Zephyr runs exclusively on solar power at altitudes of up to 59,000ft. The Zephyr S is equipped with cameras, but it has been designed to use a variety of payloads.

Potential civil applications for the Zephyr include providing imagery, live video streaming and internet connectivity. For defense, the Zephyr can be fitted out to provide a "connectivity backbone" for military operations and could also be used for surveillance activities, said Airbus. "It's fine to be flying, but we also need to offer a capability as well," said Rosenmann.

Two versions of the drone are being developed. The Zephyr S is configured with a single tail, while the Zephyr T will have a twin tail and be able to carry a heavier payload. \\



// The Zephyr being launched for its record-breaking endurance flight on July 11 in Arizona

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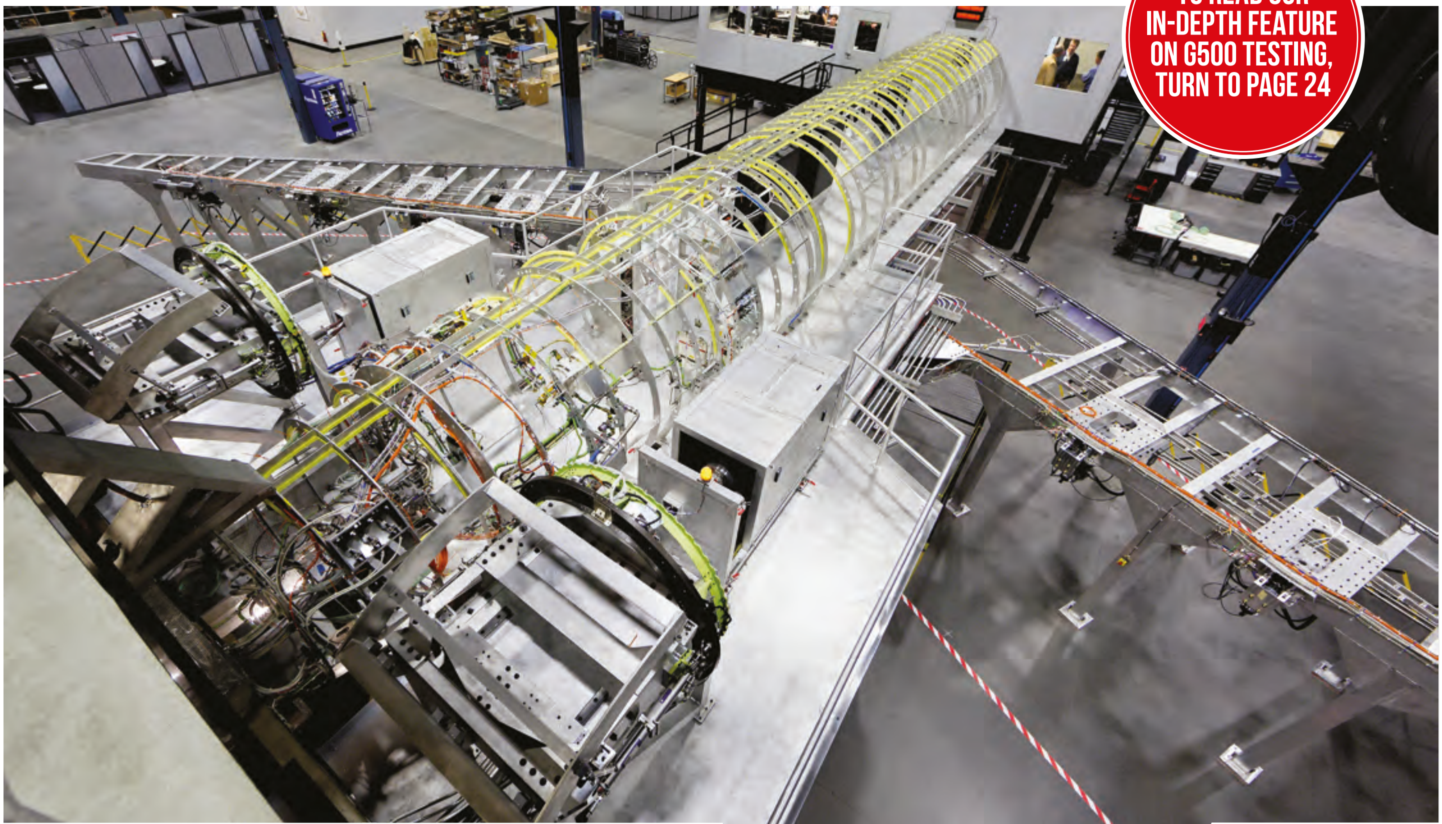
TO READ OUR IN-DEPTH FEATURE ON G500 TESTING, TURN TO PAGE 24



// The Gulfstream G600 iron bird completed its 'first flight' back in February 2016

G600 BEGINS FAA CERTIFICATION

Gulfstream's G600 jet is undergoing its certification field performance testing after its stablemate, the G500, received its type and production certificates in July. The twin-engined, large-cabin business jets, which were first revealed in October 2014, share a top speed of Mach 0.925, with the larger G600 having a range of 6,500 nautical miles (12,000km) compared with the G500's 5,200 nautical miles (9,630km).

Mark Burns, president of Gulfstream said, "We continue to make steady progress toward certifying the G600 later this year and beginning customer deliveries in 2019."

The G600 has already completed the ice shape and stall speed testing for its FAA certification. Since first flight, the five aircraft in the G600 flight test program have flown more than 2,290 hours during 600 flights.

Prior to flight tests, both aircraft were tested in new laboratories at Gulfstream's Savannah headquarters, built for the joint G500/G600 development program. More than 57,000 hours of lab testing was conducted before their first flights.

The labs contain a simulation environment to develop fly-by-wire controls and perform human factors evaluations; a systems integration bench; a full flight deck integration test facility to evaluate major avionic and aircraft systems and software; an outfitted cabin to test the galley; and iron birds to evaluate the fly-by-wire flight controls, hydraulics, electrical systems and landing gear. \\

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BOMBARDIER ADDS ANOTHER GLOBAL TO TEST FLIGHT PROGRAM

Bombardier is making steady progress testing its most recently announced Global Express business jets after adding the first Global 5500 test aircraft to the program. Both the Global 5500 and Global 6500 long-range, large-cabin jets are powered by 15,125 lb-thrust Rolls-Royce Pearl 15 engines. The use of the Pearl engine was a surprise announcement made during the unveiling of the Global Express 6500 flight test vehicle (FTV) at the European Business Aviation Conference and Exhibition in May.

The Global Express 5500 has a range of 5,700 nautical miles and can carry up to 16 passengers, while the 6500 has a range of 6,600 nautical miles and can carry up to 17. The aircraft have a top speed of Mach 0.9 and are 13% more fuel efficient than existing Global Express aircraft.

The improved performance is thanks in main to the Pearl 15 engine, which was certified in February after a month of secret tests on the Global 6500 FTV in Wichita, Kansas.

The new Globals also incorporate many features developed for Bombardier's Global 7500 business jet. They include a lightweight wing with a reprofiled trailing edge to improve aerodynamics and leading-edge devices that enable a steep approach to runways.

The Global 5500/6500 test flight program is on track to enable entry into service before 2020, said Bombardier.

Meanwhile Bombardier's Global 7500 ultra-long-range business jet is close to finishing certification flight tests, with first delivery planned for before the end of this year. The company is ramping up production.

The Global 7500 is the largest and longest-range business jet ever developed. The aircraft has a range of 7,700 nautical miles and capacity for up to 19 passengers.

Bombardier has so far completed full-scale structural testing of the aircraft on the complete airframe static test rig.

Full-scale fatigue testing has also been executed according to Bombardier's planned schedule. The company has also validated the interior sets for the Global 7500 in a test rig that replicates the conditions and motions of flight using a production fuselage mounted on a pneumatic bed. \\

// The Global 6500 FTV was revealed at EBACE and during flight tests at Wichita, Kansas (inset)

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// Commercial spacecraft test flight crew (top) and the Boeing Blue IVA suit worn by Chris Ferguson

STARLINER FLIGHT CREW PREPARES FOR LAUNCH

Space agency NASA has revealed the astronauts that will fly on the first USA-made, commercial spacecraft to and from the International Space Station next year. The first manned test flights of Boeing's CST-100 Starliner and SpaceX's Crew Dragon will be the first time, since 2011, that astronauts have been launched from the USA.

The astronauts for the first test flights are (above left, from left to right): Sunita Williams, Josh Cassada, Eric Boe, Nicole Mann, Christopher Ferguson, Douglas Hurley, Robert Behnken, Michael Hopkins and Victor Glover.

Chris Ferguson, the Boeing astronaut who will fly the Starliner on its maiden crewed flight, will become the company's first astronaut test pilot.

Ferguson and his two NASA crewmates will wear the 'Boeing Blue' intravehicular activity (IVA) suit during the flight. It was developed in collaboration with David Clark Aerospace, the company that supplies most NASA spacesuits, including the space shuttle suits.

According to Boeing, the Starliner suit has gone through multiple iterations and prototypes as the designers received input from several sources, including Ferguson, the Starliner's director of crew and mission systems.

"It took about two-and-a-half years to design and manufacture the Starliner spacesuit we see today," said the company. "We are continuing to test the spacesuit with astronauts and the spacecraft itself here on the ground before they are worn by astronauts during ascent and re-entry." \\

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ULTRA-THIN CAPACITIVE SENSORS

Prof. Ron Miles at Binghamton University, New York, has developed an acoustic sensor 50 times more sensitive than conventional microphones

Capacitive sensors are used in billions of products to detect motion and sound. Virtually all of the two billion miniature microphones that are produced annually rely on capacitive sensing to convert the motion of a pressure-sensing diaphragm into an electronic signal.

Devices for sensing motion or pressure use a similar principle, but a lightweight and flexible compliant element is used, which moves when the slightest amount of force is applied to it. The element has to be lightweight and flexible, so it moves easily. The motion of the element is transduced into an electronic signal by detecting the change in capacitance between it and a fixed electrode as it moves.

Unfortunately, to detect this change in capacitance, a bias voltage must be applied between the moving element and the fixed electrode. The higher the bias voltage, the more output signal is produced.

This bias voltage imposes a force on the moving electrode that can hinder its movement or cause it to collapse against the fixed electrode. Such sensors must therefore always have moving electrodes that are stiff enough to resist this imposed electrostatic force. At the same time, the pressure sensitive diaphragm has to have enough stiffness to resist the attractive force of the electric field created by the bias voltage. The mechanical restoring force of the moving diaphragm must ensure the electrodes do not collapse into each other. The diaphragm must also be flexible, so it can move, while remaining stiff enough to enable capacitive sensing. Designers don't like to compromise between two opposing requirements, so we tried to find a new way to use capacitive sensing that avoids this conflict altogether.

To create a capacitive sensor that doesn't result in adverse electrostatic forces being applied to the moving element, we devised a three-electrode arrangement. The approach completely avoids instabilities and minimizes the electrostatic forces.

Our recent results show that by including two fixed electrodes with one moving electrode, one can achieve negligible electrostatic stiffness while ensuring stability. This enables the long-sought goal of using electrostatic sensing with highly compliant and sensitive electrodes.

We used this electrode arrangement to create a microphone in which the diaphragm was as flexible as possible, enabling it to respond to tiny fluctuations in the air in a sound field. This capacitive sensing approach minimizes the influence of electrostatic forces. The extremely compliant electrode may be used with bias voltages as high as 400V, without influencing its motion. Despite the use of a large bias voltage, our results demonstrate that the electric field does not result in stiffening or softening of the motion of the moving electrode. The electric field has no noticeable effect on the response as a function of driving frequency. This electrode arrangement enables the use of very high bias voltages without adversely affecting the electrode motion, meaning an acoustic sensor could be created that has very high sensitivity of 0.5V/pascal, approximately 50 times that of conventional microphones.

While our initial study created microphones for audio frequency applications, this approach could also be used to create sensors for very low frequency sound (infrasound), as well as accelerometers and other motion sensors. \\

// BEN SAMPSON

Where data is

// The Boeing 787-10 completed its first flight in March 2017

NG

Competing pressures and the need to innovate are just some of the factors shaping the instrumentation on Boeing's flight test programs


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1 // Flight test instrumentation is installed on the first aircraft as they are assembled

Any modern tech guru will readily tell you that data is the most valuable asset to a business in the 21st century. That may well be the case, but to an engineer like Rick Stiers, instrumentation solutions architect at Boeing, it's old news. During his 40-year career in aerospace testing, data has always been a precious commodity.

Boeing Commercial Airplanes has never been busier. Engineers are currently working on the 777X. The 737 MAX 10 and potentially the NMA (New Mid-Market Airplane) are in the pipeline. These aircraft will cost many billions of dollars to develop. The cost puts tremendous pressure on the flight test programs for these aircraft, which will cost hundreds of millions of dollars through to certification.

At a recent event organized by aerospace equipment company Zodiac in Paris, the question "How can industry help the aerospace test community?" was posed. Speaking at the event, Stiers described how data – what it is being used for and by whom, and its costs – shape the specification, design and installation of the flight test instrumentation (FTI) used during the modern day flight testing of Boeing's commercial airliners.

CUSTOMER SATISFACTION

The first step in defining the FTI is to define the testing requirements. This starts with identifying who will use the data and defining what they want. Stiers says, "When working out the testing requirements for FTI, there are lots of customers and consumers to consider. It's a very complicated environment and some of the customers are completely disassociated from what we do.

"The aero-performance people care about steady-state pressure-altitude down to centimeters. The stability and control team operating in a dynamic environment with accuracies in the range of 5-10 meters. These are fundamentally two different requirements. How do you rationalize all of the data acquisition and the varying requirements for the same single parameter of pressure-altitude?"

A dozens-strong team collates the requirements for the data from the various groups, categorizes all the tests and produces a comprehensive plan. The flight test program starts with the safety tests, then the basic performance characteristics such as inflight restarts, and then moves on to the performance-related categories such as fuel consumption and roll-rate responses.

As part of planning, the FTI team validates the requirements, the system design and allocation, and accounts for any new product introduction issues and the costs associated with them. Preparations for a flight test program can start up to three years in advance. "Once we know the requirements we start making design decisions for the FTI and physically modifying a commercial jet. The certification organizations also have to be provided with documentation of all the changes," says Stiers.

The FTI team will examine if it is possible to reuse existing flight test installations and aircraft for flight test programs at this stage to reduce costs.

THE QUEST TO LOWER COSTS

The pressure to reduce costs has meant that flight test instrumentation engineers increasingly turn to COTS and consumer technology to instrument aircraft. However, according to Rick Stiers, instrumentation solutions architect at Boeing, things are rarely as simple as buying a GoPro at your local electronics store and gluing it to the outside of an airplane.

"A GoPro costs US$400, whereas an FTI camera costs US$2,500 and needs a wire," says Stiers. "We do use GoPros where appropriate, but some measurements still require an FTI camera. But sometimes they are not suitable."

A recent example was the need to look at a test aircraft's trailing static device. A camera was placed on the aft-faring behind the rudder. A GoPro was unsuitable because the aircraft was going to fly at 40,000ft, where the air temperature is -60°C (-76°F). The camera's battery would not have lasted long enough – only around 15 minutes in that environment.

On the other hand, Boeing has had great success with the replacement of all of the FTI monitors. A traditional FTI video monitor can cost up to US$8,000. The monitors need to meet basic flight safety requirements for commercial flight tests; traditional FTI monitors, which are designed for military use, are over-engineered for commercial use. Working with a company specializing in equipment ruggedization, Boeing has reduced the cost of a 23in HDMI 1080P FTI-qualified monitor to US$972 per monitor instead of several thousand dollars each.

"The pressure is sometimes emotional and irrational to not buy a simple solution. You need to understand the requirement," says Stiers.

"How can industry help the aerospace test community?"

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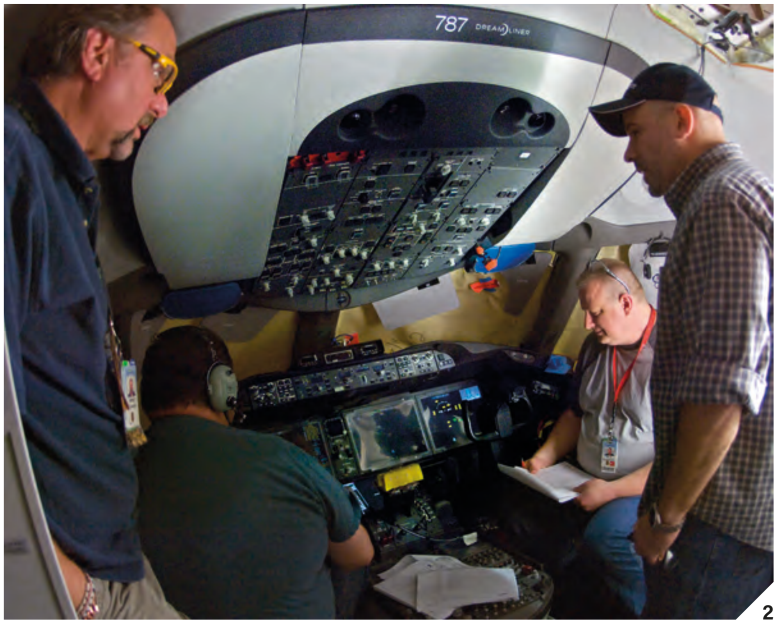

2

2 // The 747-8 freighter exits the assembly line for the first time

3 // Electrical testing prior to first power-on can take up to a week

For example, when flight testing the next-generation 737, the team was able to reuse some existing testing installations. But some things, such as the instrumentation interface designs, had to be completely new. Similarly, another cost-associated decision made during the planning stage was whether to use custom new hardware and software, which is more expensive and has longer lead times, or to use COTS equipment and software.

"All our systems are used to take certification data for new production introductions, so they have to be calibrated and certified for accuracy," says Stiers. "That means pushing calibration systems to the limit. In some cases the calibration systems are no better than the data acquisition systems themselves, which is a conundrum."

MULTIPURPOSE DATA

A primary driver when designing FTI is what the data will be used for, such as flight manuals, certification, troubleshooting and computer models. The data is also often used to improve simulators for pilot training. "The data has to validate the structural design, performance and stability and control. Then we demonstrate the aircraft to the certification organization," says Stiers.

"The data we produce is put into simulators to refine computer models for the next product. Terabytes of data are put into a big data warehouse. It's used for computational fluid dynamics, the aero-models, the kinematic models, the structural loading, the wing bending and twisting, and dynamic flight models. These uses are perhaps the greatest value the data has."

According to Stiers, the data from flight testing has a long life and is used decades later. Data recorded during flight tests of the Boeing 747-400 in 1990 were recently used to compare with the results from flight tests of the Boeing 747-8.

REDUCING COSTS

The instrumentation has to cater for each different stakeholder's requirements and the competition to meet these requirements can sometimes create cost pressures on budgets. Innovation within the FTI can provide a solution to mitigate high costs. Stiers explains, "For example, a consideration may be where to position the pressure/altitude sensor. If you just put flush-mounted ports on the skin, the data is okay for some users but not others.

"In particular, aero performance work requires a trailing device with a precision fidelity of 4cm [1.6in], it is a complex and expensive measurement."

Another challenge for the FTI team is validation. It is essential that the team can validate that they are measuring the correct things, and not performing too many tests. "We test really big airplanes with up to 5,000 analogs and 250,000 digital parameters," says Stiers. "But we also have to do quick-and-dirty tests with just 10 parameters.

"How can industry help? We need systems that are scalable in fidelity, bit rate and accuracy so we can pick the correct systems and hardware for particular test cases. There is a constant

BOEING'S NEW MIDSIZE AIRPLANE

Most industry commentators have pegged Boeing's New Midsize Airplane for a mid-2020s service entry.

Also known as the Boeing 797 and the New Midmarket Airplane, it would replace the 757 and 767. Several airlines have expressed strong interest in the concept aircraft. Predictions are that it will seat from 220-270 passengers and have a range of 5,000nm.

Boeing has yet to formally announce the development of the NMA, although some believe it could launch during early 2019 and enter service in 2025 – if the engines such an aircraft would use are ready in time.

"The whole time, everything has to be done better, faster and less expensively"

balance to be struck between cost versus value and cost versus affordability."

For a typical flight test program, Boeing will fly four to six jets for up to 12 months. The FTI configuration and the work required to install it is started up to a year before they are scheduled to fly. For a major test campaign FTI is installed in the factory in parallel with the production build.

"Depending on what instrumentation you are installing, you might have to go into the factory six to eight months early," says Stiers.

Despite the numerous internal pressures on flight test programs, Stiers still welcomes competition from Airbus. "There is huge competition between cost, affordability and performance between Airbus and Boeing for commercial jets," he says. "Without a good competitor you can become stale."

The competition is having a direct effect on FTI in three areas, measurement system accuracy and fidelity is increasing at the same time affordability is becoming more of a concern. Performance margins on aircraft are tighter. Manufacturers also have to be able to make guarantees to customers on performance-related aspects of aircraft, such as mileage, passenger loading and speed of boarding.

"At the same time, every generation of aircraft incorporates new technology," says Stiers.

"The 787 used graphite and had new engines. The 737 has very compact engines, which presented their own unique set of problems.

"And the whole time, everything has to be done better, faster and less expensively. We have to be more flexible, adaptable and we have to be able to create new versions of our test systems quickly and efficiently."

Stiers believes that one of the best ways for FTI engineers to deal with new technology and the challenges it brings is to adapt a flexible approach to data acquisition. Boeing has been using Zodiac XMA data acquisition systems "in a lot of nasty places". This includes in engines and wheel wells to measure temperature at an accuracy of 1,000 parts per million, across a temperature range of -40°C to +85°C (-40°F to 185°F).

An advantage of the XMA DAU (Data Acquisition Unit) is the firmware can be changed and adjusted to handle a variety of different parameters. The module's personality is configurable through the firmware and can be reprogrammed through the setup process to measure a whole host of data types, from millivolt level strain gauges to thermocouples, all on the same hardware. "These capabilities enable us to do more things with the hardware, making us more agile," says Stiers. "The firmware change capability provides a plethora of digital filters that can emulate other parameters.

"Flight test instrumentation requires flexible, adaptable solutions that are less hardware-intensive, with a wide variety of data acquisition and processing options that can be exercised after the hardware is done. It needs scalable solutions that can deal with 10 to 5,000 parameters."

With lead times years in advance, demanding airline customers, internal stakeholders that require more data for more different purposes – as well as external competition – the pressures have never been greater on flight test programs. It would seem that remaining agile and affordable with the use of new and COTS technology is essential to meeting test requirements and dealing with competing pressures. \\

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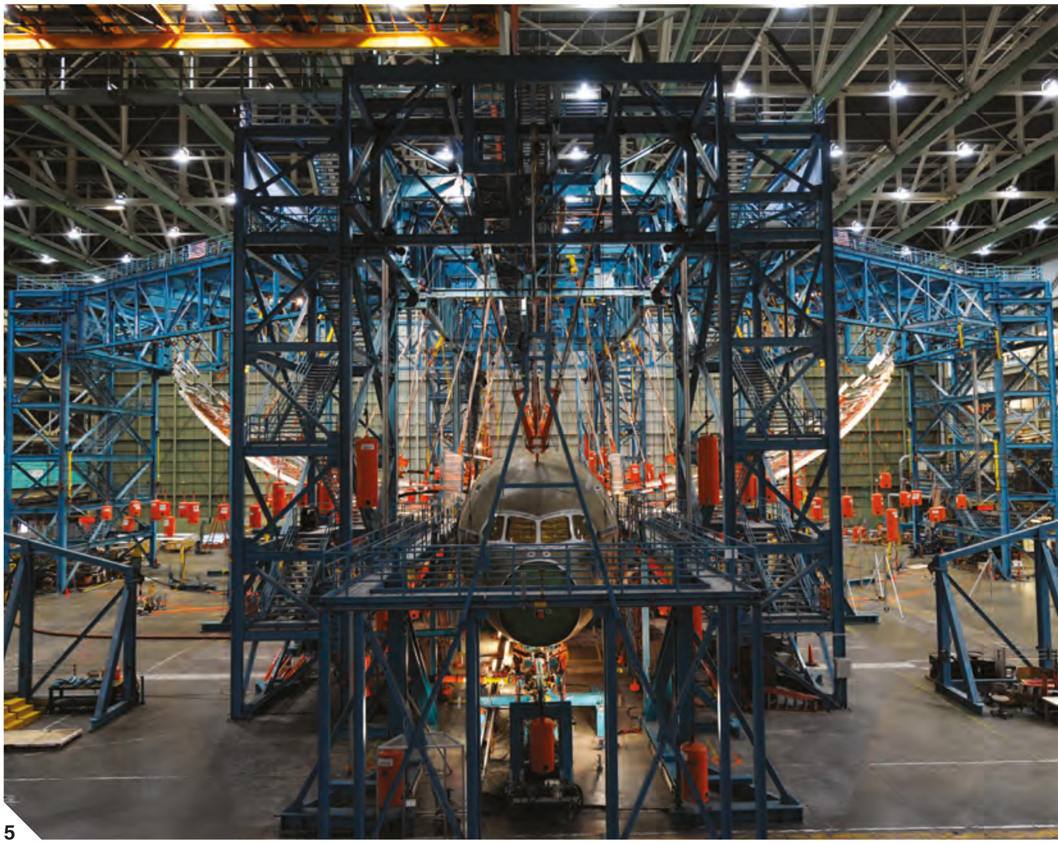

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4 // Engineers reused existing installations when testing the 737-800

5 // Ultimate load testing on the 787 Dreamliner's wings before flight testing

// PAUL E EDEN

G50

// Gulfstream made extensive use of simulators as its crews prepared for flight tests and some of the more complex ground trials

00 is go

Having found additional range in its G500, Gulfstream extended the type's flight test program into 2018. With FAA certification awarded, the airframer is working toward certifying the closely related G600 this year

1 // Successful conclusion of a high-speed taxi run in 2015

2 // Preflight cockpit checks before the maiden G500 flight

3 // The cabin was already equipped with test stations for that first flight

1

2

3

PROVING THE EXTENDED RANGE

After it announced additional range for the G500 beyond its original design goals, Gulfstream began further trials to prove the machine's extra capability. Gulfstream's Colin Miller says the extra testing work included:

- Analytical effort to validate fuel capacity, vent volume, gross weight and center of gravity
- Fuel system modification, including changes to the fuel quantity measuring system
- Validation of the required system changes
- Ground tests to validate the increased volume
- Flight testing in order to validate the performance
- Cold-weather testing and flights into known icing

Assuming there's at least a grain of truth in the maxim 'If it looks right, it is right,' Gulfstream's new G500 must be very right indeed. On July 20 the OEM announced that the G500 had been awarded its type and production certificates on the same day, an achievement Gulfstream president Mark Burns said "...speaks of the rigor inherent in the G500 program and the commitment to excellence of the entire Gulfstream team".

