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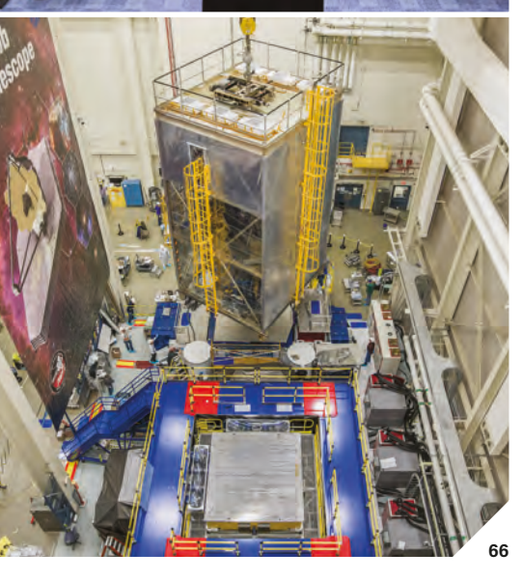

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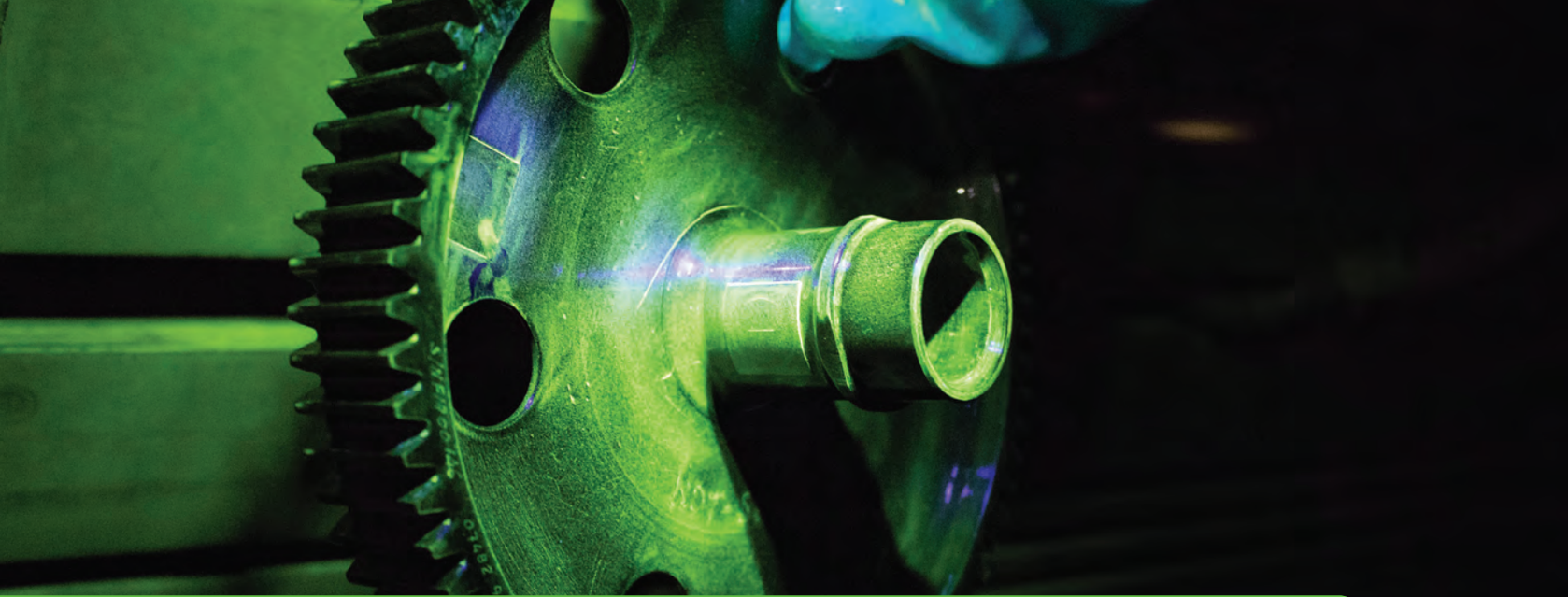

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