Rigor and engineering excellence were exemplified in the five-aircraft test program, as Colin Miller, vice president of flight operations at Gulfstream, describes. "Four aircraft were highly instrumented and outfitted with engineering test stations in their interiors. The fifth, Production-1, was an experimental aircraft with a complete interior and fully functional cabin systems.

"P1 flew more than 140,000 miles [225,300km] of operational testing around the world. In total the G500 flight-test program involved more than 75,000 lab test hours and in excess of 5,000 flight hours."

First flight is often quoted as the most memorable date in an aircraft program. But the G500's, on May 18, 2015, was in reality little more than a proving flight for the lab trials and crew training already completed.

"First-flight crew simulations were flown in Gulfstream's engineering laboratories," says Miller. "The crew spent hundreds of hours in simulators prior to the initial sortie. Simulator work-ups included practice in normal and emergency procedures, developing and practicing crew resource management protocols and techniques for everyone involved, including test pilots, flight test engineers, control room personnel and chase aircraft aircrew. The enterprise had accomplished more than 30,000 hours of pilot-in-the-loop and hardware-in-the-loop testing before that first flight."

30,000 HRS
Pilot-in-the-loop and hardware-in-the-loop testing before the G500's first flight

75,000 HRS
Laboratory test hours exceeded

Gulfstream built test labs for the combined G500/G600 development and test effort and conducted most of the subsequent flight tests from the facilities immediately adjacent. Miller says, "The Gulfstream Flight Test Center is a short distance from the engineering labs at our headquarters in Savannah, Georgia. Throughout flighting program we used the labs to train aircrew, rehearse difficult and high-risk test points prior to flight, troubleshoot anomalies, and prototype design improvements integrated into the aircraft during development."

However, there were inevitably a few test points for which flying from

4 // G500 P1 demonstrated the type's complete cabin fit and functionality

5 // Time spent in the iron bird proved cockpit and flight control systems long before first flight

"Simulator rehearsal was critical for some ground tests"

Savannah simply wouldn't do. "For environmental testing, the aircraft was first evaluated in the McKinley Climatic Laboratory," says Miller. "Later, cold weather testing was accomplished in Iqaluit, Canada. Hot weather testing took place in Arizona and high-altitude testing was performed in La Paz, Bolivia."

0.925 MACH
Maximum operating speed

51,000FT
Maximum cruising altitude

REAL-TIME ANALYSIS

Data collection methods varied with each mission. The highly instrumented test airframes were capable of employing telemetry for real-time analysis. "In general real-time analysis was used for envelope expansion tests – flutter and loads, for example.

"Aircrew would perform a maneuver in a build-up sequence, pausing between maneuvers for data analysis and clearance to continue closer to the edge of the envelope," says Miller. "For most other tests, data was collected and either analyzed post-flight or archived for possible future use. The data-analysis team included more than 50 flight test engineers and a full complement of discipline engineers."

A typical envelope expansion flight crew included two test pilots and one or two flight test engineers. For avionics development sorties, a fourth crew member could be added, while cabin testing was an altogether more populous affair, the aircraft typically embarking a full complement of test engineers and technicians.

Crews worked closely together pre- and post-fight, as well as during the sorties themselves. "Test and safety plans were largely developed before first flight," Miller says. "As the team progressed through the test program, flight test engineers were assigned in teams to execute individual test plans. Prior to each mission, the flight test engineer assigned to the mission would select a subset of test points from the test plan, based on progress to date, and prepare test cards for the crew.

"In the morning, the test team would meet for a preflight briefing. If the testing was particularly challenging, they would likely rehearse the flight in a simulator the day before. On the day of the test, the team typically flew up to three sorties, but could fly five or more depending on the type and duration of the tests."

Simulator rehearsal was also critical for some ground tests, including assessments of braking efficiency, aborted take-off performance, engine-out behavior and wet runway performance. Miller says that Gulfstream treats this type of potentially dangerous ground trial exactly as it does those in the air.

PROVING THE DATA

But with so much lab testing prior to first flight and the continued effort once the jet was flying, surely there was very little

JUST A LITTLE MORE

The G500 and G600 both have twin Pratt & Whitney Canada PurePower PW800 powerplants, and similar wing and fuselage design. The G600's 15,680 lb thrust PW815GA turbofans – compared with the G500's 15,144 lb thrust PW814GAs – enable a 94,600 lb maximum take-off weight, in contrast to the 79,600 lb for the smaller G500 jet.

Gulfstream has announced its intention to certify and deliver the G600 during 2018. That schedule appears to have been little affected by the additional G500 trials.

Gulfstream's Colin Miller confirmed recently that certification is expected "later this year".

"When results don't match predictions, we investigate"

for the flight test crews to accomplish other than prove the lab data? Not quite, Miller reports: "There are always some surprises in test programs. To ensure safety, the test team approached all hazardous testing in a build-up fashion, ensuring results matched predictions before continuing toward the edge of the design envelope.

"When results don't match predictions, we investigate. It may result in only an airborne pause while engineers analyze data, or it may require a return to base and an overnight evaluation. In cases where unexpected results may affect the fleet or other lines of testing, we have an incident reporting system that lets the entire test team know about the event and planned next steps."

With the G500 being a long-range, long-endurance machine, crews had to conduct a number of extended trials, during which it could have been possible for individuals to lose focus. It was therefore necessary to ensure exemplary crew resource management was carried out.

"On these longer missions, pilots alternate flying test points and all aircrew – including and often especially the engineer – are diligent about checking configuration and test conditions before starting a test point. In addition, crews often have an opportunity to land and step out of the aircraft at least once."

5,000
Flight hours exceeded for the G500

140,000 MILES
Global operation testing exceeded for the G500

Gulfstream had originally expected to certify the G500 in time for first customer delivery before the end of 2017, but announced a range extension for the aircraft during October 2017's National Business Aviation Association Business Aviation Convention and Exhibition in Las Vegas. Flight trials had revealed a range in excess of predicted figures, an unexpected bonus that required some additional testing before Gulfstream could release the aircraft to customers.

Around nine months later, with trials complete and certification documents verified by the FAA, the G500 was ready for delivery. At this point, the type's test program might be considered complete, but business aviation is competitive, so Gulfstream will continue G500 trials for as long as the model remains in production. "We typically keep one aircraft of each model available after certification for follow-on testing," Miller says.

There's also further work to be done on the larger, longer-ranged, yet closely related G600. "The G600 is largely common with the G500 and benefits greatly from G500 certification. Overall the G600 will require about 40% of the effort for certification that the G500 did. The tests performed on the G600 will be a subset of, and almost identical to, the tests performed on the G500. We expect certification later this year." \\

6 // G500 T1 mounted an instrumented test boom as flight test got underway

7 // T1 flew undercarriage checks on this, its second sortie, on May 20, 2015

6

7

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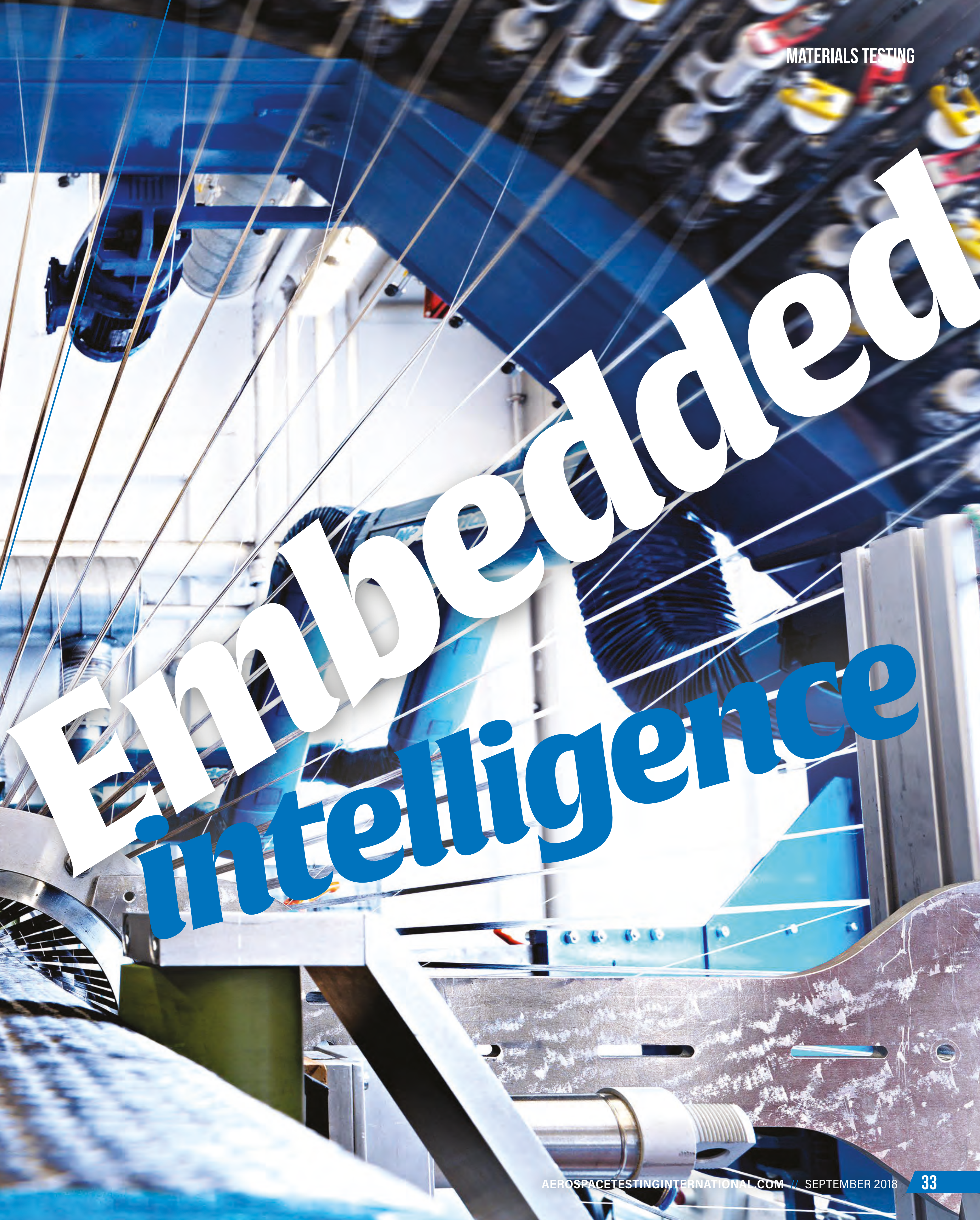
// BEN SAMPSON

Despite teething problems, researchers still believe embedding sensors inside composite materials will improve the way stress and strain are measured in aerospace

// Strands of carbon fiber are weaved together to make composite materials for Airbus aircraft



Embedded intelligence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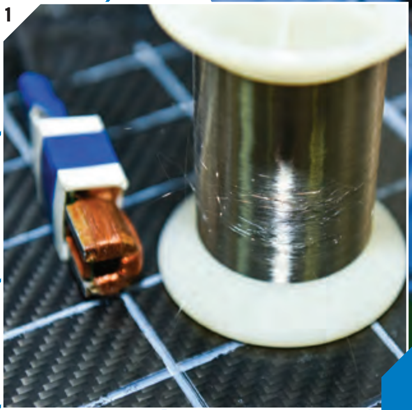

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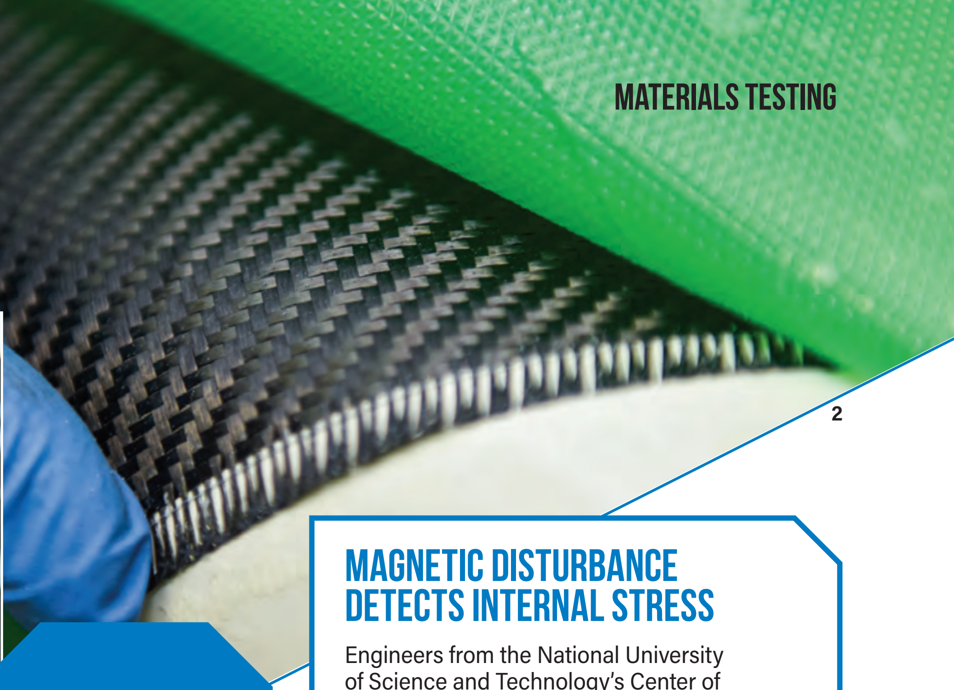


1,2 // Carbon fiber with embedded circuitry to detect cracks, developed at the Center for Composite Materials in Moscow

The *in situ* monitoring and testing of composite materials isn't a new idea. Since the 1980s researchers have developed many methods and technologies for the purpose. These include the embedding of fiber optics to form Fiber Bragg Grating (FBG) sensors, the use of piezoelectric crystal, which is formed on very thin polymer substrates, or PVDF (polyvinylidene fluoride), an active polymer on thin sheets used to measure vibration.

The most popular area of research has been the embedding of FBG sensors to measure local strain. These sensors use light that runs the length of the strand. The devices integrate with electronic instrumentation in the same way as in fiber-optic telecoms equipment.

There are a number of benefits to embedding FBG sensors in composites to measure stress and strain. They can record data on forces in a non-disruptive manner and weigh less than strain gauges. They also provide an increase in the amount of data and the speed at which it is recorded. "You can integrate a large number and you don't need a lead in and a lead out of the material – with no wires there is no weight. Also, because it is integrated into the material it makes the sensors more durable," says Dr Kara Peters from North Carolina State University, who has worked in the field of embedded sensors for more than 20 years.

There are a number of attractive applications in aerospace. Integral FBG sensors could be used to detect deformation in wings and the pressurization of the fuselage. "There are also people working on high-temperature applications," says Peters. "Having information rapidly available about an engine failure, say in a blade, could be critical in minimizing and avoiding damage.

"Likewise, being able to detect early signs of a structural failure from fatigue has similar advantages."

The other area that embedded sensors could help with is in quantifying aircraft impacts in the air and on the ground. Several inspection methods – ultrasonic, acoustic and thermographic – are used to assess the damage from an impact. Data from BG sensors could help speed up the process of identifying damage from an impact considerably.

5-10 HRS
Time before a US Army helicopter requires some form of maintenance

Nevertheless there have been very few commercial and industrial applications of FBG sensors in the last 25 years. NASA has used composites with embedded fiber-optic sensors in solar-powered, experimental drones and in high-pressure fuel tanks for rockets, primarily because they don't cause interference or sparking in these environments.

Peters believes that the primary reason the technology hasn't caught on, despite the potential advantages, is that aerospace companies are comfortable with the materials and testing methods they currently

MAGNETIC DISTURBANCE DETECTS INTERNAL STRESS

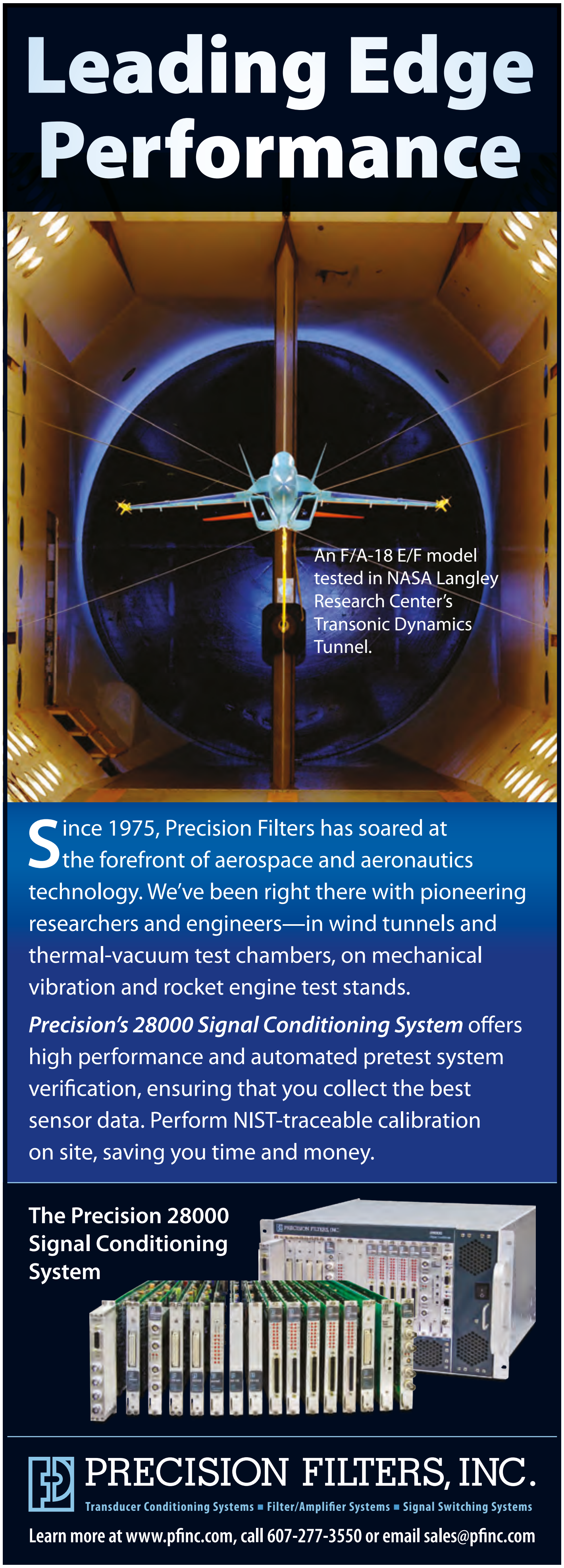
Engineers from the National University of Science and Technology's Center of Composite Materials in Moscow have developed a non-contact method of internal voltage control in polymer composites, which they say can be used to assess internal damage in composites.

The three-year project is being tested using fiberglass-based composites and epoxy binders. During the manufacturing stage, the researchers laid wires just 10-60µm in diameter between the layers, to form amorphous soft magnetic circuits.

The micro-wires of the grid are affected by stresses in the material. By measuring variations in the wires' magnetic field, data about a defect or crack can be obtained using a non-contact measuring process before the defect or crack propagates.

Crucially the researchers say they have developed manufacturing methods that enable the wires to be placed in the composite material without degrading it. The technique has been shown to members of the aviation and space industries and, according to Andrey Stepashkin, senior research associate at the Center of Composite Materials, engineers are now working on a prototype to flight test.

"In the future this technology will allow the monitoring of the structure of the wing and fuselage of aircraft in operation," says Stepashkin. "We have made the first step of a long journey, but we already see a practical application for our development."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An F/A-18 E/F model tested in NASA Langley Research Center's Transonic Dynamics Tunnel.
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3 // Continuous Composites' manufacturing process can be used to embed sensors

use: "Composites are complex materials. Getting them certified, understanding their failure modes and lifetime, is complex enough. There is hesitancy from aerospace companies because they are aware of the amount of work that has to be done. Also, putting a fiber-optic cable into a material creates additional complexity and may reduce its lifetime."

Any change in fatigue loading could introduce a new failure mechanic or change the way an existing failure interacts with its surroundings. There are also restrictions on the shape and form that composites with embedded sensors can take. "The major consideration is that you can't make 90° corners with a fiber-optic strand. You have to maintain a certain radius for it to work."

10-60µm
Thickness of the layer of wires Russian researchers are using to detect stress in composites

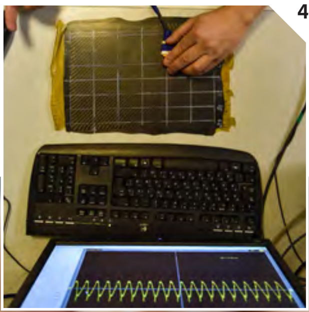
DRIVERS FOR CHANGE

Phil Irving, professor of damage tolerance at Cranfield University in the UK, believes that people are reluctant to use embedded sensors simply because they cannot be accessed if they need to be repaired. "Another problem is that if, for example, you put them in a wing to detect strain, the fiber-optic strands have to be very dense, because each strand can only detect damage when it is very close to itself.

"There's been a lot of papers and research, but it's these sorts of issues that have put people off. There isn't the need driving the development. The cost of regular manual inspections is high, but current methods work well and people are willing to pay."

According to Irving, Boeing and Airbus are both running trials of FBG technology. "The trials are at the level of single aircraft and are using strain gauges and Bragg sensors," he says. "They are collecting data to assess reliability and see if there is a need to take the technology further."

A more compelling use for embedded sensors, believes Irving, is in helicopters: "Helicopters are much more likely to suffer catastrophic damage in the engine



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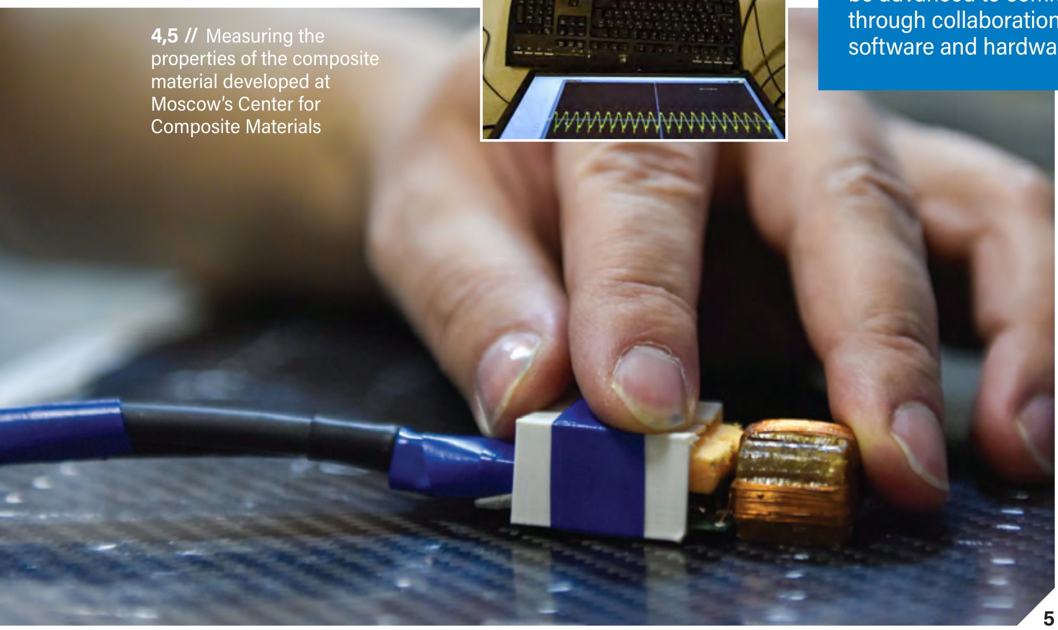

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4,5 // Measuring the properties of the composite material developed at Moscow's Center for Composite Materials

FUNCTIONAL FIBERS

Tyler Alvarado is CEO of Continuous Composites, a company based in Coeur d'Alene, Idaho, developing technology that more easily embeds fiber-optic sensors in composites.

What is your technology?
We are developing 3D printing technology that prints continuous structural and functional fibers, using a robot on a moving platform. It's not restricted to any particular type of fiber and does not require water, autoclaves or molds. Our technology is scalable with the ability to print structures with a 3m [9.8ft] radius and about 4m [13.1ft] high. We're currently building another work cell that will enable us to print items 8m [26.2ft] high by 15m [49.2ft] wide.

What can your machines do in terms of sensing technology?
We can easily print structures with the most advanced fiber-optic sensors already in them. For example, a car or aircraft with these fiber-optic sensors could collect data about stress and strain while in use. One application for this data could be for it to feed back into the development process to improve the design.

What prototypes have you produced so far?
Last year for an exhibition we produced a rudder for a ship and placed three fiber-optic strands in it to demonstrate the potential for sensing technology. We hooked it up to an interrogator and a TV so that people could see how it was able to detect the lightest of touches on the surface. It's like putting a nervous system into the structure.

Who might use the technology first?
We've had interest from the industry leaders in the aerospace and automotive sectors. The caliber of companies has been amazing. Lots of people have been interested in how you can bring a composite structure to life, enabling parts to sense and collect data about it.

How confident are you that this will be used in the future?
We are confident our Continuous Fiber 3D printing is the future of manufacturing. To get there, the technology readiness level (TRL) has to be advanced to commercialization and that's exactly what we're doing through collaboration with industry giants in the fields of materials, software and hardware, focused on customer driven objectives.

6

6 // NASA's Ikhana drone has been used to test embedded FBG sensors

7 // Data from embedded FBG sensors has been used to record strain and wing shape in UAVs

7

and have a far greater need for structural health monitoring, to predict maintenance and sense damage, than fixed wing aircraft do.

"We've worked with the RAF on technologies and techniques to better predict fatigue damage in helicopters. They were against placing strain gauges and sensors on things and were considering embedding the sensors instead."

HELICOPTERS

The US Army is also introducing more sensing technologies on its fleet of helicopters to reduce the high cost of maintaining them. A US Army helicopter can only fly for up 10 hours before it requires some kind of maintenance. The US Army Research Laboratory in Florida is running a research project to extend the maintenance intervals.

Dr Mulugeta Haile, an aerospace engineer at the lab, heads up a team developing technology to detect structural damage such as matrix cracking and delamination as it occurs in composites. The information would enable corrective actions to be taken before a catastrophic failure, so that more helicopters can be ready for flight and in the air for longer periods.

The team considered the use of a number of sensing technologies early in the three year project, including fiber-optic strands, before settling on the use of a distributed network of small ceramic piezo microphones placed on the surface of the structure to detect the noise made within the material when damage is occurring.

3,000
Strain sensors installed by researchers on NASA's Ikhana drone

Haile agrees with Peters that altering the composite itself is a major disadvantage of embedding fiber-optic sensors: "There's progress with FBG sensors, but the problem is they affect the structural integrity of the material and can be a source of crack propagation. The engineers who designed the helicopter are against anyone opening up parts of the structure. Just by placing strands inside parts, you could lose up to 20% of its integrity.

"Yes, there are some disadvantages of placing sensors on the surface. They can be knocked off when in use or moved in the maintenance hangar. But we've strategically placed them to minimize the risk."

The US Army Research Laboratory has patented the mount for the microphones it uses. It is light and applies a constant pressure so that it does not interfere with the acoustic emissions. The team has also developed a pattern for the sensors – 34 are placed so that some are 'active' and listening for damage, while others act as 'guards' and pick up other noise. Machine learning algorithms are used to help software filter out environmental noise.

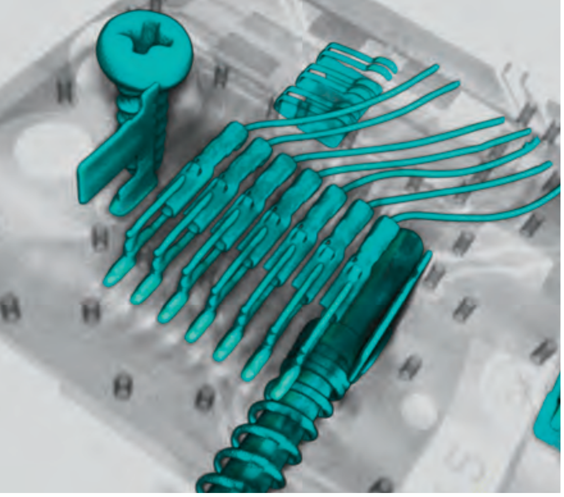
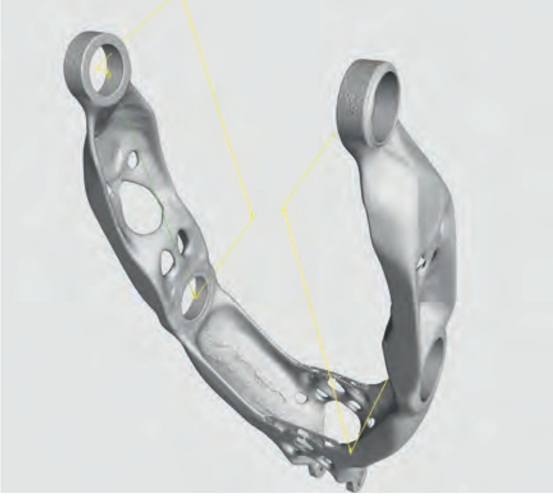
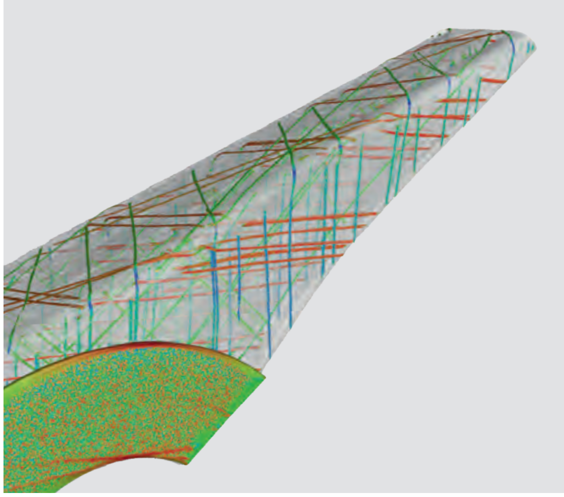
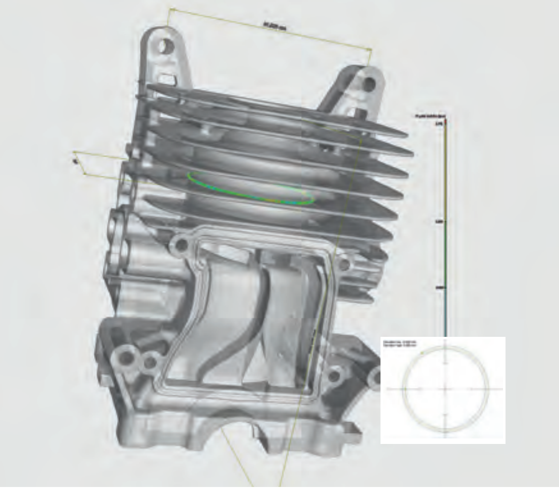
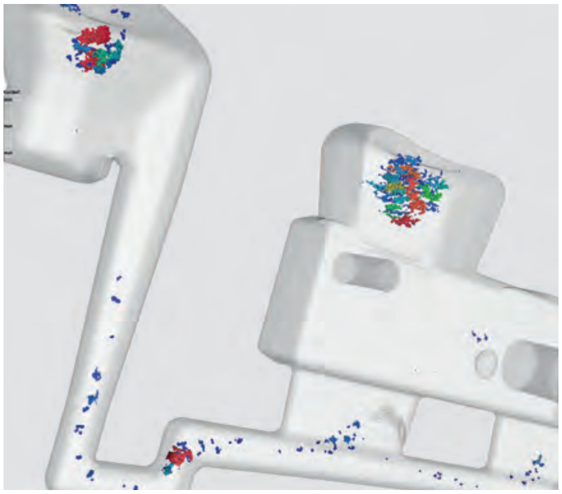
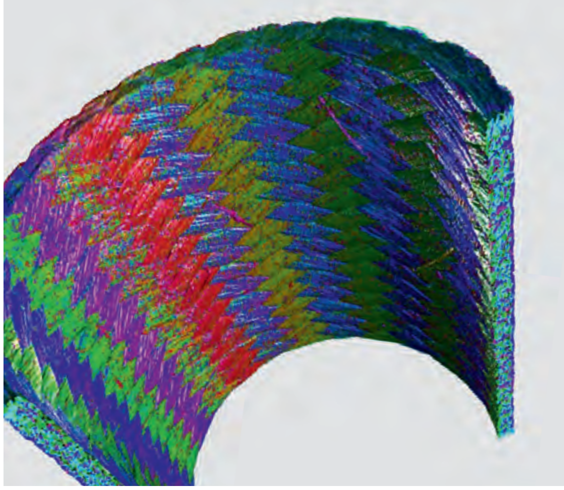
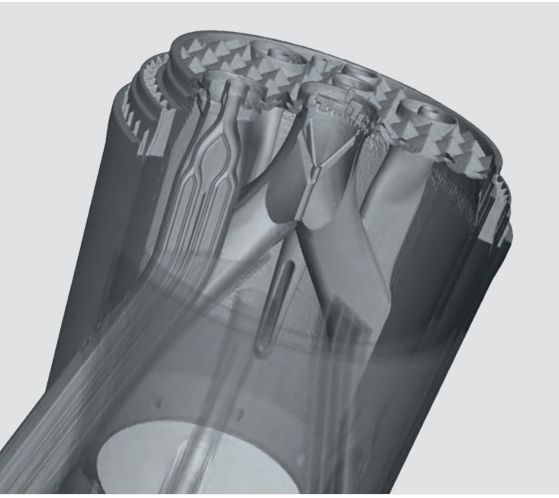
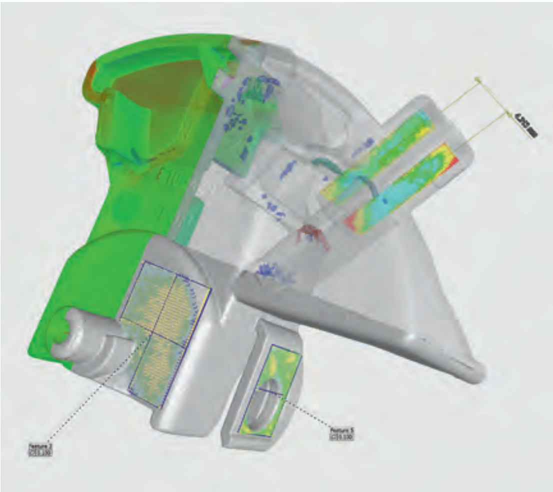
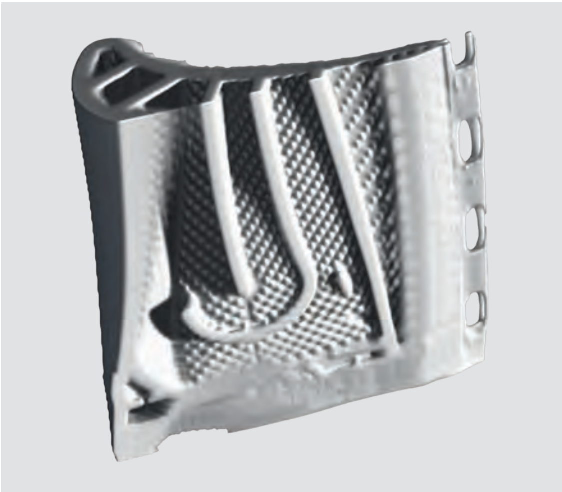
"Listening for a tiny crack on a helicopter is like finding a needle in a haystack from space," says Haile. "But during six months of flight testing on our conceptual composite UH-60 Black Hawk last year we had the eureka moment. The system successfully identified and located damage on the platform after 10 hours of flight when there was no visual damage."

Researchers are working toward certification for the system and working to reduce the computational time it takes to recognize damage. "We hope it will be ready within the next few years," says Haile.

SENSING THE FUTURE

The US Army's research shows that the development and deployment of advanced sensors is dependent on many environmental variables. However, Peters believes that it won't be long before there are more applications of embedded sensing technology in aircraft: "I think progress is happening fairly quickly. We've had the initial burst of excitement and the plateau afterward. We're now at the stage where there is hard work, but there is real growth in the use of the technology.

"Embedded sensors could be another tool for the testing and monitoring toolbox. A richer, wider variety of data sources will always make for better and more informed decisions," says Peters. \\

// ANDREW WILLIAMS

Small world

The dozens of small companies aiming to enter the market for small satellites and low-cost launchers have to use agile and innovative testing equipment and processes while developing new technology

ers

// Inside the control room of startup Launcher's rocket engine testing center

Since the birth of the Space Age, the high cost and long lead times associated with launching satellites into orbit have represented a major barrier to the commercialization and exploration of space. As a result, the sector has been occupied mostly by large companies and government-backed organizations. However, in recent years the rapid growth and evolution of nano- and microsatellite technology has given birth to a burgeoning industry and led to the establishment of almost 70 companies and organizations dedicated to the development of low-cost launch platforms.

Rocket-developer Skyrora in Edinburgh, Scotland, was founded in 2017. The company is set to begin its engine testing program this year, having 3D printed its first engines and began production of its proprietary oxidizer propellant. Daniel Smith, director of business development at Skyrora, says, "Our launch vehicle is suitable for use in the UK thanks to a number of factors, including our choice of propellant combination, which has storability benefits and removes any requirement to de-tank during weather delays."

According to Smith, the team is adopting a step-by-step approach to development and has already begun to test systems and de-risk the suborbital vehicles. They will then move on to testing the orbital vehicle to coincide with the first UK spaceport being operational.

"Our strategy is to combine proven and new technology to produce a launcher that is reliable and cost-effective. There's no need to reinvent the wheel across the board," says Smith.

Skyrora's rocket engine is based on technology from UK programs from the 1950s and 1960s, such as Skylark and Black Arrow, and will run off high-test peroxide (HTP) and kerosene.

Smith says that the key to successful development for Skyrora is to "take the relevant elements of what worked so well before and use modern, advanced manufacturing techniques to improve the build efficiency and bring the cost of mass production down"

For example, the engineering team is planning to use 3D printing to make parts of its engines "where it makes sense to", says Smith.

TESTING FLEXIBILITY

Elsewhere, Calverton, New York-based startup Launcher is also in the process of building an orbital launch vehicle, capable of delivering a 300kg (660 lb) payload to a 200km orbit. The company is developing a low-cost 3D-printed engine with a staged combustion cycle.

As Max Haot, CEO of Launcher, explains, the company is following a three-phase plan to develop the final 22,000 lbf (98,000N), LO_X/RP-1 (liquid oxygen/rocket propellant 1) staged combustion engine, called Engine-2 (E-2).

The first phase, which has run for the past 12 months, has focused on the development and testing of Engine-1 (E-1), a 500 lbf (2,220N), LO_X/RP-1 pressure-fed, 3D-printed engine made up of three Inconel 718 parts and an augmented spark igniter. E-1 is a 1/40th subscale version of the flight engine, which will be used to test the company's regenerative cooling design in advance of the larger E-2 chamber. "E-1 is also being used to build our test site, electronics, software, test stand development,

1 // Hot fire testing of Launcher's E-1 rocket engine in progress

2 // E-1's test stand

1

2

3 // Launcher's E-1 is a 1/40th scale version of the final flight engine

and operation skills and 3D-printing experience. We are nearing the end of this test campaign," says Haot.

Phase 2 will run for the next three years to develop E-2. According to Haot, LO_X pump development is currently in progress, with the goal being to test the turbo pump assembly "by the end of 2019, with the engine firing by the end of 2020".

Phase 3, which will only start following a successful E-2 test campaign, will consist of the scaling up of the team and funding to develop the full launch system. The first test flights are expected to be in 2024 and 2025, with commercial operation expected by the end of 2026.

Haot says, "We believe the key is 3D printing the engine to optimize the size and performance to handle 22,000 lbf. We need to ensure that we can take advantage of 3D printing for low-cost and flexible iterations without tooling."

For Haot, the fact that the Launcher team has its own test site and test stand, developed end-to-end, is critical to testing flexibility and quick iterations. For example, he reveals that the team does not use off-the-shelf DAQ hardware or software.

"Everything is custom electronics and software, so we have full control and so we are close to an actual flight architecture for software and electronics," he says.

"Keeping the team small and staying a startup, we are able to test E-1 every week with just three people on-site. We are staying focused and small until we complete our E-2 engine development."

"Everything is custom electronics so we have full control"

Low-cost projects in aerospace are not restricted to providing cheaper access to space. The Space Drone project is aiming to reduce the cost of satellite maintenance. Arie Halsband, CEO of Effective Space, believes a number of satellites that "required hundreds of millions of dollars to place into orbit" are made redundant each year, not because they are fundamentally broken, but "because their fuel reserves are depleted".

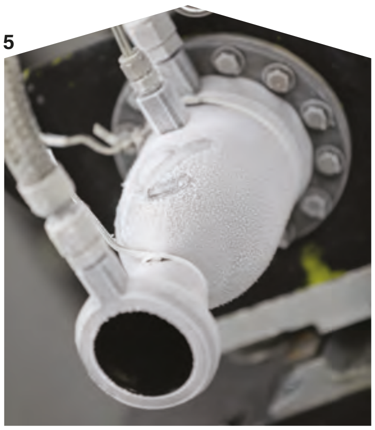
LAST-MILE LOGISTICS

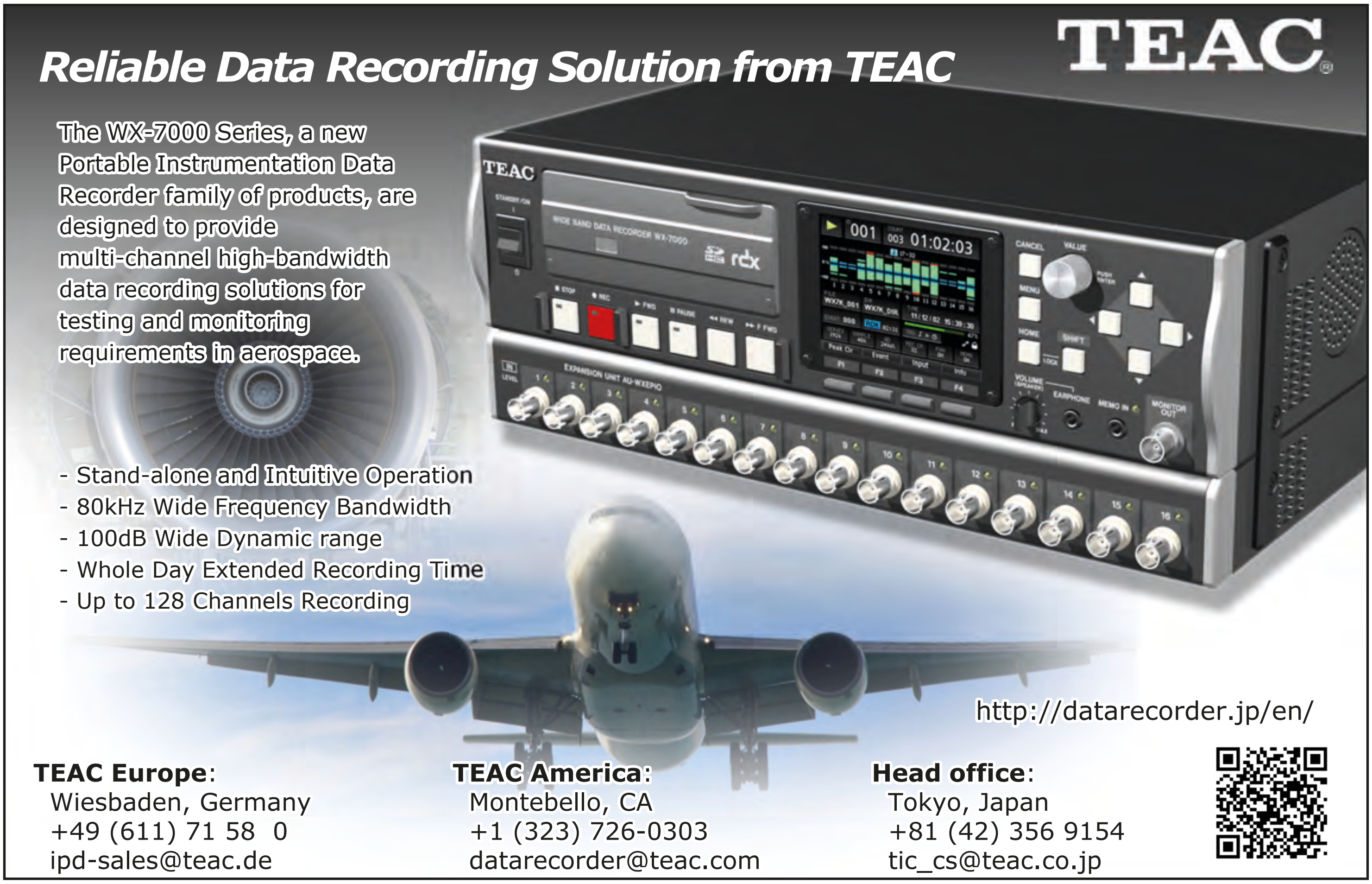
In an effort to address this challenge, the company plans to deploy and operate a fleet of small spacecraft capable of delivering, positioning, maintaining and monitoring satellites. According to Halsband, in January this year Effective Space signed a multi-year contract worth more than US$100m with a leading regional satellite operator for a mission that will start in 2020 and includes the "life extension of two communication satellites".

Each spacecraft will weigh around 400kg (880 lb) and measure about 1m³ (35ft³) in size. The Space Drone is propelled by what is described as an external jet pack with a proprietary, rideshare compatible, all-electric,

4 // Max Haot, Launcher CEO

5 // Launcher's E-1 after hot-fire tests

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6 // Robots have been used to recreate the dynamics of docking with satellites to test the Space Drone

7 // Arie Halsband, CEO of Effective Space

"Space Drone docks with the host satellite"

small yet capable platform design. "It safely and accurately performs rendezvous and docking with the host satellite with a patent-pending non-intrusive docking arms system. Its electric propulsion also allows for up to 15 years of service," Halsband says.

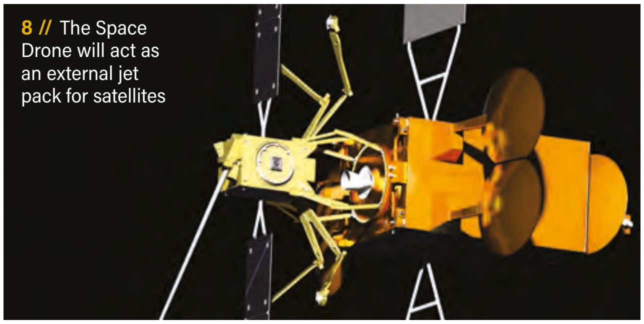
Development of the Space Drone began in 2014, and by December 2017, the spacecraft had achieved hundreds of successful docking tests. This first phase of testing used hardware-in-the-loop testing at technology group GMV's facility in Madrid, Spain, to emulate zero-gravity dynamic conditions. The GMV facility is also used for ESA ground tests of a spacecraft's docking equipment and the procedures it conducts with the International Space Station.

Engineers at GMV will also verify the rendezvous and docking system, test the sensor engineering models, and check the onboard computers that run the guidance, navigation and control software, as well as the docking arms system, ensuring that the spacecraft are fully validated for launch.

"No satellite operator would pay for a servicing spacecraft if the cost were the same as buying and launching a replacement satellite. To prove the business case for in-orbit servicing, it was therefore vital to create a viable spacecraft that could be built, launched and operated for at least half of a normal satellite's price," says Halsband.

A notable measure the company has employed to reduce cost and testing timescales is to pursue a 'minimum viable' product approach. Unlike previous attempts, and "certain other current attempts" to provide satellite servicing capabilities, the Space Drone's design strictly uses GEO station-keeping and attitude-control maneuvers.

"Relying on an all-electric solution, deployable mechanisms and a simple and safe docking system, all contribute to the simplicity and the robustness of the platform," Halsband says.



8 // The Space Drone will act as an external jet pack for satellites

REVOLUTIONARY ADVANCES

The furthest forward in the small satellite launch sector is Huntington Beach, California-based startup Rocket Lab. The company's Electron rocket is designed with a focus on delivering a high number of launches. After a successful launch from New Zealand in January this year,

REUSABLE ROCKETS

One of the other key ways of reducing the cost of entry to space is by reusing rockets. A number of organizations are actively testing reusable rocket technology. One of the frontrunners is the Jeff Bezos-backed spaceflight services company Blue Origin, which is testing its New Shepard reusable launch system – a vertical take-off and vertical landing (VTVL) rocket.

Late April saw the successful completion of the rocket's eighth test flight, during which it carried a second round of commercial payloads for in-space science and technology demonstrations. According to the company, the rocket's reusability will improve the affordability of space exploration and research.

In December 2017 the European Space Agency and ArianeGroup signed a contract to develop a full-scale demonstrator of the Prometheus system – billed as an ultra-low-cost reusable rocket engine – with ground testing to start in November 2020. As part of the parallel Callisto program, the ESA also plans to test its capability to launch, land and relaunch a rocket from the Guiana Space Centre in South America.

9 // Rocket Lab has the world's first private orbital launch site in Mahia, New Zealand

10 // Peter Beck, Rocket Lab CEO

SMALL SATELLITE BOOM TO BENEFIT ALL

According to nanosats.eu, the world's largest database of small satellites, there are almost 1,500 small satellites in orbit. More than 300 small satellites were launched last year, surpassing previous expectations and predictions. Experts estimate that within the next five years, around 2,600 small satellites will be launched into orbit.

Small satellites are satellites of low mass and size, usually under 500kg (1,100 lb). Nanosats are between 1kg and 10kg (2.2-22 lb).

Peter Beck, CEO at low-cost launch company Rocket Lab, says, "Small satellites keep us connected, provide security, help us monitor resources and environmental change, and enable us to explore new and exciting science."

In Beck's view, easier access to space will help to "democratize" the space sector, so that universities, research groups and small satellite startups can access Earth's orbit more easily.

"We'll see an improvement in current technologies, such as more weather satellites for better natural disaster prediction. We'll also see entirely new innovations, such as internet being provided from space. There are currently around four billion internet users in the world. That leaves almost another four billion without internet access. That would put the knowledge of the world into the hands of billions more people."

"Our testing is done in-house and we've invested significantly"

it is the only dedicated small satellite launch provider to have deployed satellites to orbit.

Peter Beck, CEO at Rocket Lab, says, "Until now, small satellites have been a secondary payload, hitchhiking on a rocket with larger satellites that dictate the orbit and launch schedule, which is often prone to delays.

"We provide a service dedicated solely to small satellites, giving our customers flexibility over when they launch and the orbit they want to reach."

According to Beck, the Electron launch vehicle will feature the first electric pump-fed rocket engines in the world. All components for the Electron are designed and made in-house by the company, which also operates its own launch site on the Mahia Peninsula in New Zealand.

Rocket Lab has adopted several strategies to minimize costs and the time it takes to make rockets. For example, the electric propellant pumps reduce mass and its Rutherford engines are 3D printed in just 24 hours.

"We have used both commercial and in-house simulation tools to develop everything in the launch vehicle, including guidance and propulsion," says Beck.

"To test launch vehicles, we follow all the traditional military and NASA standards. Rocket Lab is test heavy – we build hardware early and we test not only to qualification, but to failure too.

"Most of our testing is done in-house, and we've made significant investments into a range of equipment, including vibration tables, shock test machines, and thermal and vacuum chambers."

Looking ahead, Beck says that the company plans to scale up production and increase launch frequency over the next several years. It aims to reach a launch cadence of one flight a month by the end of 2018, one every two weeks in 2019, and then scale up to weekly launches from there.

To support the increased launch frequency, the company also plans to scale up its Huntington Beach manufacturing facility to turn out 100 Rutherford engines this year, and increase its production from one Electron a month to one every week.

"Beyond this, we'll look to expand our existing launch frequency capability and launch inclinations by developing a dedicated launch site in the USA to serve government and commercial missions.

"The site will provide even more flexible and rapid launch opportunities for our customers," adds Beck. \\

11 // Rocket Lab's rocket engine test cell in New Zealand

Hot pro[p]

With growing commercial interest in space, as well as in the development of supersonic and hypersonic aircraft, the unique capabilities of the Scirocco Plasma Wind Tunnel in Italy are increasingly in demand

Acknowledged as the world's largest and best-performing plant for testing thermal shields for spacecraft, the Italian Aerospace Research Centre's (CIRA) Scirocco Plasma Wind Tunnel (PWT), 25km (15 miles) north of Naples, can create air flow around the thermal shield of a vehicle similar to the speeds that occur when it re-enters Earth's atmosphere – up to 12 times the speed of sound and at temperatures of several thousand degrees Celsius.

The brainchild of Italian scientist Luigi Napolitano, who convinced the Italian government to co-fund its cost, the PWT was originally built to qualify the thermal protection systems of the Hermes European space shuttle. The Hermes project was canceled before the complex opened in 2002.

The Scirocco PWT is powered by an arc heater of 70MW maximum electrical power. It is able to generate a plasma jet up to 2m (6.5ft) in diameter, at Mach 12, for a test duration of up to 30 minutes.

In the PWT a column of compressed gas, typically air and argon, is heated to temperatures in the range of 2,000-10,000K. In this condition the gas dissociates and becomes plasma, a mixture of ions and electrons. The plasma flows in a converging-diverging conical nozzle, similar to those used to propel a rocket, and accelerates to hypersonic speeds. The plasma jet is discharged inside the test chamber where a robotic arm injects the test article into the hypersonic stream.

The jet is directed into a long diffuser where the transition from hypersonic to subsonic takes place, before the flow is cooled by a heat exchanger and a vacuum system generates the required vacuum conditions in the upstream test leg.

A cooling system removes the rejected heat of the plasma in the test leg through closed-loop cooling circuits, which contain demineralized water circulated at up to 50 bar or by tower water.

The operations and experiments are remotely controlled and monitored using a suite of test instrumentation and measurement technologies including video systems, IR cameras, IR pyrometers, thermocouples, heat flux sensors, pressure sensors and optical emission spectroscopy (OES) that fully characterize the jet free stream conditions and the test article behavior.

Eduardo Trifoni, CIRA's PWT test engineering group leader, believes the Scirocco PWT is most noteworthy for being the world's most powerful arc jet wind tunnel in operation: "The arc heater's maximum electrical power

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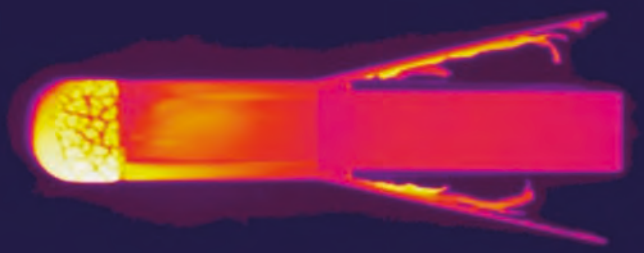

// The re-entry test of the QARMAN cubesat was the first time a full-size spacecraft had been tested in a plasma wind tunnel


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1 // Interior of the Scirocco's test chamber

2 // A full-scale test of the Dream Chaser's thermal protection system was conducted during March 2018 in Scirocco

is enough to light up a town of 80,000 people," he says. "It can generate the world's largest hypersonic plasma jet as a result of its maximum nozzle exit diameter of 2m (6.5ft), which enables the testing of real-scale models with a front diameter of 60cm (23in) and over. The footprint of the facility, including its subsystems and auxiliaries, is incredibly large. The size can only really be conveyed by satellite imagery."

The arc heater's power is supplied by an AC/DC static converter system that occupies an entire building and uses thyristor bridges to deliver a maximum current of 9,000A and a maximum open circuit voltage of about 25kV. A compressed air system supplies the arc heater with a maximum gas flow rate of 3.5kg/s at a pressure of 87 bar. This is housed in a large auxiliary facility that contains a set of reciprocating compressors. The vacuum system consists of steam ejectors using high-pressure water steam at 30 bar and 250°C (482°F), which is generated in a large 80MW auxiliary facility.

The tower water circuit is cooled by huge evaporative towers, which are able to process a water flow rate of about 12,000m³/h.

STRONG INTEREST

With more and more companies taking an active interest in the commercial exploitation of space, CIRA's plasma wind tunnel is in great demand. A recent test campaign performed for Sierra Nevada Corporation (SNC) is a good example. The tests were conducted as part of SNC's development of the Dream Chaser spacecraft. The vehicle has been selected by NASA to provide the cargo delivery, return and disposal service for the International Space Station from 2020 under the Commercial Resupply Service 2 contract.

"The components under test were full-scale technology demonstrators of the Dream Chaser's thermal protection systems," explains Trifoni.

"The performance of the components was fully compliant with expectations under flight representative conditions for spacecraft atmospheric re-entry. The results take the vehicle one step closer to flight readiness."

A new ceramic material (C/SiC), developed by CIRA in collaboration with a spin-off from the University of Milan, Petroceramics, has also been successfully qualified in the Scirocco PWT. "The test concerned a full-flap demonstrator of about 40 x 30cm (16 x 12in), exposed for 10 minutes to a high-enthalpy hypersonic flow representative of the reentry conditions from low Earth orbit," continues Trifoni.

"The component reached temperatures of about 1,500K without suffering any kind of deterioration, thus confirming its suitability as reusable thermal protection. The positive outcome of the test paves the way for Italy's role in the field of structural thermal protection systems for future European Space Agency programs."

CUBESAT SURVIVAL

Another test in June saw the Scirocco PWT blast away at QARMAN (Qubesat for Aerothermodynamic Research). Cubesats are low-cost nanosatellites based on standard 10cm units. They typically end their spaceflights burning up in the atmosphere as their orbits gradually decay. But the three-unit QARMAN is designed to withstand re-entry.

QARMAN has been designed and manufactured by VKI (von Karman Institute for Fluid Dynamics) and funded

NO COMPARISON

To the uneducated, one wind tunnel may seem like any other, but Eduardo Trifoni, PWT test engineering group leader at the Italian Aerospace Research Centre (CIRA), is quick to point out a key difference. "A plasma wind tunnel performs aerodynamic heating tests to stress thermal protection systems and measure the achieved temperatures, whereas a regular wind tunnel performs purely aerodynamic tests," he says.

"In particular, complex aero-thermal phenomena are simulated by the PWT to reproduce the real conditions that will be experienced by the component during atmospheric re-entry.

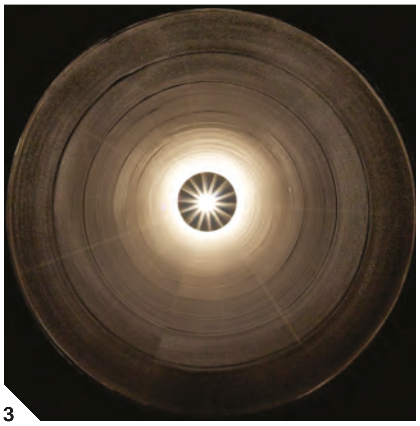
"CIRA has developed a deep knowledge of the basic physics of highly reactive flows around full-scale components in order to achieve this.

"This knowledge is used to set up the test conditions and correctly interpret the results. The experimental evidence collected during the test is used to drive the design of the thermal protection systems and avoid fatal accidents during flight."

However, Trifoni readily acknowledges the debt Scirocco owes to the plasma wind tunnel at the NASA Ames Research Center: "Scirocco was constructed following the lead of the arc jet facilities developed in the late 1950s at the NASA Ames Research Center for the US space program and is comparable to them."

70MW
Maximum electrical power supplied to Scirocco's arc heater to create plasma

80,000 PEOPLE
The size of town that 70MW of electrical power could supply



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"Scirocco is just beginning to prove its worth"

3 // The Scirocco PWT can accept test articles of 600mm (23.6in) and over in diameter

4 // It requires several large buildings to supply its power and airflow

5 // The charred remains of the QARMAN cubesat after the re-entry test

by the European Space Agency. The project aims to demonstrate the possibility of non-powered rendezvous with sets of cubesats, the use of a passive de-orbiting system and the collection of scientific data during its re-entry into Earth's atmosphere. The cubesat is equipped with temperature and pressure sensors together with an emission spectrometer, so that it can gather precious data as it travels down through Earth's atmosphere.

"This test marked the world premiere in arc jet testing of a complete, full-scale spacecraft and represented a tremendous step forward in our ground testing, since up to now only single components have been tested at a time," says Trifoni, proudly.

QARMAN, which also features a cork-based heatshield, titanium sidewalls and silicon carbide panels, survived in good shape despite being subjected to 6.5 minutes of testing under flight representative conditions, where the integral heat load of the re-entry phase was duplicated within the PWT.

Following the successful test, QARMAN is planned to be launched in 2019. It will be deployed from the International Space Station and orbit around Earth for four months before re-entry. The data it collects will be transmitted to Iridium telecom satellites.

"The precious outcome of this test gives us confidence that the QARMAN design will indeed make it through the re-entry phase," says project leader Davide Masutti from VKI. "We have been able to consolidate our design strategy based on ground-testing, numerical models and flight data."

BRIGHT FUTURE

A team of highly skilled staff, operating support personnel and specialized maintenance services are required to operate Scirocco. In particular the engineering activities that lead from

5

determining test requirements to test execution and evaluation of results are extremely complicated and multidisciplinary. None of this is cheap, but Trifoni believes the facility is just beginning to prove its worth.

"The role of Scirocco in aerospace testing and research is to support the programs of future space vehicles and hypersonic aircraft developed by Italian, European and global industries and academia, and to progress the knowledge of aerothermodynamic phenomena at hypersonic speed," he says.

"Of particular interest will be the testing of sustainable spacecraft components able to demise during re-entry at the end of their life. There are also experiments recreating how meteorites interact with entry conditions, which will improve the understanding of the spectral features of the ablation products, with the long-term objective of recognizing and classifying meteorites entering Earth's atmosphere.

"The role of Scirocco and other PWTs in future hypersonic aircraft programs is to support the development of thermal protection systems and hot structures that can withstand high thermal fluxes and cope with the integral heat load accumulated during flight missions.

"Most observers expect to see a hypersonic aircraft flying in 20 to 30 years, but globalization is speeding up a solution based on a suborbital spaceplane that could revolutionize the game in 10 years, linking Rome to Sydney in just a few hours." \\

10,000K
Maximum temperature possible in the plasma wind tunnel

12 MACH
Airflow speed that can be created in the plasma wind tunnel

// ROB COPPINGER

Beyond the pu

Electromagnetic testing is adapting to the potential threat of directed energy weapons, which pose a far greater challenge than the electromagnetic pulse from a nuclear blast

// The P-8A Poseidon anti-submarine jet in the Naval Air Warfare Center's anechoic chamber at Patuxent River

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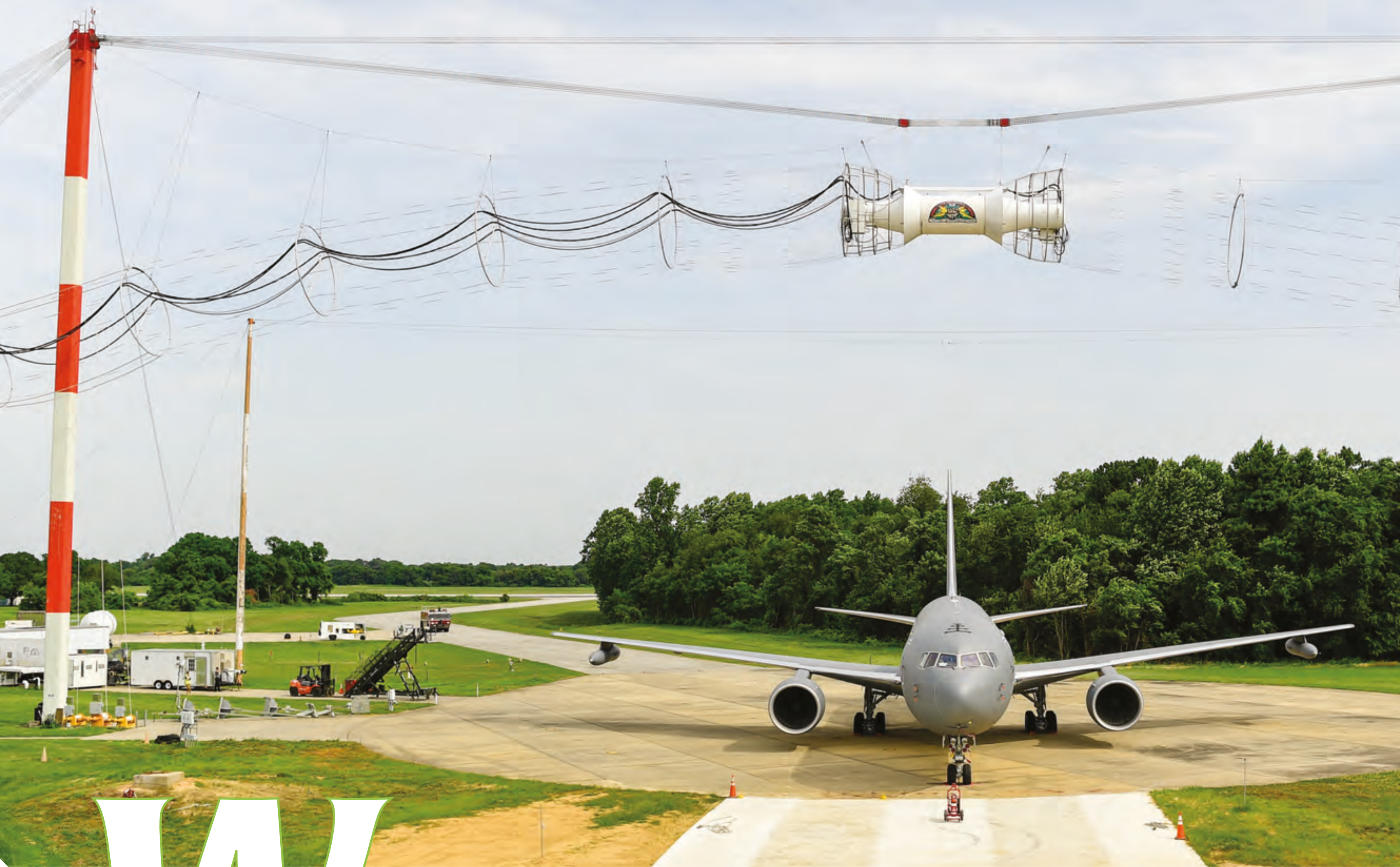

While an atomic bomb or missile is the deadliest weapon of all, its shockwave, and the extremely high temperatures it causes, are contained within a limited area of a few dozen kilometers. However, the electromagnetic wave it sends out, an electromagnetic pulse (EMP), will damage electronics far beyond the horizon.

The EMP of an atomic bomb will destroy any unprotected electronics on an aircraft, including avionics. The energy of the pulse will be absorbed by an aircraft's antennas and its fuselage; through those materials, typically metal, the avionics will be destroyed. The EMP and its effects were discovered in the 1950s, when atomic bombs were being tested above ground. The solution developed is simple; put the electronics in an enclosure designed to absorb the EMP.

More than 60 years on, in terms of importance, the EMP threat is slowly giving way to the directed energy threat. Directed energy is not as powerful as an atomic bomb's pulse and would be emitted from a source far closer to the target than a nuclear explosion. But directed energy, in the form of microwaves, has the potential to undermine existing avionics' defenses.

However, learning how to defend against directed energy, ultimately, did begin with the research that started early in the atomic age on EMPs and how they interact with aircraft. The US Air Force built a huge wooden structure to place its aircraft on (see sidebar, *ATLAS-1: The US Air Force's cold war EMP test rig*) to carry out tests and better understand what the EMP phenomenon meant for its bombers and fighters.

EMP TESTING METHODOLOGY

During the cold war, the US military was most concerned with a high-altitude electromagnetic pulse (HEMP), where a nuclear bomb is exploded above the atmosphere, radiating down an EMP. Since then, modern electromagnetic testing has grown to encompass more mundane sources of radiating energy, such as radars and radio towers. An aircraft's resilience to lightning is also tested. Researchers are developing technologies that will improve an aircraft's capability to withstand lightning strikes (see sidebar, *Researchers develop lightning protection for civil airliners*). Currently, many large civilian aircraft have a metal mesh under their skin to conduct lightning's energy away from sensitive systems and dissipate it. Avionics are enclosed in similar Faraday cages, which redirect electromagnetic radiation. For military aircraft, EMP and lightning research has resulted in MIL-STD-461D. "Avionics boxes for aircraft for flight control, radar, and the like, have to be able to withstand high levels of electromagnetic energy," says Mitch Midgley-Davies, BAE Systems' air sector Typhoon sensors technical lead for platform radio frequency interoperability.

The avionics are subjected to the wide range of electromagnetic field strengths that could be encountered. The electromagnetic testing process begins on a laboratory bench, before anechoic chambers or the use of equipment outside. "Once components and systems are installed in the airframe, we go through the same process as the supplier did – but inside the airframe," adds Midgley-Davies.

100
The number of direct energy shots Boeing's CHAMP EMP weapon can reportedly fire per sortie

OUTDOOR TESTING

While ATLAS-1 is no longer required by the US Air Force, outdoor facilities are still used for EMP testing. Last year, the US Air Force's latest tanker, the Boeing KC-46A,

1 // A Boeing KC-46 being tested at Naval Air Station Patuxent River's electromagnetic pulse and radiation pads

underwent electromagnetic testing for a range of threats including HEMP. "We conducted the EMP testing, met all the test requirements, and passed all test points," a Boeing spokesperson said. "We demonstrated the critical systems as defined in the test plan."

The testing was managed by Boeing, the US Air Force and US Naval Air Systems Command. It was conducted in two locations: the US Naval Air Station Patuxent River's EMP and Naval Electromagnetic Radiation Facility pads; and at Edwards Air Force Base, California, at the 772nd Test Squadron's Benefield Anechoic Facility. During tests on the EMP pads at Patuxent River, a production KC-46A received pulses from a large coil transformer situated above the aircraft. The outdoor test simulated and evaluated the KC-46A's protection from EMP during flight.

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

FAR-FIELD TESTS

The 772nd Test Squadron's Benefield Anechoic Facility is the only chamber in the world large enough to equate to

"The threat of EMP is giving way to the directed energy threat"

ATLAS-I: THE US AIR FORCE'S COLD WAR EMP TEST RIG

The United States Air Force (USAF) Weapons Lab built the Transmission-line Aircraft Simulator (ATLAS)-I simulator, also known as Trestle, to test the impact of an electromagnetic pulse, an EMP, from a high-altitude nuclear weapon detonation.

One of the largest wooden structures ever built, the 1,300ft high(400m), 600ft wide (183m) test stand was built at Kirtland US Air Force Base (AFB) in New Mexico. Designed and built in the 1970s, the structure was made primarily of wood, and held together by a mixture of fiberglass and wood bolts.

It was used to test the largest aircraft the USAF had, such as the Boeing B-52 bomber. Kirtland AFB described the ATLAS-I as the largest EMP simulator in the world. It was one of 18 EMP simulators built in the USA. The wooden structure extended out and down into a 120ft deep (36m) bowl-shaped depression to stop the electromagnetic energy interacting with the ground.

From 1980 to 1990, military aircraft were placed on top of this huge wooden structure and electromagnetic pulses were fired at them. This was done using the transmission lines that extended from one end of the wooden structure to the other, with the lines traveling down either side of the aircraft.

ATLAS-I needed 0.2TW of electricity, which was fed into the structure's capacitors. Once they were fully charged, the energy – the equivalent to about 200kJ – was released all at once to replicate the arrival of an atomic bomb's EMP. The energy release was at one end of Trestle and the energy flowed through the parallel lines. The aircraft were instrumented to enable the US military to understand the impact of the EMP on the avionics and other systems.

ATLAS-I has long since been superseded with modern equipment and simulation, although it still stands, unused, at Kirtland AFB.

Image: McChord AFB

2 // An E-4 airborne command post in the EMP simulator at Kirtland Air Force Base, New Mexico

outdoor testing, according to Midgley-Davies. As a result, demand for the chamber is high. This means test engineers are frequently forced to conduct electromagnetic tests outdoors, so they can test in the 'far-field' region. This is the area where an electromagnetic field behaves differently compared with its behavior close to the transmission point, but still has an effect. "You have to try and get the aircraft into the far field of the antenna, which for big antennas is quite difficult," says Midgley-Davies.

Outdoors testing also enables engineers to characterize the aircraft's responses to electromagnetism. Those tests can then be repeated in the anechoic chamber without any possible interference from external radio frequencies coming from beyond the outdoor test zone for verification.

Another defense that is employed against electromagnetism is the use of filters in antennas. A filter is designed to stop any induced current from the EMP traveling further into the electrical circuits and doing damage. Filters are tested on the laboratory bench, outdoors and in anechoic chambers.

ADAPTING FOR EMP WEAPONS

The nature of electromagnetism and its interaction with aircraft are all well understood. Defenses such as Faraday cages and filters can be used to protect the avionics. But, within the military realm, more credence is beginning to be given to the potential threat from directed energy weapons. While the EMP from a nuclear weapon might sound terrifying and powerful, it is a one-off event that is short-lived and well understood. Midgley-Davies says that a directed energy weapon would produce a far more sophisticated and prolonged attack than EMP from a nuclear blast, and a defense against it requires much more consideration.

There are two types of EMP weapon, an EMP bomb and weapons which fire a microwave beam at a target. Boeing announced in 2012 it had successfully tested this second type of EMP weapon. The Counter-electronics High-powered Microwave Advanced Missile Project (CHAMP) was conducted in partnership with the US Air Force Research Laboratory's directed energy directorate. CHAMP was tested using a cruise missile fired from a B-52 bomber at the Utah Test and Training Range. While flying a pre-programmed route, CHAMP fires bursts of energy at electronic targets. The frequency it fires energy at can be changed and it can fire more than once – unlike an E-bomb, which can explode only once. To date, the US military has not made public any possible orders for CHAMP missiles.

Since the CHAMP test, there have been claims in the media of Russian and North Korean EMP weapon development programs. But while there is speculation that Russia has EMP weapons it can deploy, nothing has been publicly acknowledged by the Russian government, or any other nation.

Testing an aircraft's capability to survive an E-bomb attack is much the same as a HEMP; the test facility needs to be able to test the effect of the far-field region, where the electromagnetic energy is still strong enough to be effective. A direct energy microwave weapon that fires bursts of energy needs a different test. As a weapon like CHAMP is a powerful microwave emitter, an emitter has to be set up either within an anechoic chamber or at an outdoors facility and a target hit with the microwaves to see the effects.

The anechoic chambers that have helped us understand the use of radars and other high-intensity radiated fields will also help defend aircraft against the multifrequency, high-intensity, location-specific threat that is posed by the EMP microwave weapons being developed. But there is also likely to be a strong role for computer simulation, which is already commonly used to study the effect of electromagnetic fields. While physical testing costs and development time constraints rise, the price of computing power continues to fall.

The physical testing of atomic weapons, which originally confirmed the existence of the EMP, is now done with computers. The electromagnetic threats, and an aircraft's defenses against them, could one day be modeled entirely by that well-known electromagnetic digital device – the computer. \\

200KJ
Energy released by Trestle's capacitors to simulate the EMP from an atomic bomb

100,000A
Current carried by the fuselage of an airplane when struck by lightning

RESEARCHERS DEVELOP LIGHTNING PROTECTION FOR CIVIL AIRLINERS

In thunderstorms, an aircraft can act as a lightning rod because its fuselage is electrically conductive, sparking a strike. Like an electromagnetic pulse weapon, a lightning strike could potentially damage an aircraft's avionics. The US government's Federal Aviation Administration estimates this will happen to an airliner once a year. Aircraft avoid storms because of the threat of lightning, heavy rain and turbulent winds, but this is not always possible.

Boeing-sponsored researchers at the Massachusetts Institute of Technology (MIT) have developed a technical solution that electrically charges the aircraft to stop a lightning strike. The solution places electromagnetic sensors with actuators and power supplies to charge the aircraft around the fuselage.

As an aircraft flies through a storm, which has a growing ambient electric field, one end of the fuselage loses electrons, becoming positively charged, while the other end gains electrons, becoming negatively charged. This difference causes a flow of plasma, which is free electrons and positive ions, along the fuselage. This plasma eventually extends into the charged thunder cloud. It is through this plasma that the lightning reaches the aircraft and then onto the ground.

If the sensors detect a change in the charge of the fuselage's two ends, the actuators release their energy. The Boeing/MIT researchers believe that adding energy to the fuselage makes it more difficult for the formation of the plasma that extends to the clouds, triggering the strike.


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// BEN SAMPSON

Full spectrum warf

As the importance of electronic warfare increases, testing technology is coming out of the lab for use on front-line aircraft

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1 // The Typhoon's radar was recently upgraded to deliver a larger array for detection and tracking of threats

2 // An RAF Typhoon pilot's helmet displays threat information on its visor

Military chiefs and the heads of governments around the world are preparing for future conflicts to be fought in one of the unlikeliest of locations – the electromagnetic spectrum.

The Pentagon's Electronic Warfare (EW) strategy includes the development of both offensive and defensive technologies, while the value of contracts for devices such as radar jammers is steadily climbing from millions to billions of dollars. Market research firm ReportsnReports predicts that by 2022 the EW market will have increased in value to US$30bn, from the US$24bn it was worth in 2017.

Military aircraft are being built with increasingly complex Defensive Aid Suites (DAS). These consist of radars that detect and warn of threats such as missiles and anti-aircraft artillery. Chaff, flares and electronic countermeasures are employed to defeat such threats. Engineers have developed built-in test equipment (BITE) to check an aircraft's electronic subsystems, including the DAS, are working as intended before a mission. In crude terms, the pilot of a jet hits the BITE button before take-off and the different systems check that they can all communicate as required with each other. But BITE has a flaw.

Dave Lord, director of electronic warfare for Leonardo's Tactical Systems business in the UK, says, "BITE is a good thing, and is sophisticated enough to give confidence before every flight. But, it doesn't inject a signal from outside of the system. For example, if an antenna or cable on the airplane is disconnected, cross-coupled or damaged, it can't detect it."

MISDIRECTION

The consequences of an incorrectly calibrated antenna in a DAS could be catastrophic. "A military aircraft has to be able to detect the threat outside of the range of the missile before deploying counter-measures. With the incorrect sensitivity, you could maneuver into the threat instead of outside of it," says Dr Bruce Holley, a consultant to Leonardo's Tactical Systems' business.

"The antennas have to be balanced such that they both have the same sensitivity. If you are flying straight on the nose, then each one has to have an equal signal, because with certain systems if one antenna is degraded, the threat appears to come in an opposite direction, causing the pilot to fly into it," says Holley.

US$30BN
Predicted value of the electronic warfare market in 2022

360°
Threat picture provided by radar on the Eurofighter Typhoon

The solution is to test the DAS's antennas are working correctly. In the past, this meant using a test range or a large anechoic chamber, both expensive, time-consuming options.

Instead, the Leonardo system brings a small anechoic chamber to the aircraft. The anechoic hoods fit non-intrusively over the DAS antennas. Attached to the hood is a unit that generates various RF signals to stimulate the antenna, replicating potential radar threats. Different threats can be simulated from different ranges and angles of arrival by varying the RF signals and their sensitivity.

"We have a repeatable system for stimulating the EW system using the hoods, to see if it is able to detect threats at the correct particular ranges – that it has the correct sensitivity. One of the most innovative aspects of the system is the way that the hoods are designed to interact with the antenna in a repeatable way. It's the repeatability that's key to verification," says Holley. The hood contains antennas in various positions, which align

3 // RF pulses from the handheld device simulates threats before a mission

THE TYPHOON'S DEFENSIVE CHECK-UP

Technicians working on the RAF's Typhoon force have a 'Defensive Aid Suite garage', where the aircraft are taken to test and maintain DAS. The Typhoon's DAS test and verification is automated – the unit that stimulates the system communicates directly with the aircraft's databus.

Dave Lord, director of electronic warfare for Leonardo Tactical Systems, says, "The operational availability has increased since it has been introduced."

4 // The Typhoon's defensive aid suites are regularly checked to ensure their operational effectiveness

with the aircraft's antenna to enable the direct injection of the RF signal. The RF signal goes through the antenna and the DAS electronics to the cockpit display. The system can also measure the power coming off radar jammers.

"Our DAS verification system closes the BITE gap. That gap may only be 10% of the DAS system's performance, but imagine you disconnect an aerial on a radio. It won't work. It's an essential 10%. We can ensure that the system is capable of picking up threats."

"The BITE doesn't take into consideration the RF cable runs or the antenna's degradation. Our solution measures the cable and the antenna losses," says Lord.

CAPABILITY GUARANTEES

The DAS verification system is based on technology that was first developed in the USA and used by the US Air Force across all of its platforms. It was initially bought into the UK for use on the Harrier, Sea King and Jaguar aircraft from 2000. "Since then we've developed and refined our test and simulations. We now have an exportable product being developed in the UK," says Holley.

The electronics in the RF generator units have been developed to reduce the size of the equipment and expand the frequency coverage.

The system provides what Leonardo calls "through life capability assurance" for military aircraft. This covers not just wear and tear on an operational aircraft, but also possible faults that technicians and engineers may introduce through modification and updates. The system is operated by avionics technicians on the frontline via GUIs; Leonardo trains personnel in its use.

310,000 LB
Maximum take-off weight of the A400M

120KM
Cabling in the A400M

The company recommends a tiered testing regime: complex test, less complex tests, and confidence checks before a flight. At the most complex, highest-tier DAS verification can take up to five hours, or with fewer test points it can be done in about 40 minutes

HARDWARE IN THE LOOP

A further benefit of the RF hood system is the verification of Mission Dependent Data (MDD). This is software that tunes an aircraft's EW sensors to see threats. MDDs are specific to platforms and regions. All modern military airplanes run on MDD, so that they can accurately display threats to the pilot in the cockpit as alphanumeric tags or tones. There is virtually no bleed of RF signals from the hoods. This means engineers can use classified MDD to replicate the real signals of missiles and see if the jet's DAS is seeing the correct threat. "MDDs have tolerances, and if they are out of tolerance, the aircraft won't see the threat correctly," says Lord.

Leonardo has also developed the RF verification technology as a handheld device to provide a go/no-go conditional test. The device is pointed at the aircraft and the operator walks around it. The device fires a test RF pulse and as long as the pilot sees the tag and symbology in the cockpit at the right bearing, the mission can start. The handheld device is programmable from 0.2GHz to 40GHz. "For an operational mission, if there is a specific threat system out there, the parameters can be loaded into the device to ensure it can see the threat," adds Lord.

A400M ANTENNAS AND CABLES

The RF hood system has recently been developed for, and will be imminently introduced for use on, the RAF's

"This is not a pass or fail, it shows that the DAS works"

A400Ms. Leonardo then aims to move into the international market for the RF hood system. There are 150 A400M platforms on order across several nations, so the opportunity is large.

"The device has been received extremely well once people have seen it," says Holley. "The concept is difficult to explain. This is not a strict pass/fail, it shows the DAS works adequately."

Another useful capability of the system is the ability to verify and fault-find in cabling. A schematic of an aircraft's cable runs is provided with the system. When injected, the signal will spike if there is a break in the cable. So instead of taking the whole aircraft apart, the technician can work on a specific part of the airplane. This could prove especially useful on the A400M, which is one of the largest and most complex aircraft built and contains a lot of cabling.

"The A400M is probably one of the most complex DAS systems being manufactured. To verify the system's capabilities is hugely important to the user community. The DAS frequency coverage is large and it's a big aircraft, with long cable runs," says Lord.

5 // The A400M has one of the most complex defensive aid suites currently being made

FUTURE RF DEVELOPMENTS

Leonardo engineers are looking at developing the DAS verification system in two ways. The first is to broaden its use into training. The same equipment that is used on aircraft can train air crews from basic to operational and mission rehearsal level. "We are going to introduce technology that switches the RF signals quick enough so as to simulate a multi-threat environment, " says Holley.

"If you are planning a mission, maybe at night, there will be an EW soak of the area before the mission and there will be a 3D terrain map. That data would be overlaid with the tactical routing and the electronic order of battle. We now have software that can handle timelines. By injecting RF signals that correspond to the mission and switching them when necessary, air crew will see the EW aspect of their sortie before it happens," says Holley.

This would allow the aircrew to prove the system and prepare mentally and physically for the mission. "One of the worst things is that you are distracted by something superfluous. This enables them to ignore those things and prioritize the important things," says Holley.

"Unlike the big aircraft simulator, this stimulation will be recreating what this particular system will look like on that particular night. It's not a simulation – this concept is representative of a real operational scenario," says Holley. "Live hours are declining and virtual hours are increasing in training. This bridges the gap between the two. It means that, particularly for special forces, EW skills can be refreshed while on the frontline," says Lord.

Engineers at Leonardo have so far built the fast switching technology and the software has been developed. The company plans to demonstrate the training capability later this year on the A400M

Other improvements to the system include tweaks to the hood design; and making them from carbon fiber so that they are lighter and easier to handle. Engineers may also look at how the RF is generated, so it can be done in the hood rather than the external unit. Leonardo is also looking at using the same concept in the naval domain and in testing land vehicles.

"Another consideration is that although we are doing this for electronic warfare, we can also do it for anything that transmits or receives on an aircraft, including all the avionics, communications, and electro-optical mores," says Holley.

Essentially, the case for the RF hoods comes down to capability assurance and the saving of money by reducing the amount of operational flight testing that has to take place on an aircraft fleet. "If a new aircraft type is delivered, it might have spent 200-300 hours on the range. What about the rest of the fleet? We are ensuring all aircraft are operating to the same standards," says Holley. \\

6 // The A400M's defensive aid suite can be tested quickly with the handheld RF device

// DAVID SMITH

With delays and cost increases of aircraft test programs increasingly blamed on software problems, what technology and tactics are available to keep software testing under control?

Software every

where

1 // As flight decks have become digital, the testing requirements for the software that runs them has increased

During a modern airplane's flight, hundreds of millions of lines of code will run. Software is present almost everywhere in the aircraft, from mundane components like galley equipment to highly critical ones such as flight control systems.

Each line of code has to be checked for faults. Each software unit has to be tested to see how it integrates with other units, and then tested at a higher systems level. It's a laborious process. Increasingly, cost overruns and delays in airplane development are linked to software testing. But it's vital to get software right.

"If software fails, you can get awful incidents like the flight 447 Air France A330 crash over the Atlantic in 2009, which killed everyone on board on the way from Brazil to Paris. It was caused by one hardware failure, but the root of the incident was the software's inability to recognize and report the hardware fault," says Dylan Llewellyn, international sales manager at software company QA Systems.

CRITICAL PLANNING

The amount of software on aircraft is set to increase. For example, as engines evolve they are becoming more software dependent. FADEC (full authority digital engine control) engines are entirely controlled by software. Among commercial aircraft, the A380 is well known for having large amounts of code. But nothing compares to the amount of code within the F-35 jet fighter, which has been beset by long delays because of the mind-boggling complexity of its software development.

To avoid disasters such as Flight 447, and to reduce costs, software testing should be done as early as possible in a development program. Massimo Bombino, an expert in avionics software and regional manager of Southeast Europe for Vector Software, recommends planning software testing from "day zero" of a development program and forming small agile teams of software developers. These teams should plan all the software unit testing and integration testing from day zero to minimize the risk of nasty surprises and last-minute regression testing, which is conducted when code goes wrong.

1,000

Software faults identified on the F-35 after more than 25 years of development in January 2018

"Regression testing is a nightmare and a big issue for the whole software industry. It's especially a challenge with safety-critical aviation software. Everything can be running perfectly, then at the last hurdle you introduce a new element and it fails. It's very tricky and time-consuming to solve unless you have advanced technology," says Bombino.

There are two ways to prevent regression testing, believes Bombino. The first is to test rigorously from the start. But if there are too many problems and it is too late, it is better to conduct change-based testing. Vector Software has technology that enables a subset of tests to be run according to just the code changes, thereby improving the efficiency of testing.

INDEPENDENT VERIFICATION

According to DO-178C, the primary document by which the FAA, EASA and Transport Canada have agreed to

F-35 DELAYS CAUSED BY UNREALISTIC GOALS AND C++

Tucker Taft, director of language research at AdaCore, says that the F-35 Joint Strike Fighter has become too complex because every one of the high number of stakeholders in the project is demanding ambitious requirements. "All the amazing technical qualities can be in conflict and they keep changing their minds."

The F-35 has taken more than two decades to develop and has been plagued by huge time and cost overruns. The lifetime costs stand at an estimated US$1.5tn, partly because of the enormous price tag for software development and testing. As recently as January 2018 the Pentagon was forced to admit that there are still close to 1,000 software faults on the jet, but won't say precisely what they are.

"The software development keeps getting the blame, but the whole project management can be seen as at fault," Taft says. "The program has goals that are almost impossible to reach. The lesson is to put a stake in the ground and say we will build it this way and stick to it."

Over-ambition may bear some of the blame, but it is undeniable that software development has also contributed. Taft believes that writing the software in C++ has also caused the overruns. "When you factor in the cost of debugging later on, it's worth doing a little more training to use a language that's less problematic, such as Ada," he says.

2 // The F-35B hovering

3 // The F-35's sensors and software detect and process terrain and threats

2

3

"The secret is to make testing a fully fledged part of the process"

AUTOMATED ADVANTAGE

One of the reasons aircraft testing is so expensive is the high cost of testing, but automating the process can save time and money, according to Dylan Llewellyn (pictured), international sales manager for software testing company QA Systems.

Llewellyn says his company's Cantata tool can test in a month software that would otherwise take several months to test. But the industry is resistant to using automated tools. "Icebergs don't move fast and outsourcing companies don't always inform the manufacturers that these tools can cut expenses substantially.

"The message is always that it will take a team of 60 a year and will cost US$1m, rather than saying you can test it quicker by licensing an automatic tool for several months," he says.

Cantata is qualified to test software to DO-178C's stipulations. It works by allowing testers to put code into the tool and telling it the standard it has to be tested to. Cantata will then run the code. Users can see the script and modify it in real time. At the end of the process, the tool tells the testers if the code has failed. It signals the reasons for failure and details the lines of code at fault. "You can test the smallest possible units of code, but it also works for integration testing when you put lots of smaller units together," says Llewellyn.

approve all commercial software-based aerospace systems, software must be tested by independent parties. The software process is therefore mostly outsourced to third parties, although some aircraft OEMs use separate in-house teams. These independent parties perform verification and validation testing to establish that all the bugs in the code have been removed.

8 MILLION
Lines of code on an F-35

Tucker Taft, a computer scientist and director of language research at software developer AdaCore, says that another problem is that if testers find lots of faults at the verification and validation stage, the errors can be hard to trace back to the original software developers.

"The old-fashioned way of putting software together until you think it's worth testing doesn't work with hundreds of millions of lines of code," says Taft. "Smart companies today frontload their testing processes by finding faults during design and not waiting until integration testing.

"The most modern, agile companies use test-driven development, where you don't start writing code until you've written the pre-imposed conditions that it must pass. The secret is to make testing a fully fledged part of the process."

When Taft tests software for faults, he carries out static analysis, in which a tester tries to mathematically prove that errors will manifest without running the code. Experience has taught him that certain types of software are hard to examine using the conventional tests written by programmers and that it can be more straightforward to obtain formal proof of software unit's safety using static analysis. However, the exact opposite can be the case with some other types of software units.

"For part of the system, you focus on mathematical proofs and for other parts you use a more dynamic testing strategy," Taft says. "Customers often like a combined strategy because they get the confidence of mathematical proofs."

As part of more formal testing for certification, Taft prefers to define pre- and post-conditions for software.

4 // The cost of developing the Boeing 777's software is reported to be US$800m

Pre-conditions imply that before the software sends data to a component, the code has to have certain properties. Unless the software is in an appropriate state, it will not be allowed to send the data. Testing can verify that the pre-conditions are satisfied. Later, the post-conditions state what predetermined data the tester should get back from the software.

"When you use pre- and post-conditions, you can do a lot more formal verification and determine whether the software all fits together," Taft says. "It makes it easier to do integration testing, which has always been one of the greatest challenges, as each contractor builds and tests in isolation, but when you put it together something inevitably goes wrong."

120 MILLION
Lines of code on an A380

MODELS AND FUZZ

Developments in technology are helping to reduce the software testing workload. As well as automated testing, the use of mathematical modeling for software testing has evolved rapidly in recent years. It can now simulate with great precision what an airplane will do when the software is installed.

Large manufacturers, such as Boeing and Airbus, have embraced the model-based approach to testing software and have created detailed, accurate models.

"When you use pre- and post-conditions, you can do a lot more verification"

These models can be shared with subcontractors so that they can carry out hardware-in-the-loop tests, where hardware is tested within a simulation of an aircraft's software systems. "These simulations require a lot of horsepower, so it's not trivial to create them, but they're worth their weight in gold," Taft says.

Another trend is 'fuzz testing', which involves blasting the software with large amounts of random data, called fuzz, to try to break it.

Taft compares fuzz testing to the tricks white-hat hackers use to expose weaknesses in corporate security systems. "Fuzz testing hasn't yet reached the practical level, but there's a lot of research in academic circles and I think it will play a big part in future testing. You never know when a hardware failure might generate random data, or it could be a hacker trying to break in," he says.

Despite these technical advances, most aerospace companies find software testing onerous. QA System's Dylan Llewellyn was part of a team testing the power distribution software on the 777X. The code was written in blocks and tested to ensure that when it was added to the mix it didn't have a negative effect on what was already there. "If you have bad code in legacy code it causes havoc," he says. "That's why when they went from the Boeing 777-300 to the 777X, they didn't use any of the legacy code."

PART OF THE PROCESS

The procedure was fairly typical, with multiple teams, each consisting of four or five engineers each, working independently to develop and test the software. Meanwhile a team of around 60 independent experts carried out the verification and validation work.

"There was a huge amount of testing done for the 777X. We had dozens of engineers testing one block of code for 10 months," says Llewellyn

Testing of the power distribution software started on what is called non-flyable code A. The teams continued all the way to non-flyable code W, testing various units and integrations. By the time they got to that stage they had tested everything, including at systems level. The next stage was to test the flyable Y level. The teams then installed the software on an iron bird and tested it for redundancies and multiple systems failures before it was installed in a test aircraft.

With software playing such an integral role in modern airplanes, it is perhaps not surprising that software testing is such an involving endeavor that can often prove problematic. But as the complexity and amount of code on aircraft increases, aerospace companies will be forced to get to grips with software testing through both better technology and better management of the process. \\

Boldly going where no woman has gone before...

MEET ANJA FRANK, HEAD OF TEST FACILITIES AT DLR LAMPOLDSHAUSEN

Anja Frank heads up the team at DLR Lampoldshausen in Germany that ensures that the European Space Agency's rockets are able to launch spacecraft safely. As well as managing 100 staff, she oversees facilities such as the test stands, tank farms, steam generators and the cooling water systems.

DLR Lampoldshausen, which is Germany's Institute of Space Propulsion, covers a $350m^2$ ($3,770ft^2$) site. It has seven test stands, with an eighth under construction. Rocket engines have been tested at Lampoldshausen since 1959, from the Europa rocket through the entire Ariane program, up to today's Ariane 6, as well as rockets for the European space industry. The site specializes in testing rocket engines under high-altitude conditions. Its P4.1 test facility is the world's most modern altitude simulation test facility for cryogenic upper-stage engines. It also hosts Germany's largest rocket test facility, the P5, which was designed to test the engines for the Vulcain Ariane 5 main-stage.

Frank and DLR Lampoldshausen have never been busier, but here she finds time to tell *Aerospace Testing International* how the facility works and what motivates her as a woman to succeed in a predominantly male workplace and profession.

HOW AND WHY DID YOU BECOME AN AEROSPACE TEST ENGINEER?

My father worked in the space business and infected me with his passion for it. He used to talk about his job with such enthusiasm – it created an interest in it for me. I took aeronautics and astronautics at the University of Stuttgart, but the focus was always space. As a child, my big dream was to go to Mars – something I haven't given up on yet. I started at the test facilities at Lampoldshausen 15 years ago when I worked on the main-stage engine for Ariane 5.

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

It was very different from the theory I learned at university! Calculating and putting things on paper is one thing, but it was very different to see the test benches in action.

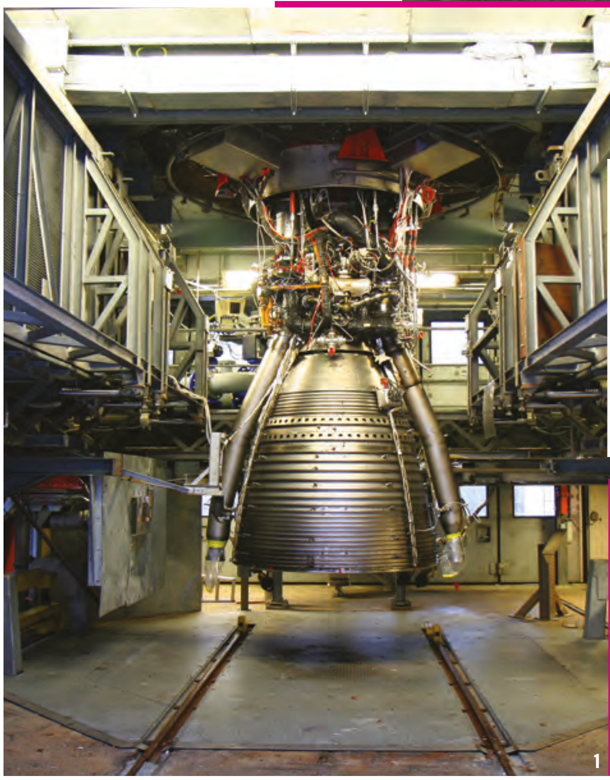
I learned early on that you can plan and prepare, but unplanned things will always happen. When you test, you think about the failures that can arise and you are well equipped for those, but when other failures emerge, you have to think fast.

CAN YOU DESCRIBE THE TESTING CONDUCTED AT LAMPOLDSHAUSEN?

We gather pressure, temperature, vibrations and force measurements, and flow measurements for engines. We have direct-thrust measurement systems for the smaller engines.

The benches are designed to simulate the same systems of a launcher under a wide range of conditions and capabilities. For the upper stages, the bench also needs to simulate the environmental conditions – vacuums mostly.

On the engine's interfaces we try to simulate the real conditions they will face,



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2

1 // The NE-X nozzle, part of Ariane 5's main engine, before testing at Lampoldshausen

2 // Hot run of the Vulcain 2 main-stage engine for Ariane 6

"Safety is always the paramount consideration"

3 // Testing of liquid oxygen/methane propulsion technology on test stand P3

or could face, when in use. We test for failure by seeing if we can still ignite them if there is a problem with several components. We test the lifetime of the engines – how often can you ignite or what is the running time of a thrust chamber.

We normally have engines for a few months and during that time they are ignited, depending on the test plan, several times, normally every two weeks. In between tests we analyze the previous tests' results and refill and check the infrastructure.

WHAT'S A TYPICAL DAY AT WORK FOR YOU?

Normally it starts with checking emails and then a planning and scheduling meeting about what is happening in the facility, what problems we have, and how to solve them.

I'm not in the facility every day because there is a lot of management work to do. But I still hear the tests and when I can make time I try to be in the command room, because that is the best way to keep in touch and get a feel for what is happening. I think it's important to do that, because sometimes you have to explain to people who are not close to the tests the system and any issues, so it pays to understand.

Also, the actual tests are still the most fun and interesting part of the job to me.

WHAT PROJECT IS TAKING UP MOST OF YOUR TIME AT THE MOMENT?

The Ariane 6 engines, including the entire upper stage, and that stage's Vinci engine. The Vinci is being tested under high altitude simulation conditions and we are building a new test stand, P5.2, to test the entire Ariane 6 upper stage, which is almost complete. Normally we try and modify facilities, but this upper stage was too large to fit in an existing stand.

Plus at the same time we are testing the Vulcain 2.1 here – the first stage rocket for Ariane 6.

Technically, the new engines have properties that have changed and so the parameters of the testing have to change. To test the whole upper stage, you need to also test the electronics systems and computers, which is a different type of task for us and presents new technologies and challenges to deal with.

HOW HAS TECHNOLOGY CHANGED YOUR JOB?

We have new systems and are always upgrading, but the hardware doesn't change as fast as the software. Digitization is progressing on the engines and in the testing facilities and equipment around the engines, with features such as intelligent health monitoring systems.

When I started, communication was different. Now with emails you have very fast exchanges and access to data. Fifteen years ago this took longer and you had

4 // The altitude simulation test rig is used to more accurately recreate the conditions during a launch

5 // Artist's impression of test rig P5.2 where the upper stage of the Ariane 6 will be tested

"My aim is to do a good job and that is more important than proving that being a woman doesn't matter"

more time to prepare reports; now, everyone wants instant results and faster troubleshooting, creating more pressure.

WHAT IS THE MOST CHALLENGING ASPECT OF YOUR JOB?

It is just so busy! We have a lot of testing activities running in parallel and then the building work for the new stand at the same time.

We are also working in a very international context and you have to be careful when communicating. You have to avoid misunderstandings when testing. We have huge amounts of propellant, and the energy that it creates, if directed incorrectly, could cause a lot of damage.

We have to extremely fast in a technically very challenging environment and still be safe. We work to the same stringent regulations as nuclear power plants. Safety is therefore always the paramount consideration.

WHAT RECENT CHANGE IN THE SECTOR HAS AFFECTED YOU?

There have been a lot of the technical changes in data acquisition and handling of data. The commercialization of space is affecting our activities. We need to be competitive with the market, to do things more cheaply, while remaining safe. Testing is people-orientated – you need experts, and that costs. Commercialization is increasing the demand for skilled people, which affects us.

But the innovation and drive that commercialization brings is also a great thing and the new launcher is driving us to achieve improvements. Ariane 6 will be a vital part of the new space business and that mindset drives all of the staff here.

HOW HAS BEING A FEMALE AFFECTED YOUR CAREER?

Unfortunately, there are not a lot of women in the profession, but it is increasing. I've never thought about it as a problem personally. I have encountered prejudice, but I know I don't need to be a man to be successful in this career. Sometimes proving people wrong can be a motivation to succeed, but it's not my main one. My aim is to do a good job and that is more important than proving that being a woman doesn't matter in a male-dominated workplace.

I do outreach work and projects in local schools as a role model. I believe having mixed teams is a good thing because it offers a diversity of views, perspectives and skills – and that can help develop and implement complex technical projects.

WHAT ARE YOU MOST PROUD OF IN YOUR CAREER TO DATE?

I'm proud of the position I've reached in my career. I am also very proud of my team at the moment. They are running a lot of projects at the same time. They are really pushing the development of Ariane 6. To do everything well to budget and within deadlines is difficult, both technically and administratively.

WHAT ADVICE WOULD YOU PASS ON TO A YOUNG PERSON WHO IS CONSIDERING A CAREER IN AEROSPACE TESTING?

It's important to have a real enthusiasm for this sector, which is true for all careers. It's an interesting job, never boring. You can look forward to being surprised a lot of the time with test results. This means that you have to be flexible, keep an open mind, and never think you are 100% sure of the reason something is happening.

You have to be able to cope with huge amounts of information and face different fields of expertise that may not be your own. \\

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// ANTHONY JAMES

THE AVIATION CONFERENCE OF THE YEAR!

Image: ©newFACE Consortium

Day 1: Thursday, November 8

9:00 - 1:00PM – KEYNOTE PRESENTATIONS

ROOM A

9:00am - Delivering aerospace technology for an increasingly electric future
Rob Watson, director, Rolls-Royce Electrical, UK

9:30am - Emission-free flight: vision or reality?
Prof. Josef Kallo, head of energy systems integration, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany

10:00am - Presentation title to be confirmed
Glenn Llewellyn, general manager, electrification – corporate technology office, Airbus, France

11:00am - Energy storage for electrified aircraft
Dr Ajay Misra, deputy director, research and engineering directorate, NASA Glenn Research Center, USA

11:30am - An e-volution in electric and hybrid boundary layer ingestion
Simon Taylor, chief engineer, GKN Aerospace, Netherlands

12:00pm - Presentation title to be confirmed
Dr Frank Anton, executive vice president eAircraft, Siemens Corporate Technology, Germany

12:30pm - Electric aviation: hype or reality?
Dr Arvind Gangoli Rao, associate professor, Delft University of Technology, Netherlands

2:00 - 4:00PM – LATEST INNOVATIONS FOR ELECTRIC & HYBRID FLIGHT POSSIBILITIES

ROOM A

2:00pm - Ceramic matrix composites taking flight beyond GE Aviation
Michael Peretti, director, advanced programs, GE Aviation, USA

2:30pm - Evaluating aircraft with electric and hybrid propulsion
Dieter Scholz, lecturer, Hamburg University of Applied Sciences, Germany

3:00pm - General aviation 2025 – a supercomputer on wings
Rene Nardi, technical director, Inotech LLC, USA

4:00pm - Digital displacement: hydraulic power for the digital age
Dr Niall Caldwell, managing director, Artemis Intelligent Power Ltd, UK

4:30pm - Assessment of a rotorcraft thermo-electric powerplant using Simcenter Amesim
Dr Olivier Broca, product line manager aeronautics space and defence, Siemens Industry Software, France

2:00 - 5:00PM – NEW CONCEPTS TO ENABLE ELECTRIC FLIGHT OF REGIONAL AIRCRAFT

ROOM B

2:00pm - eVTOL: Electrical challenges and opportunities
David Debney, chief of future aircraft concepts, Rolls-Royce, UK

2:30pm - Recent developments in Safran's roadmap toward more-electric propulsion
Pierre-Alain Lambert, head, energy and propulsion, Safran Tech R&T Center, Safran, France

3:00pm - Kickstart the future of sustainable aviation
Pieter Lantermans, senior stress engineer, GKN Aerospace, Netherlands

4:00pm - Electrification – partner in the increase in aerodynamic and propulsive efficiency
Nelson Cámara Aguiar, lead engineer for efficiency improvement solutions, Altran, Spain

4:30pm - What have we learned from MEA enabling hybrid-electric propulsion?
Cristian Anghel, technology fellow, Honeywell International Inc, USA

5:00pm - Regional STOL aircraft with DEPS technical progress
Andrey Dunaevsky, programme manager, Central Aerohydrodynamic Institute (TsAGI), Russia
Semyon Mikhalyov, research officer, TsAGI, Russia

ADVISORY PANEL

Josef Kallo, head of energy systems integration, Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany

Peter Malkin, strategic research advisor, Newcastle University, UK

Mark Husband, lead technologist of electrical systems, Rolls-Royce, UK electric & hybrid aerospace TECHNOLOGY SYMPOSIUM

Day 2: Friday, November 9

9:00 - 10:30AM – CERTIFICATION

ROOM A

9:00am - A certification basis for electric VTOL aircraft
Dr Lionel Tauszig, senior PCM – continuing airworthiness rotorcraft, European Aviation Safety Agency, Germany

9:30am - Certification of lithium batteries as key enablers for electric aeroplanes
Carlos Javier Muñoz García, new electrical technologies expert, European Aviation Safety Agency, Germany

10:00am - On the certification of high-capacity battery systems
Robert Hess, systems engineering manager, BAE Systems, USA

11:00AM - 5:00PM – ELECTRIC & HYBRID PROPULSION SYSTEM DESIGN & VALIDATION

ROOM A

11:00am - ECO-150-300: a turbo-electric distributed propulsion transport for 2035
Benjamin Schiltgen, VP of finance/aerospace engineer, Empirical Systems Aerospace Inc, USA

11:30am - Assessment of alternative architectures for electrifying a regional turboprop transport aircraft
Alexander Schneegans, managing partner, PACE Aerospace Engineering & Information Technology GmbH, Germany

12:00pm - Hybrid propulsion system concept for commuter passenger airliners
Dr Anton Varyukhin, head of department, Central Institute of Aviation Motors, Russia

12:30pm - The role of power systems design in hybrid-electric aircraft
Peter Malkin, strategic research advisor, Newcastle University, UK

2:00pm - Computational support for comparing future electric and hybrid aircraft architectures
Dr Jonathan Menu, research engineer, Siemens Industry Software NV, Belgium

2:30pm - A supercritical CO_2 closed-cycle hybrid propulsion system
William Tahil, research director, Meridian International Research, France

3:00pm - TRADE: Turbo electRic Aircraft Design Environment
Dr Michael Sielemann, aerospace industry director, Modelon, Sweden

4:00pm - Electric aircraft range extender hybrid-electric motorcycle
Richard Glassock, research fellow, The University of Nottingham Institute for Aerospace Technology, UK

4:30pm - Requirements for electrical power supply system elements for electric aircraft
Sergey Khalyutin, CEO, LLC Experimental laboratory NaukaSoft, Russia

9:00AM - 12:30PM – ENERGY STORAGE & TRANSMISSION

ROOM B

9:00am - Longevity of lithium-ion batteries
Dr Matthias Vetter, head of department – electrical energy storage, Fraunhofer Institute for Solar Energy Systems ISE, Germany

9:30am - Innovative thermal conductivity switching material to enhance battery module/pack safety
Dr Tomohiro Kawai, principal scientist, Mitsubishi Chemical Corporation, Japan

10:00am - Preliminary study of sodium water reaction for electrical propulsion
Víctor Manuel de Frutos, systems engineer, Airbus DS, Spain

11:00am - Powertrain development for electrical aircraft beyond the limitations of batteries
Roel van Benthem, R&D manager energy systems and thermal control, Netherlands Aerospace Centre, Netherlands

11:30am - Electrical behavior of composite material used in hybrid-electric aerospace
Dr Jameel Khan, electrical materials engineer, Rolls-Royce, UK

12:00pm - New carbon-fiber-reinforced materials for an electrically driven aircraft
Simon Bard, scientific assistant, University of Bayreuth, Germany

12:30pm - Hybrid aerospace powertrains: a rotorcraft case study
Phil Mellor, professor of electrical engineering, University of Bristol, UK
Julian Booker, professor of mechanical design engineering, University of Bristol, UK

2:00 - 4:30PM – ELECTRIC DRIVE SYSTEMS AND POWER ELECTRONICS

ROOM B

2:00pm - ATI INSIGHT: electrical power systems
Mark Scully, head of technology – advanced systems and propulsion, Aerospace Technology Institute, UK

2:30pm - Designing and testing electrical machines – challenges for helicopter environments
Dr Mircea Popescu, chief technology officer, Motor Design Ltd, UK

3:00pm - Novel electric drive systems for aircraft electric and hybrid propulsion
Dr Evgeni Ganev, chief engineer, Honeywell Aerospace, USA

4:00pm - Power electronic systems of highest power density
Florian Hilpert, group leader aviation electronics, Fraunhofer Institute for Integrated Systems and Device Technology IISB, Germany

4:30pm - Design of superconducting AC propulsion motors for hybrid-electric aerospace
A C Smith, professor, University of Manchester, UK

Topics under discussion

- eVTOL: electrical challenges and opportunities
- Energy storage for electrified aircraft
- Boundary layer ingestion
- Ceramic matrix composites
- Electrical behavior of composite material
- Aerodynamic and propulsive efficiency
- Certification
- Alternative architectures for electrification
- Range-extender technologies
- Power systems design

RELIABLE A

The telemetry sector's most comprehensive program of training, research and professional enrichment opportunities are on offer at this year's International Telemetering Conference and Exhibition (ITC), which is being held in Glendale, Arizona, on November 5-8.

ITC 2018 is the 54th event in the exhibition's history. Each event grows in size and quality and this year is no exception, with more than 2,000 telemetry engineers, scientists and management personnel from several different sectors expected to attend. The event brings customers, suppliers, academics and the engineering community together in one place to network, view the latest technology, and discuss the latest trends and issues.

INDUSTRY CHALLENGES

The theme at ITC 2018 is 'Reliable and Secure Data Links and Networks'. The need to transmit data securely and reliably has always been fundamental to telemetry. But today, the amount of data produced by instrumentation is increasing, while telemetry systems themselves are becoming more complex, with an increasing need to ensure networks are secure from hacking and snooping. The development and effective operation of telemetry systems will only become more challenging to accommodate these pressures.

ITC 2018 aims to assist engineers meet their telemetry goals and ensure their systems exceed expectations in terms of performance. The conference's keynote presentation, from Galen Rasche of the Electric Power Research Institute, will cover the threats, challenges and opportunities facing infrastructure and networks in terms of cybersecurity, and will describe what lessons can be learned by telemetry professionals.

The keynote heralds the start of more than 100 technical presentations to be given by experts over the course of three days. These presentations will cover all facets of telemetry system design, implementation and operation.

At the same time, the exhibition will give conference delegates the chance to see the latest technical solutions for telemetry. With more than 60 exhibitors confirmed and around another 20 expected, attendees can be certain that there is a product that can help meet their requirements on offer.

SPECIAL RELATIONSHIP

The conference program has been developed by the ITC Conference's general chair and technical program chair, Kurt Kosbar, associate professor in communications and signal processing at the Missouri University of Science and Technology; and Dr Michael Marcellin, regents professor of electrical and computer engineering at the University of Arizona. The technical sessions cover a range of topics within telemetry, from antenna and RF to sensors, data acquisition, channel modeling and synchronization.

The general chair and technical chair are appointed by the International Foundation for Telemetering (IFT) and, like the rest of the conference's staff, they are volunteers. The IFT, which was launched in 1964, is a non-profit corporation that aims to serve the technical and professional interests of the telemetering community, and sponsors the annual conference.

The relationship between suppliers and telemetry users in both government and industry facilitated by the IFT is at the heart of the successful yearly conferences. It has also contributed to the advances in telemetering and instrumentation systems that users rely on today and helps to educate telemetering professionals worldwide. This tradition, which has continued for more than half a century, continues this year with ITC 2018 in November in Glendale, Arizona.

ND SECURE

DATA, LINKS AND NETWORKS

Now in its 54th year, the International Telemetering Conference and Exhibition takes place in Glendale, Arizona November 5-8, 2018

VENUE DETAILS

Renaissance Glendale Hotel & Spa,
9495 W. Coyotes Blvd,
Glendale, Arizona 85305

A minimum four-night stay is required at the hotel. The cut-off date for conference room block-booking is October 18, 2018

OPENING HOURS

Tuesday, November 6
9:00am–6:00pm
(Welcome reception Monday, November 5, 6:30–8:30pm)

Wednesday, November 7
9:00am–6:00pm

Thursday, November 8
9:00am–12:00pm

www.telemetry.org

DON'T FORGET!

Online registration for this event closes on November 2, 2018, at **www.telemetry.org**

VISIT LUMISTAR AT BOOTH 1015

Modular re-transmission system

Lumistar will be introducing its new Modular Telemetry Re-Transmission System and Modular Range Loopback Test System at ITC 2018.

Building upon the proven success of the LS-28-DRSM Series Modular RF Telemetry Processing System, these new products incorporate RF digital modulation to create a "complete transceiver system in the palm of your hand".

Lumistar will also be demonstrating its modular new desktop operating system-less LS-68-M decom system.

Lumistar was founded by a group of experienced telemetry engineers to create a customer-friendly telemetry experience. It strives to make its products as functional and applicable to as wide a range of requirements as possible. The company is employee-owned, which Lumistar says emphasizes the quality of its products and their ease of use, and ensures that it prioritizes customer support. Lumistar tries to make every decision about its products' features based upon what is right for its customers. Personal demonstrations are available at the company's booth.

VISIT MICROWAVE INNOVATIONS AT BOOTH 411

Transmitter and receiver solutions for flight test

Microwave Innovations provides transmitter and receiver product solutions that deliver telemetry for artillery, targets, missiles and space launch programs for flight test and operational systems. The company's products are designed to meet the most demanding stock, vibration, temperature and EMC requirements.

Microwave Innovations provides reliable solutions for the most difficult mission environments, with solutions for UHF to Ku/Ka-band, with L, S and C-band transmitters for test range and space launch communities.

Its flight-proven transmitters are power- and size-efficient with RF Output Power from 0.25W to 60W with data rates up to 50Mbps for ARTM modulations.

The company has 20 years of experience supporting the most challenging programs while providing custom engineering, parts programs, qualification testing, program management, ATE and meeting supplier data requirements, and is an AS9100 certified supplier.

START THE WEEK WITH A SHORT COURSE!

This year, there are 11 day-long short courses on offer to ITC Conference delegates on Monday, November 5, before the main conference begins.

The courses are given by industry experts and are designed to help with industry professionals' continuing education needs. The instructors summarize new developments in each field and facilitate the discussion of the latest trends. Early booking is recommended to avoid disappointment because spaces on these courses are limited. Here is a selection of some of the courses on offer this year:

- *Advanced modulation and demodulation techniques, Terry Hill, Quasonix*
  This course's material will cover the legacy PCM/FM waveform, SOQPSK and multi-h CPM and demodulation techniques for these waveforms.

- *Basic signals and modulation, Dr Stephen Horan, NASA Langley Research Center*
  Delegates will hear about the basic concepts necessary to understand the data communications process within the telemetry system.

- *iNET Telemetric Networks, Thomas Grace, NAVAIR Patuxent River, and Ben Abbott, Southwest Research Institute*
  Participants on this course will learn about core telemetric networking principals and the applicable networking technologies.

- *IRIG 106-17 Chapter 7 Packet Telemetry Downlink Basis and Implementation, Johnny Pappas, Zodiac Data Systems*
  This course will help delegates develop a basic understanding of the IRIG standard, focusing on the implementation of airborne and ground system hardware.

- *Telemetry for high-latency, error-prone networks, Robert Ritter, IM/RT Logic*
  This tutorial will give detailed information on packet-based telemetry standards that are designed to operate reliably in error-prone and high-latency conditions.

- *Fundamentals of microwave and radio frequency, Mark McWhorter, Lumistar*
  As well as giving an overview of electromagnetic theory and the many common uses of RF-microwaves today, Lumistar will discuss the RF-microwave components found in telemetry systems.

- *Basics of aircraft instrumentation, Ken Miller, NAVAIR*
  This course will describe the best data acquisition system design criteria used to meet customers' data requirements and needs.

REGISTER FOR COURSES AT WWW.TELEMETRY.ORG

VISIT CURTISS-WRIGHT AT BOOTH 101

High-performance, ultra-lightweight DAQs

Curtiss-Wright will be showcasing its range of data acquisition, recording, networking, telemetry, imaging and ground station products at this year's show.

Notable highlights include the new ultra-performance and lightweight Axon data acquisition unit, a new IP camera, a tri-band transmitter, and exportable encryption technology.

There will be live demos of these products and others at the booth, including the most modern and capable data-acquisition system available today.

Curtiss-Wright will also be presenting three papers on future technologies. These presentations are: a non-traditional implementation of a traditional flight safety system; the use of photogrammetric analysis with high-speed cameras; and integrated data acquisition solutions for aerospace platforms that have highly restrictive space and weight requirements and harsh environmental conditions.

VISIT ZODIAC DATA SYSTEMS AT BOOTH 803

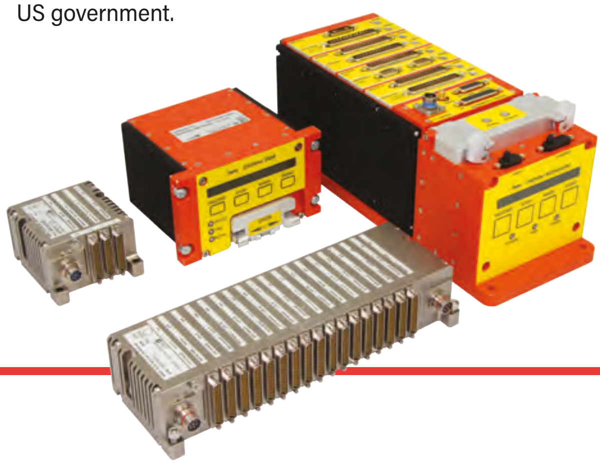
H.265/4k video on Chapter 7

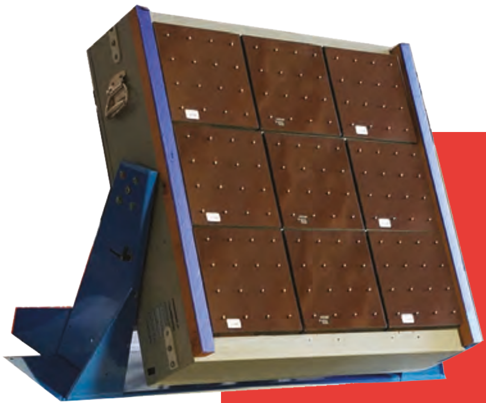
Zodiac Data Systems is the only provider to offer airborne and ground equipment and solutions from acquisition to processing for flight testing.

Technologies on display at this year's conference include H.265/4K video capabilities and demonstrations of Chapter 7, Chapter 10, and the company's MDR-GT, accommodating 10GigE speeds and beyond. All Zodiac's products are based on common standards.

Also on display will be Zodiac's XMA Data Acquisition Unit (DAU), which is used in the most challenging airborne applications along with the space/missile versions of the DAU. In addition the RX-1, a full-featured receiver, can be seen at the booth.

And new for this year, visitors can experience a virtual reality display of Zodiac's Tri-band SPARTE antennas, with all the required filtering, which have been delivered to the US government.





VISIT CDSI AT BOOTH 609

Universal beamforming technology

Creative Digital Systems Integration (CDSI) has developed Universal Beamforming Technology (UBT) under US government sponsorship since 2014.

UBT embeds intelligence in a modular multi-element antenna 'tile', or Digital Beamforming Module (DBM), and is made 'universal' via different digital personalities, and attaching to a single-band or multiband RF panel.

Each DBM as shown can autonomously acquire and track multiple telemetry (TM) sources with one personality, or multiple communication channels with another.

Larger antenna apertures are created by interconnecting multiple DBMs in planar, conformal or even non-contiguous plug-and-play configurations.

Recent tests with a 9-DBM portable TM station shown (~1m^2 aperture) demonstrated 100% link availability from a 5W airborne source at a range of more than 150 miles (240km).

Visit CDSI at Booth 609 to see whether it can provide a DBM personality for your application.

VISIT TELSPAN DATA AT BOOTH 213

IRIG Chapter 10 recorders, switches and gateways

Testing technology supplier Telspan Data is a leader in IRIG 106 Chapter 10 hardware and software technologies for airborne, shipboard, ground, range and laboratory environments.

The company's ruggedized product range includes high-speed, high-capacity data recorders, Ethernet switches with FPGA processing, GigE video network controllers, and instrumentation/Ethernet gateways. Ground-based products include bit syncs, PCM decoms, recorders and reproducers. 'Data fusion' software products provide real-time decoding, processing, display and distribution from CH-10 sources and other network-based instrumentation systems.

These products and more will be on display at the event, including the MITR high-speed, high-capacity CH-10 processor, recorder and publisher. The MITR accepts inputs from fiber-optic/copper Ethernet and fiber channel, 1394, sFPDP (serial front-panel data port) and other data sources. Input channels are recorded and published, while mirrored outputs provide full active TAP capabilities.

The MITR features built-in FPGAs to perform real-time data filtering and protocol translation, and internal GPS, IRIG and PTP time engines to enable multiple clocking capabilities. Ethernet interfaces are provided for CH-10 data publishing, while PCM outputs (HDLC/CH7) provide real-time data streaming.

DON'T FORGET!

Register for as little as US$100 before November 2, 2018, at **www.telemetry.org**

SPECIAL PANEL SESSION

Creating the future test range infrastructure: Wireless inter-range network environment

Wednesday, November 7
8:30-10:00am

A major challenge to testing is balancing the development of complex systems requiring the transmission of increasingly large amounts of data with diminished access to the RF spectrum.

A major test infrastructure paradigm shift toward bidirectional, highly integrated, wireless inter-range network environment that seamlessly supports all range operations and data types is required to continue testing systems efficiently.

The implementation of a wireless, inter-range network environment relies on leveraging network-based telemetry capabilities and applying a mobile 'wireless' cellular program.

A panel of experts, chaired by Thomas O'Brien from the USA's Office of the Secretary of Defense's test resource management center, will discuss this important topic.

SPEAKER SPOTLIGHT

Galen Rasche,
Senior program manager, power delivery and utilization sector, Electric Power Research Institute

Rasche manages the Electric Power Research Institute's (EPRI) Cyber Security Program, which seeks to improve the resilience of the USA's power infrastructure by researching protective measures, threat and incident management, and risk management. He launched EPRI's Cyber Security Program in 2012 and is an expert in smart grid security and the penetration testing of embedded systems

Prior to joining the EPRI, Rasche led the Embedded and Application Security Group Southwest Research Institute and has performed cybersecurity research for several US government and commercial organizations.

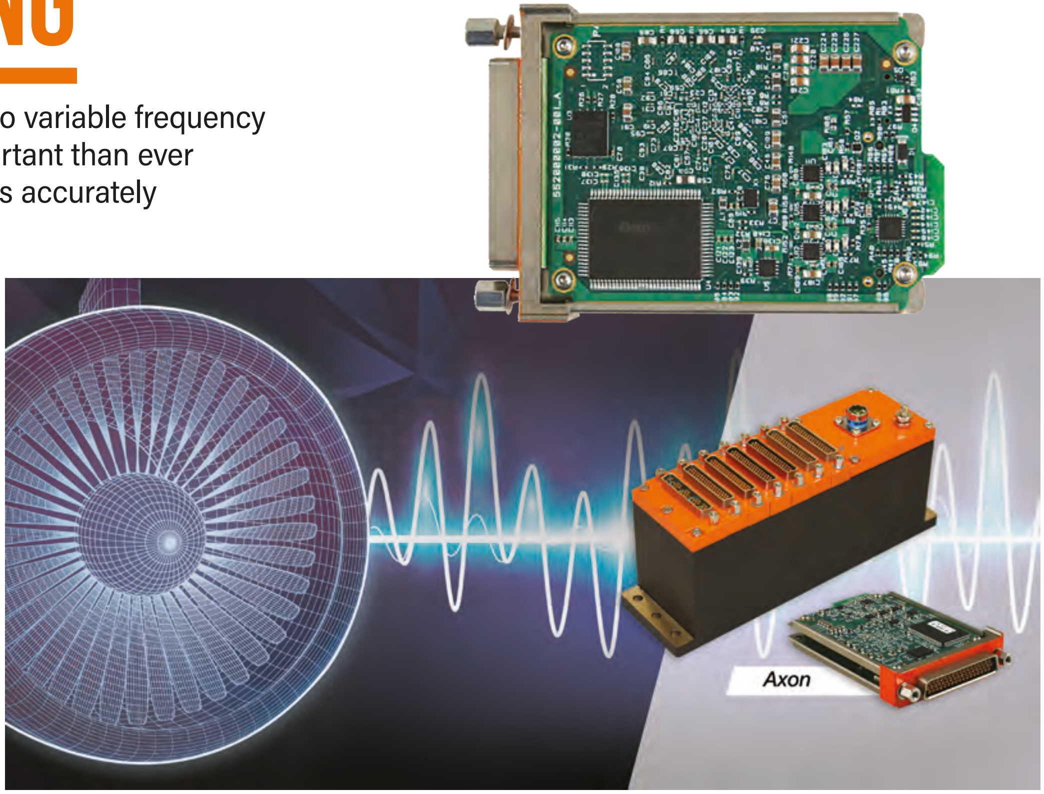
His presentation, 'Protecting the grid – cybersecurity in the electric system', will outline how cybersecurity has become a critical priority for electric utilities. The sector has become increasingly dependent on information technology and telecommunications networks. Cybersecurity measures now have to be used to ensure reliability and security.

Recent examples include the cyberattacks on Ukraine's electric grid in 2015 and 2016. The US-CERT alert in March 2018 also highlighted the energy, nuclear, water, aviation and critical manufacturing sectors being targeted by foreign governments.

The presentation will review recent attacks on industrial control systems and their networks, discuss how the electric sector is responding to protect its assets, and provide the lessons that can be learned by other sectors.

IMPROVED POWER MONITORING

With modern aircraft shifting to variable frequency power, it's become more important than ever to monitor power requirements accurately



// The Axon ADC-408 supports 1.8Msps sampling rates

Historically, aircraft designers used constant frequency drives to deliver the constant source of 400Hz AC electrical power needed to operate onboard systems. The use of high-frequency 400Hz AC, although less efficient than 60Hz, provided the advantage of using lighter, more compact power supplies on board the aircraft. The resulting weight savings from the use of smaller and lighter 400Hz electrical generators helped to reduce overall costs.

AC generators, such as oil-cooled integrated drive generators, were used to turn mechanical power into fixed frequency electrical power, typically 115V AC power at 400Hz (3 phase). It is an engineering challenge to deliver constant frequency power because the output from a jet engine gearbox, which is the source of the electrical power, will vary as the engine operates from full to idle power. In order to turn the gearbox's variable speed into a constant rotor speed requires the use of bulky, sometimes heavy transformer equipment.

Recently, though, the aircraft industry has moved away from this approach, eliminating the requirement for constant frequency and instead embracing support for the use of variable frequency electrical power. Modern aircraft such as the A320neo, B737max, and C919 require that many onboard electrical systems are designed to handle variable frequency – typically 115V AC 200-900Hz. Examples of aircraft equipment that can support variable frequency AC power include fuel and hydraulic systems motors which, because they operate at different speeds, can reliably handle variable power loads. In contrast, equipment such as cockpit displays, fuel pumps and brakes, rely on DC power.

As aircraft design makes the shift from constant to variable frequency electrical power requirements, the challenge becomes how best to monitor the data throughput. In response to this demand, Curtiss-Wright has developed a breakthrough variable frequency power monitoring module for use with its Axon data acquisition unit (DAU). The AXN/ADC/408 module detects the presence of power transients based on preset voltage, current and frequency threshold parameters.

But detecting transients isn't enough in itself. Instead, for optimal data use, after a transient is detected, the power monitor needs to be able to output the raw data at a rate high enough to enable the plotting of any detected transients. To support this intensive throughput requirement, the AXN/ADC/408 module transmits Ethernet packet streams over each of its six input channels with raw data sampled at 450kS/s. Input signals are captured at data bandwidth rated up to 120KHz. The bandwidth can also be down-filtered, using the module's built-in digital filter, prior to processing by the math engine.

With its unmatched performance, this unique new sensor module can handle 50Mbps data traffic across each channel. The combination of the AXN/ADC/408 and the Axon chassis, with its packetized data architecture, supports 800Mbps over the backplane – the most data throughput of any DAU on the market today. The raw data can be packetized into any standard format: iNET-X, IENA, TmNS, Ch10 and DARv3. Multiple modules can also be integrated into a single chassis. In addition, the AXN/ADC/408 does not require an external transformer for the voltage channel, since the voltage is divided down on the module. To ease design-in, the DAU supports all legacy parameters provided by current Curtiss-Wright power monitoring solutions. It also supports many more parameters listed in ISO 12384/GJB181A-2003, including steady-state parameters and transient parameters. For example, the AXN/ADC/408 is the industry's only variable frequency power monitoring solution that supports 1.8MS/s sampling rates, enabling a wider range of measurements to address a variety of power monitoring applications. \\

QUALITY ANALYSIS WITH COMPUTED TOMOGRAPHY

Flexible and intuitive CT inspection systems can help keep up with the growing demand for inspection in the aerospace industry

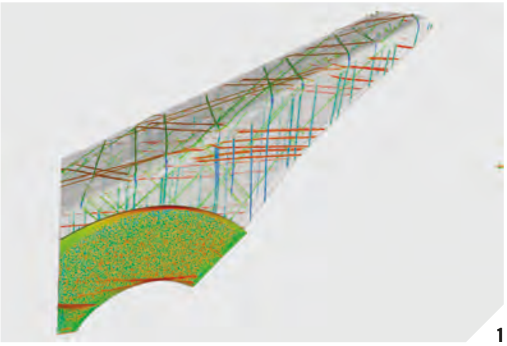
2

The aerospace industry has increasingly been applying x-ray technology and in particular computed tomography (CT) to quality assurance and measurement tasks.

With CT it is possible to obtain in-depth views into three-dimensional material structures. CT systems are used during the production of prototypes as well as for spot-check sample inspections. They have to meet the most critical aerospace demands as, for example, defined in the ASTM standards. The spectrum of parts having to be inspected is comprehensive and diverse, and is steadily growing because of new materials and production methods such as additive manufacturing (AM).

The identification of porosity, inclusions and cracks in cast parts and turbine blades, and the measurement of wall thicknesses, are typical inspection tasks. The position of cooling bores in turbine blades has to be confirmed, and the inspection of wax and ceramic molds is necessary to avoid production faults. Bleed-air ducts, braking components, climate-control and anti-icing systems have complex shapes and many welds that are subjected to very high mechanical and thermal stress loads. The quality of these components is essential. Additional challenges come with AM where precise structures and shapes of internal channels in an exhaust gas probe made of heat-resisting alloy need to be checked.

Due to their low specific weight and high mechanical strength (high fatigue resistance), carbon and glass fiber-reinforced materials are increasingly used in the aerospace industry. These parts need detailed analysis for delamination, foreign materials, concealed damage and fiber orientation, as well as the correct position of fiber bundles, fiber ruptures or damage inside honeycomb structures. These are only a few examples from of a range of applications that vary in size, material and complexity.



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To meet all these requirements, Yxlon has introduced the flexible FF85 CT system, which stands out for its dual-tube configuration, an open micro-focus tube with up to 225kV and mini-focus tube with up to 450kV, along with a selection of flat-panel detectors and the user-friendly Geminy software platform. The software provides intuitive smart-touch operation, remote monitoring, push messages and different user profiles for the best inspection results, without the need for any special prior knowledge. Control of the system is realized by two touch monitors with easy-to-follow graphics or with the handheld device for convenient positioning from the inside of the cabin/bunker.

3

1 // Structure analysis of a fiber-reinforced plastic blade

2 // CT volume of a 3D-printed exhaust gas probe of heat-resistant alloy by RSC Engineering

3 // Yxlon FF85 CT with dual-tube configuration and easy manipulation of x-ray components and the test part thanks to the handheld device inside the cabin

The new CT algorithms ensure optimum image resolution with a larger field of view. The innovative ScanExtend feature enables horizontal field-of-view extension and is suitable for scanning larger objects or for maximum magnification of smaller parts. The scan is performed in one rotation of the test part and reconstructed without artifacts. This saves time compared with current algorithms.

Also, functions like the FlexCenter virtual rotation axis and the HeliExtend feature increase the range of applications, quality of inspections and time efficiency. Functionality such as the HeliExtend Dual – Helix CT with horizontal field-of-view extension – uses the advantages of both trajectories and extends the already generous inspection range. Finally, data quality can be optimized using correction filters for beam hardening, ring artifacts, noise, bad pixels, focal spot drift, etc.

With all these features, the FF85 flexible CT system supports the operator in keeping up with steadily growing demand in the aerospace industry and achieving the best inspection results for a broad spectrum of specimens. \\

READY FOR THE NEXT EVOLUTION

Siemens has launched Simcenter Testlab Neo, its next-generation multidisciplinary testing platform

The world of aerospace testing needs to evolve to meet new ways of making meaningful products. This is what Simcenter Testlab Neo is all about. Just like its predecessor, LMS Test.Lab, Simcenter Testlab Neo aims to be the go-to test engineering platform for the next generation of multidisciplinary test engineers, and a trusted tool that aerospace engineers of all ages can count on to get the job done in the best possible way.

Aficionados of the Simcenter Testlab Classic software can rest assured. The two platforms will work transparently with free data exchange between them. Simcenter Testlab Neo also works seamlessly with all Simcenter SCADAS hardware. There are also new licensing models, so every user has access to practically all of the Simcenter Testlab capabilities including data acquisition and processing.

Simcenter Testlab Neo doesn't reinvent the wheel. The latest platform builds on years of engineering experience. It includes a new task-driven user interface for the beginner as well as the expert, which facilitates increased work productivity and overall navigability. The software's fully customizable and flexible process designer speeds up analysis, supports multidiscipline analytics, and lets users embed simulation models as part of any process flow. There are more intuitive and interactive graphs, and selectable display panels speed up interpretation of results. The new platform is straightforward, increasing testing productivity, fostering team collaboration, and encouraging passion for the job at hand.

Simcenter Testlab Neo closes the simulation-testing loop by putting the model in the process using a method called Simcenter Testlab model-based system testing. This allows model-driven data selection of multiphysical simulation results from Simcenter Amesim software.

Existing users will appreciate the fact that Simcenter Testlab Classic elements still guide users through the measurement process, but the Simcenter Testlab Neo platform features a new central concept, called 'Tasks'. Users build up their measurements by creating a sequence of tasks and task groups. Tasks address a very specific function in the process and task groups contain various tasks that need to be completed for specific process steps. By following tasks and task groups on an easy-to-use interactive screen, similar to a smartphone's, the user is guided through the various measurement and process steps.

The new releases feature several innovative solutions such as the innovative and powerful Maximum Likelihood estimation of the Modal Model (MLMM) modal parameter estimator for modal analysis and ground vibration testing including automatic optimization of frequency response function fitting. This new solver iteratively identifies the parameters of a modal model at a push of a button.

Aerospace experts will value the new sound-quality tools for easy aircraft noise analysis, a new V24-II Simcenter SCADAS module for the highest accuracy and channel density, a new VBDS4 universal signal conditioning module, and sound source localization improvements including new Bayesian quantification for extra accuracy.

Environmental testing experts in the space industry will also appreciate the several dedicated enhancements in Simcenter Testlab for closed-loop control. The newly introduced closed-loop acoustic control solution is designed to control the acoustic level and shape in reverberant rooms. It also enables manufacturers to respond to the most stringent safety and tolerance requirements in the space industry, including force limiting on force measurement devices.

With the Simcenter portfolio, the world of testing has begun to merge into the world of simulation. Simcenter Testlab provides a portfolio of versatile tools that can evolve the digital twin process while supporting the need for quality data within the design process. The Neo and Classic platforms both provide highly effective and productive testing processes that can close the loop with simulation and promote greater testing productivity, more insights, increased confidence and easier collaboration. \\

1 // Simcenter Testlab Neo includes a new task-driven user interface

SMALL FOOTPRINT, BIG FEATURES

The ever-decreasing form factor of interfaces provides challenges and benefits for testing professionals

1// AIM Smart Cable – ASC1553 together with the AIM MiniPCIe card AME1553

In all areas of electronic equipment use, size and weight are critical factors and today drive the need for equipment to become smaller and lighter. Specifically, for the design of portable special avionics test and maintenance equipment, these factors are becoming paramount. Suppliers are challenged to find a corresponding solution beyond the 'traditional' industry standard form factors like the PCI, PCIe and PXI.

The PCMCIA (ISA based) and PC Card (PCI based) interface types both have more or less the same footprint, the credit card size mainly supported by commercial laptops. When the USB interface increased in popularity they disappeared and are no longer supported by commercial laptop vendors. The interfaces can now only be found in a small number of specialist semi-rugged/rugged laptops. The designated successor of the PC Card, the ExpressCard (PCIe based), did not gain popularity, due to the increasing success of the USB.

However, there are a couple of issues that need to be considered when looking at USB interfaces, since with commercial laptops, USB devices are usually mechanically connected differently from in the PCMCIA/PC Card approach. The partially integrated PCMCIA/PC Card is widely seen as being better suited to field applications than the mechanically less robust PCIe and USB A-type connectors.

Due to the popularity of USB applications, the AIM design approach was to use a Smart Cable (ASC) that integrates all the interface electronics into a D-Sub, 37-pin connector shell that can easily be attached to any USB 2.0 port. The bus interface electronics reside inside the connector shell and functional features are equivalent to the PCI-form factor, enabling test, simulation and monitoring of a MIL-STD-1553 bus with concurrent Bus Controller (BC), Multi-Remote Terminal (MRT), Bus Monitor (BM) and physical replay functionality. Critical timing and bus protocol-related functions are still executed on the small interface core SoC (System on Chip) devices inside the connector shell and do not stress or overburden the USB connection with any real-time protocol performance. Software compatibility between the bigger form factors and the smaller footprints, also makes migration of existing application software easy and efficient.

The migration of bus analyzer systems that use smaller form factors, such as the AIM Smart Cable (MIL-STD-1553 and ARINC429), becomes a very interesting option for extremely lightweight test, simulation and monitoring systems when combined with a tablet PC.

One point to note is the important difference between dedicated PCI/PCIe-based interfaces and USB interfaces. The former are more tightly coupled to the PC backplane, which gives rise to some advantages such as interrupt handling of specific events within the customer application software rather than the abstraction of interrupt events via USB, with higher latencies.

The most recent introduction of the PCIExpress MiniCard (Mini PCIe) provides the smallest form factor yet. This is relatively new in the avionics test market and brings back into play the tightly coupled interface core to a PCIExpress backplane. The entire interface has to fit on this footprint, including the physical front end adaptation to avionics buses such as MIL-STD-1553 and ARINC429.

Ideally all functions and features of former larger footprint interface types are now available on MiniPCIe. This was one design goal for the AIM MiniPCIe card (AME1553), so that full MIL-STD-1553 test, simulation and monitoring capability with concurrent BC, MRT BM and physical replay can be offered in this form factor with full software compatibility with existing AIM interfaces.

AIM has already successfully migrated a customer application, which was previously tied to a PC card interface, to a MiniPCIe card, confirming the suitability of this small form factor for test and simulation applications. Generally speaking, for the MiniPCIe form factor, full integration into the corresponding host platform or laptop/tablet PC would be required for a customized I/O connection.

The advantage is the implementation of a more rugged test and simulation or maintenance equipment, since the I/O can use suitable rugged connectors.

In summary, small form factors like the AIM Smart Cable or MiniPCIe are not forcing users to relinquish any test and simulation features, nor to give up any software compatibility to their existing applications or AIM bus analyzer software. \\

HIGH-SPEED IMAGING TOOLS

High-end testing such as particle tracking or material measurement requires the best high-speed imaging

1

High-speed imaging provides powerful data for analysis in many aerospace applications. As the capabilities of high-speed cameras advance, the research and analysis possibilities grow. As seasoned researchers and engineers know, only one part of the equation is obtaining high-quality data. The second part is processing it to reach a conclusion.

Applications in aerospace such as jet engine and combustion analysis require very high frame rates; however these applications also require considerable amounts of light. If an image is too dark for analysis, gain can be applied to lighten it, but at the cost of adding noise into the image, which may make it difficult to analyze. Therefore, the high-speed camera should be as light-sensitive as possible. ISO measurements are often used to specify sensitivity; however, camera manufacturers measure light sensitivity differently, making comparisons difficult.

An alternative to consider is the pixel size. While there are many trade-offs in designing high-speed sensors, in general larger pixels are more light-sensitive. For example, the Phantom Ultra high-speed series from Vision Research with frame rates up to 25,700fps at full 1MP resolution uses a sensor with a 28µm pixel, the largest in the industry, providing very high light sensitivity.

Applications such as particle tracking or material measurement studies require the high detail provided by cameras with 4MP or more and high-quality images. Two factors of image quality are read-out noise and dynamic range. The lower the read-out noise, the cleaner the image is, especially in the dark regions that are common in many high-speed applications. Dynamic range measures the sensor's ability to distinguish shades of light. The higher the range, the more the camera can distinguish between bright white or absolute black and the shade next to it. For example, the Phantom v2640 is a 4MP camera that reaches 6,600fps at full resolution and provides among the highest dynamic range and lowest noise floor available.

In the aerospace industry, critically important engineering processes demand troubleshooting and analysis data in the form of high-speed imaging. In many of these processes during video capture, sensing devices integrated within the same event being recorded rapidly respond to physical, chemical, or optical changes.

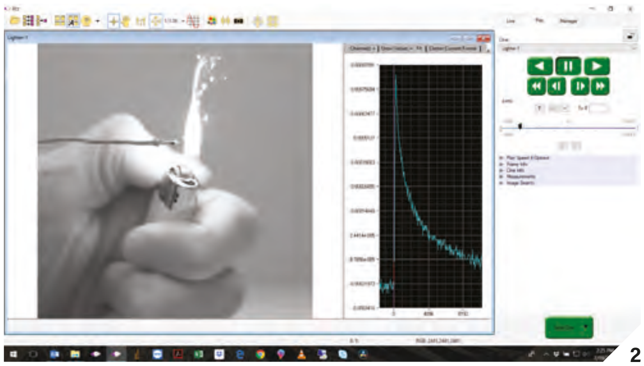
Traditionally, the collection of high-speed video and sensing data has been mutually exclusive, where signals from configured sensing devices are digitized via a data acquisition unit (DAQ) and stored in a PC. To improve workflow, Phantom Camera Control (PCC) software, the software that accompanies all Phantom cameras, offers the user the option of synchronizing high-speed images with acquired DAQ data. This is accomplished by first configuring the camera and sensing device with National Instruments' USB X- or M-Series data acquisition modules.

To ensure precision in timing and synchronization, ready and strobe signals from a Phantom camera are sent to the DAQ module. Successful configuration permits the viewing of the recorded slow-motion video together with the acquired sensing data in a frame-by-frame manner directly in the PCC software. The user also has the option of choosing between collecting one data point per frame capture or selecting the maximum sampling rate as specified by the configured DAQ unit. \\

1 // The Phantom v2640 offers high-quality 4MP images

2 // High-speed images synced with sensing data

3 // Phantom cameras connect directly to DAQ units for improved workflow



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INSTRUMENTS FOR GROUND VIBRATION TESTING

Proper selection of test equipment and setup are essential for consistent results

1 // Triaxial ICP modal accelerometer wing mounted with an electrically isolated base

2 // Modally tuned impulse hammer in use on an airplane aileron

3 // Modal shaker, with a thru-hole armature, stinger and force sensor mounted under a wing

(Images: Belgian Defence)

Modal testing of aircraft and spacecraft can be complex and proper equipment selection is critical. When choosing accelerometers for modal analysis of aircraft or spacecraft, the top considerations are resolution, frequency response, phase, small size, flexible mounting, transducer electronic data sheet (TEDS), and keeping the cost low per channel.

An accelerometer's mass and sensitivity are proportional. This means a general guideline is to select the best resolution available in a moderately small package. A typical accelerometer has 100mV/*g* sensitivity, a fraction of a milli-*g* resolution, and a mass of 5g or less. This minimizes the mass loading effect of the sensor while still allowing for reasonable resolution and a lower cost per channel.

When handling hundreds of sensor channels, it becomes extremely important to use an organized, modular cabling system and automated channel management to save setup time. The TEDS function of the IEEE1451.4 standard stores digital data, such as the sensor model number and calibration value inside the analog accelerometer, making it available for automatic recall during test setup. A simple reverse bias scheme applied to the two-wire ICP signal toggles the sensor into digital mode and establishes communication with a TEDS-enabled signal conditioner or FFT analyzer. This is a time-reduction technique when your test article is a high-value asset such as an aircraft or satellite.

Modally tuned impulse hammers are an easy way to deliver impulsive forces of amplitude and frequency. When combined with response accelerometers, the resulting motion of the test specimen provides transfer characteristics and structural health determination. Impulse hammers are useful on full-scale aerospace structures and components like turbine blades, electrical components and other subsystems. Hammer kits consist of matched components that are tuned for testing structures within certain size and mass categories. A selection of tips is included with each hammer, along with an extender mass that gives the hammer a frequency content tailored to the impulse force waveforms of the structure being tested. Impulse hammer selection involves determining the size and mass of the hammer that will provide the force amplitude and frequency content required for proper excitation of the structure under test.

Shaker testing is also used as a method of measuring forced input. This gives added ability to adjust the amplitude level, performing sine, swept sine, sine burst and random vibration excitation in a controlled manner. The setup of shakers is more complex as they require mounting of stingers and force input transducers. However, the effort can be worth it for the added precision it offers the test.

Piezoelectric force sensors and impedance heads are two sensors that are commonly used for measuring input forces. An impedance head is a sensor that measures force and the resulting acceleration response at the driving point in one device. This is a critical measurement in experimental modal analysis for accurate modal scaling and it is recommended that impedance heads be used in most cases.

In summary, the complexities of modal testing of aircraft and spacecraft can be simplified by working direct with vendors that are experts in this type of testing. With proper attention to ICP accelerometer selection and excitation test setup details, either by modally tuned impulse hammers or modal shakers, test engineers can acquire quality frequency response function measurements, which are fundamental for modal extraction analysis and consistent results. \\

NETWORK-CENTRIC FLIGHT TEST ARCHITECTURES

The easier management and control of large amounts of data can be achieved with the modern Ethernet over IP and the right software

The integration of various high-speed sensors and 10Gb plus Ethernet backbones within the flight test instrumentation (FTI) community has vastly increased data rates, onboard processing requirements, pure network architecture and cybersecurity requirements. These latest high-speed systems often need to record traditional low-speed data such as PCM, 1553, video, analog and discrete signals. Conventional hardware-based CH10 recorders are too slow for new programs, have too much latency and limited processing power. The new requirements for recording high- and low-speed signals in a usable and protected format has moved the industry toward new FTI technology.

Ampex Data Systems produces airborne solid-state recorders and, like GDP Space Systems and Acroamatics, is within the Delta Information Systems portfolio of companies. Ampex is the only avionics company to offer a complete, high-speed NextGen FTI solution designed to combine conventional data and the latest network requirements in a future-proofed system with onboard machine-learning-based data management and cybersecurity options.

In addition to NextGen FTI, Ampex's sister division, Delta Digital Video, is delivering the next generation of video encoders. Delta's new 7800 Series H.265 video encoders provide far greater compression efficiency (~50%) than H.264 solutions. Implementation of H.265 provides better video quality or twice as many channels over existing TM links. Required storage capacity can also be reduced when recording video that is compressed using H.265.

Today's telemetry ground stations are migrating from traditional serial pulse-code modulation (PCM) data distribution to telemetry over IP architectures.

GDP Space Systems and Acroamatics Telemetry Systems kickstarted the migration to telemetry over IP by pioneering Bit Synchronizers with Ethernet data output capabilities at the International Telemetry Conference (ITC) more than 15 years ago.

Today, these two companies are continuing to develop innovative technology solutions that support Ethernet data and control interfaces. GDP Space Systems' network-centric products include telemetry receivers, bit synchronizers, telemetry gateways, best source selectors, Ethernet recorders, and telemetry data processing and display systems.

Ethernet transport can be used as a modern matrix switch, meaning data streams can be easily electronically routed between acquisition, distribution, and processing and display devices. This method is far superior to previous methods of routing data through legacy matrix switches via coax cables, distribution amplifiers and patch panels.

Ethernet transport is essential in today's systems, as data rates have increased to a level that legacy infrastructures can no longer support. Ethernet allows many hundreds of megabits of data to be sent over a single link, distributing them to an unlimited number of devices on the network through commercial switches and routers. Additionally, it provides secure, lossless data distribution between geographically dispersed assets.

GDP Space Systems and Acroamatics Telemetry Systems Telemetry Range Management Software (TRMS) application has been developed to enable easy operator access and management of the routing of data between devices across a network. Control and status of GDP Space Systems, Acroamatics Telemetry Systems and other third-party devices are supported by TRMS. The software also includes debug and status tools that enable the operator to know when data is flowing and to effortlessly test, pinpoint and resolve problems. \\

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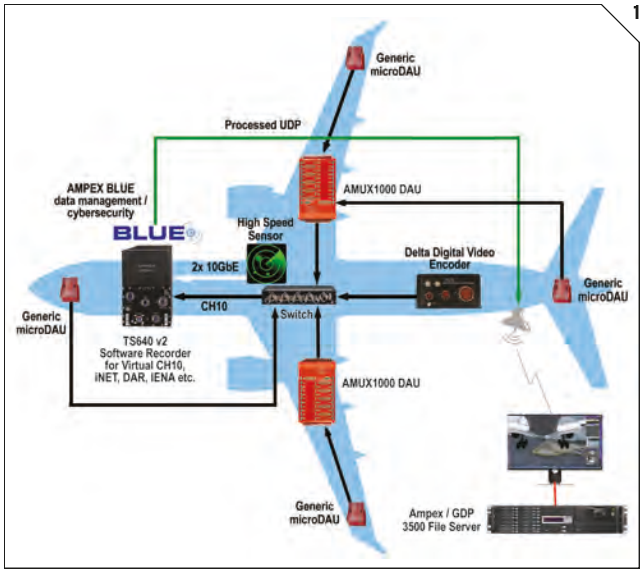

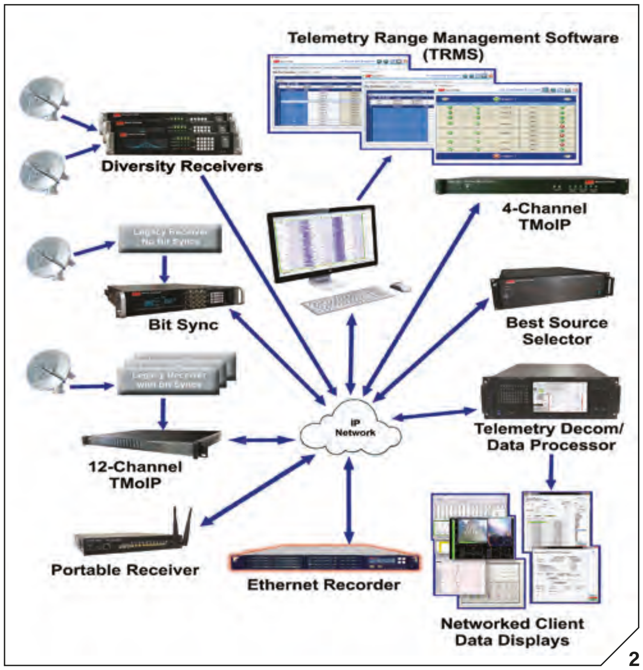

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1 // A typical network setup for flight test

2 // A selection of telemetry solutions delivered over an IP network

SOFTWARE TO PROCESS FATIGUE DATA

A new software platform built to handle and analyze large volumes of data can reduce overall fatigue test time and risk

1 // The GI.bench user interface

For the certification of aircraft structures, a huge amount of testing is required to guarantee failure-free behavior under all operating and environmental conditions. Yet the conflicting trends of increasingly complex structures and a reduction in development times are causing test engineers to continuously look for ways to reduce risk and save testing time.

A typical fatigue test for large components or full-scale structures is divided into a number of flight blocks. At the end of each flight block the test is stopped and the test specimen is inspected for cracks. These manual inspections are time consuming and the time interval between these inspections is relatively large. Structural abnormalities may be detected too late and may result in retrofitting in-service aircraft.

Condition-based inspection of the test specimen, instead of interval-based inspection, is a potential solution to reduce the total fatigue test duration and to quickly detect abnormalities. One of the implications is that more sensors are required to monitor the behavior of the test specimen and to detect or predict structural failures. As a full-scale fatigue test can generate data at rates of up to 10MB/s, totalling hundreds of terabytes at completion, data processing and analysis have become a major bottleneck.

Gantner Instruments has developed an innovative software platform to efficiently process large volumes of measurement data and analyze it rapidly. The software, called GI.bench, combines a time series database management system with a powerful stream processing engine. Measurement data that needs to be accessed right away, so-called 'hot data', is available in the database. Data that is less-frequently accessed and only needed for auditing or bookkeeping – 'cold data' – is kept in the stream processing platforms. This raw data is safely stored in redundant, fault-tolerant clusters.

Measurement data is backed up automatically. Flexible data aggregation ensures that test data is continuously logged to the database at a low sample rate. However, the same data can be replayed into the database and stored at a higher sample rate in case detailed analysis around an unexpected event or specimen failure is required. This approach minimizes the investment cost for IT and storage infrastructure in the test lab, while maintaining the necessary computing performance for test-critical data analysis tasks.

To get a better understanding of the mechanical response of the test specimen, powerful querying capabilities enable engineers to analyze a large amount of sensor data on-the-fly. Trend monitoring over the entire life of the fatigue test will quickly signal any significant change in strain between repetitive load conditions. Fatigue prediction and crack probability algorithms can identify possible loss of structural integrity during the test and immediately inform the operator and/or stress analyst when deviations occur.

Increasingly, more test labs use specialized control, monitoring and data acquisition systems. Examples in the field have shown that the lack of integration between these systems still leads to late detection of fatigue crack initiation, or worse, test specimen failure. One of the reasons is that multisource data and/or metadata is not readily available during the test. Measurement data can therefore not be fully analyzed until the end of the fatigue test.

The GI.bench platform comes with an extensive set of APIs to integrate third-party data streams, for example from a servo load control system. The primary strain gauge data can be enriched with load data, condition numbers and other test metadata. On top of that, the open software architecture supports a variety of publish-subscribe-based protocols, like MQTT (Message Queue Telemetry Transport) and DDS (Data Distribution Service), for seamless integration with other monitoring, analysis and reporting tools. This approach avoids wasting time on collecting, merging and processing data, and enables engineers to focus on what is most important: analyzing data. \\

HIGH-BANDWIDTH TELEMETRY TRANSMITTERS

The demand for more bandwidth for test data transmission is driving design engineers' requirement to start building up enhanced systems as soon as possible

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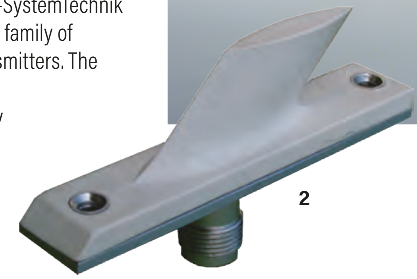

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Fighter aircraft, drones and missiles require hundreds of analog and digital signals as well as video streams and digital buses to be captured, formatted and transmitted to the ground station. For a successful mission or test campaign, ground operators need to gather in real time as much housekeeping information as possible about the various onboard subsystems and the vehicle itself, as well as payload data and video streams. For detailed flight analyses, mission controllers, test engineers and scientists on the ground typically prefer to receive raw data, rather than heavily processed and compressed data, as some important details could be lost through the use of these processing and compression algorithms.

Therefore the available RF spectrum is a critical resource for modern telemetry systems as the requirement for data bandwidth keeps increasing. New modulation schemes have been tested for suitability in flight test scenarios. The traditional and very robust, but bandwidth inefficient, analog frequency modulation is being replaced by digital SOQPSK and multi-h modulation, which are much more bandwidth efficient.

Because of its demand for high bandwidth, aeronautical telemetry, which was traditionally allocated in the L-band and S-band, is currently moving into the C-band. The range 5,091-5,150MHz is allocated worldwide, which makes it possible to use the same telemetry radios and systems across international boundaries. However, this frequency migration involves new challenges and the demand for efficient, rugged and reliable airborne telemetry equipment.

Future telemetry applications require a high data rate and high transmission power for long distance communication applications. In the case of fighter aircraft, abrupt motion changes and non-directive onboard antennas require high transmitted power to maintain uninterrupted communication with the ground station.

The demand for higher transmission power at higher frequency throws down a great challenge to transmitter designers, especially while other constraints, such as efficiency and size, remain unchanged due to space and power scarcity on board. Therefore it is necessary to have highly efficient and rugged devices with high power density at the newly allocated frequency band.

The telemetry industry will have to gradually migrate to the bandwidth-efficient modulation schemes and also move to the C-band in coming years. STT-SystemTechnik took the initiative to design a family of multipurpose telemetry transmitters. The new transmitter families are mechanically and electrically compatible with existing transmitter units to keep any modification efforts to a bare minimum, with no need to change mounting provisions or cable harnesses. They provide up to 20W of RF output power, which is remotely programmable, as well as the carrier frequency and deviation. Users can choose between different modulation schemes, such as analog (FM) and digital (SOQPSK), as well as the frequency band in which they wish to operate.

It should be kept in mind that a suitable airborne antenna is required to operate the transmitter in the selected band. The existing S-band antennas will not operate in the new frequency band. To avoid mechanical modification of the fighter, missile or other aircraft, the mounting provisions of the C-band antenna has been kept the same as the existing S-band antenna standard.

Unfortunately this means that all existing ground and airborne telemetry systems need to be replaced with new equipment capable of operating with these new modulation schemes and in the different frequency bands. S-band is still available, but approval for aeronautical telemetry applications will probably be discontinued in the near future.

Users should therefore start building up test systems to experience the differences when operating at 5GHz instead of 2GHz, as well as the performance of the digital modulation in real flight test scenarios.

STT-SystemTechnik is offering a communications package comprising of telemetry transmitter and antenna so that interested users can start investigating the frequency bands and modulation schemes and their specific behaviors. \\

1 // The TS900 transmitter is light weight and small

2 // S5100B C-Band airborne antenna

3 // Brimstone missiles onboard a Tornado fighter *(Image: MBDA)*

PRESSURE SCANNER THERMAL CONTROL UNIT

Pressure scanners are often subject to extreme conditions in flight test, engine test and wind tunnel applications. High vibration, dramatic temperature changes and moisture contamination are common issues that must be considered when selecting instrumentation for these tests.

The MPS4264TCU thermal control unit incorporates Scanivalve's latest pressure scanner, the MPS4264, into a package that meets the needs of the most rigorous test requirements. The MPS4264 pressure scanner incorporates temperature compensated piezoresistive pressure sensors that must remain within their temperature compensated range of 0-70°C (0-158°F) to provide accurate pressure measurement. The MPS4264TCU is designed to provide this controlled temperature environment for MPS4264 series pressure scanners by implementing a heater circuit within the thermal control unit case. This rugged IP54-rated aluminum case has been shock and vibration tested to MIL-STD-810G.

Extreme temperatures are also a challenge when test conditions exceed the temperature compensation range of pressure scanners. To address this, the MPS4264TCU is available with heating and cooling provision in three configurations: the standard ruggedized package, the ruggedized package with a heater, and the ruggedized package with heating and cooling provision. The optional heater provides protection to -60°C (-76°F), and by introducing user-supplied cooling air the cooling kit provides protection for the module up to 125°C (257°F). \\

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ACCELEROMETERS FOR GROUND AND FLIGHT TEST

The Endevco 7290 series has been used by flight test engineers to gather low-frequency data for more than 30 years.

Meggitt's latest version, the Endevco 7290G variable capacitance accelerometer, uses the same trusted MEMS sensing technology combined with state-of-the-art signal conditioning for excellent accuracy and performance over temperature.

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

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

If a tri-axial measurement is required, the Endevco Model 7298 has six ranges from 2-100*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, Meggitt claims, to provide users with the most accurate vibration data. In addition, the 7298 is durable, with high shock survivability and a hermetic package including a water resistant connector.

The Endevco family of piezoelectric, piezoresistive, IEPE (integrated electronic piezoelectric) and variable capacitance accelerometers; piezoresistive pressure transducers; rate sensors; electronic instruments and calibration systems, ensures critical accuracy and reliability in aerospace, automotive, defense, industrial, medical, power generation, R&D, and test and measurement applications. \\

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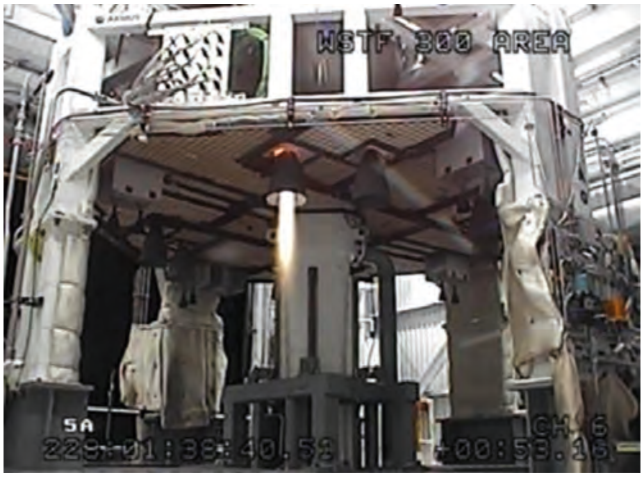
NASA ORION MAIN ENGINE TESTING



NASA's White Sands Test Facility is performing propulsion subsystem qualification testing for the Orion's European Service Module. The Propulsion Qualification Module includes testing the main engine, auxiliary engines, reaction control engines, and their respective hypergolic propellant and control systems.

The Orion Main Engine (OME) requires simulated altitude pressure conditions during firing to prevent flow separation and subsequent damage in the supersonic nozzle.

Jacobs designed and fabricated a water-cooled supersonic rocket diffuser and engine nozzle adapter for the OME, along with ancillary support structure and cooling water systems to maintain a low pressure at the OME nozzle exit plane. The rocket diffuser features helical cooling water passages and may be remotely moved axially away from the engine to allow access for inspection. The cooling water system features articulating joints at the rocket diffuser interface to allow diffuser movement without disconnecting the water piping. The engine nozzle adapter is also water-cooled and serves as the bridge between the engine nozzle and the diffuser.

Jacobs also designed, fabricated and conducted a scale model test program at NASA Stennis Space Center to confirm the aerodynamic and thermal performance of the diffuser. The scale test program used liquid oxygen and gaseous hydrogen as propellants, with the oxidizer-to-fuel ratio adjusted to simulate the correct exhaust gas properties of the hypergolic full-scale engine. \\

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BLOCKED WASTE LINE SOLUTIONS

Blocked waste lines can not only cause inconvenience for airline passengers in flight, but can also lead to high costs for the airline, particularly if they create an aircraft-on-ground (AOG) situation.

However, a solution to this problem is available to airline maintenance crews. Following thorough research into this maintenance issue, in partnership with a well-known European airline, Test-Fuchs engineers have developed an autonomous waste-line blockage remover that can be used on the ramp and in the hangar.

The diesel or electrically driven trolley serves as an all-purpose tool to clear and remove pipeline blockages for onboard vacuum-lavatory systems.

When a waste line blockage is reported by an aircrew, the Vacuum Toilet Blockage Remover is towed to the aircraft in question and when connected, removes the obstruction by using system compatible negative pressure. Diapers, milk jugs, passports, false teeth and other solid waste are removed in record time. The entire operation takes as little as 30 minutes and can be done while passengers embark or disembark from the aircraft. The aircraft can continue its operation without delay and an unscheduled maintenance stop is avoided.

The clearing procedure also avoids the disassembly of the waste line, providing a great saving on maintenance time and costs. During the operation, waste is gathered in a tank and disposed of in an authorized waste receptacle at a later date. The tank is large enough for several operations.

The Vacuum Toilet Blockage remover is an airline's answer to expensive AOG situations caused by waste line blockages. \\

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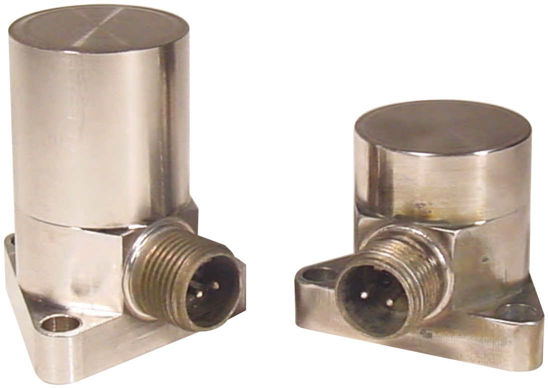
ACCELEROMETER FOR HARSH ENVIRONMENTS

CEC Vibration Products is a designer and manufacturer of vibration, temperature, force, torque and load sensors primarily used in harsh environment sensing applications. The model 4-171 series accelerometer is the company's newest addition to its sensor product line. This low-profile accelerometer was designed for both onboard aircraft engine monitoring and test cell turbine research and development applications.

These self-generating piezoelectric accelerometers offer high sensitivity and a stable output for continuous high-temperature operation. Rated for 850°F (454°C) applications, the 4-171 series provides a balanced differential output and is available in 10, 20 and 50pC/*g* sensitivities. This accelerometer does not require an external power source thanks to the 4-171's self-generating functionality, making the device an ideal choice for onboard vibration testing applications.

CEC Vibration Products offers a full line of signal-conditioning products to complement the accelerometer and velocity transducers used in most vibration measurement systems. CEC's remote charge convertors, low-noise cables, high-temperature cables and fully programmable monitoring systems are found in turbine engine test cells around the world. \\



ROMANIAN INSTITUTE OFFERS A FULL RANGE OF R&D

The National Institute for Aerospace Research 'Elie Carafoli' (INCAS) is the leading research establishment in aerospace sciences in Romania, with a tradition of over 60 years in aerospace engineering, flow physics and applied aerodynamics, using modern technologies and infrastructure of national importance. INCAS has been involved in all major national aerospace projects for both civil and military areas, and currently acts as a major player in EU policy making for research and development under FlightPath 2050 and Horizon 2020.

INCAS has carried out its activities under different names and structures since 1950, when the Applied Mechanics Institute of the Romanian Academy was established. In 1991 the Aviation Institute was reorganized along with the entire aerospace industry and INCAS was established.

As a research and development establishment, INCAS's mission is to offer dedicated services to the aerospace community. INCAS handles everything from blue-sky research and applied research to technological development and implementation of the obtained production results.

INCAS operates leading infrastructure for aviation research, including wind tunnel testing capabilities from low subsonic regimes up to Mach 3.5 supersonic regimes. \\

MOUNTING CHECK FOR ACCELEROMETERS

The actual, physical mounting of accelerometers to the test structure is the first link – and often the most problematic link – in the measurement chain. Any problems with mounting will corrupt the data for the measurement – and cannot be corrected later. Sometimes mounting errors occur because accelerometers are mounted in locations that are difficult to visually inspect, but even when visual inspection is possible, mounting errors can still be missed.

Accelerometer Mounting Check (AMC) is a Brüel & Kjær patented method for validating the integrity of the measurement chain. The goal of AMC is to ensure efficient and confident data acquisition; it is easy to use and is especially useful for multichannel measurements or measurements where the accelerometers are not easily accessible.

The AMC technique uses an electric voltage to excite the mounted accelerometer, which can be switched between mounting check mode and measurement mode. Performing the check identifies any accelerometer mounting issues, enabling the test engineer to fix problems before the measurement, or note the channel that the data is not usable on. After the test, performing AMC again enables validation of data before leaving the test area, ensuring that the test will not need to be set up and run again later.

Knowing whether or not the transducers are mounted correctly provides great confidence in your acquired data. As a result, measurements only need to be made once, reducing overall time and cost for the testing process. \\

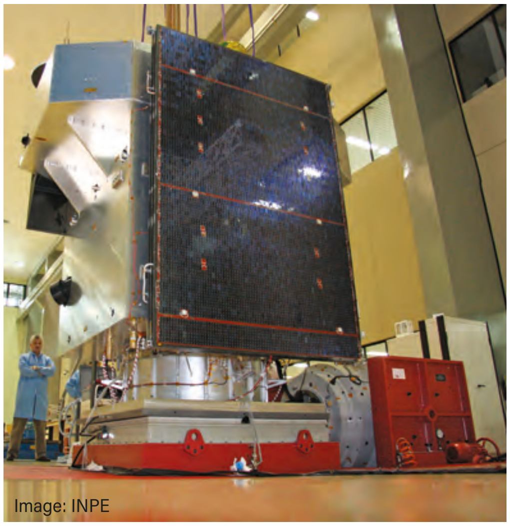


Image: INPE

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MOSQUITO'S RENAISSANCE

Recent recognition of the de Havilland Mosquito's innovative design and role in World War II has provided a boost for an early prototype of the fighter-bomber

After 78 years, the de Havilland Mosquito W4050, based in North London, is enjoying a new lease of life. In April, W4050, which was the first prototype Mosquito built, received an Engineering Heritage Award from the UK's Institution of Mechanical Engineers. The award was given in recognition of the all-wooden, multi-role fighter aircraft's design and technical innovations.

Then in May, the de Havilland Aircraft Museum that houses W4050 in the UK received £2m (US$2.6m) of UK National Lottery funding to build a new hangar. The Mosquito will be the star attraction of the revamped museum. The award and funding comes after a grant of £41,000 (US$53,000) was used to refurbish the historic aircraft in 2015.

The twin-engined, shoulder winged Mosquito has come to be seen by historians as one of the most under-recognized success stories for the Allied forces during World War II. Designed primarily as an unarmed fast bomber, the Mosquito proved so successful and versatile that it was adapted to several roles: fighter, night fighter, U-boat hunter and reconnaissance.

The techniques developed to produce the fighter also pioneered the composite methods of construction used to make aircraft today. The Mosquito was made entirely from wood, which was pressed and glued together in molds. This approach was taken because metal was so scarce in the UK during World War II and new aircraft were needed so rapidly by the Royal Air Force.

Nicknamed the 'Wooden Wonder', a total of 7,781 Mosquitos were built between 1940 and 1950. Some 30 aircraft have survived, just three of which are airworthy – one in Canada and two in the USA. A campaign to raise £5m (US$6.5m) to return a Mosquito based in New Zealand was also launched in July this year.

The Mosquito's fuselage is built mainly of a balsa and plywood sandwich, and the wings are formed as a single unit from wooden spars and stringers with plywood webs and skinning.

Prototype W4050 was designed and built at Salisbury Hall, on the same site as the de Havilland Museum. It's fighter-bomber design was originally submitted to the Air Ministry in September 1938, but was rejected several times before it was finally commissioned and built in 1940. Geoffrey de Havilland, owner of the de Havilland Aircraft Company, famously refused to carry out modifications to the design requested by the Air Ministry.

W4050 flew for the first time in November 1940 piloted by Geoffrey de Havilland Jr, who became the chief test pilot. The aircraft passed official trials in February 1941 and an order for 195 airplanes was placed in June the same year.

After the trials, W4050 was used for experimental test flights for the Mosquito family of aircraft, including new Merlin 61 engines in June 1942 and Merlin 72 engines in December 1943. The aircraft served as an instructional airframe at de Havilland's factory, before being transferred to the museum in September 1958.

Not only is the Mosquito's design and technology worthy of preservation, the story behind its development is worth remembering too, as a fascinating testament to the single-minded vision and ingenuity of the engineers at the de Havilland Aircraft Company. \\

NOV 25, 1940
First flight

W4050
Model number

54FT (16M)
Span

41FT (12M)
Length

19,670 LB
Gross weight

382MPH (615KM/H)
Top speed

326MPH (525KM/H)
Cruising speed

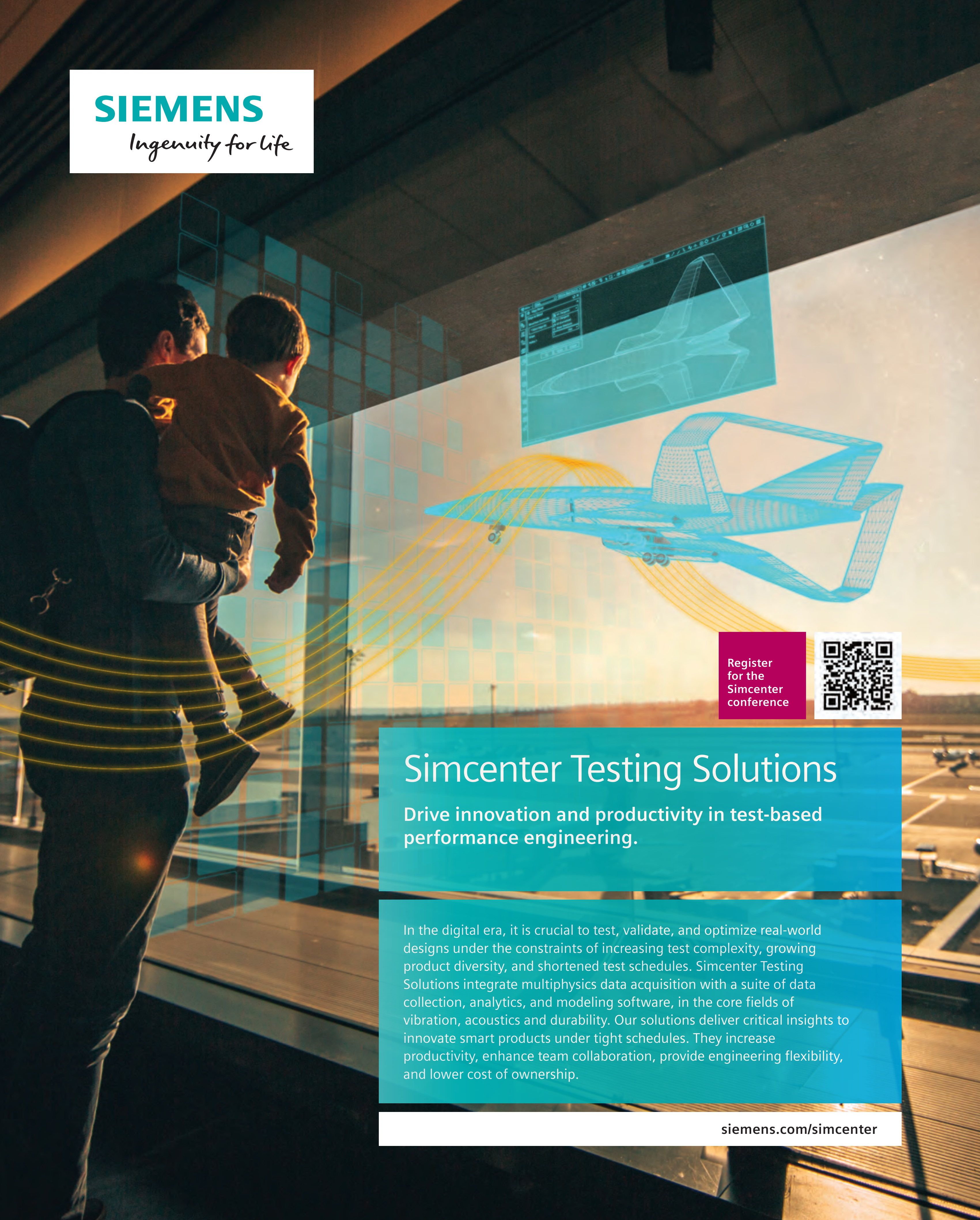
2,180 MILES
Range at full load

35,000FT
Ceiling

1,460HP
Thrust of each of the two Rolls-Royce Merlin 21 engines

131
Passengers – one class maximum

Watch the documentary 'The plane that saved Britain'
BIT.LY/DHMOSQUITOFILM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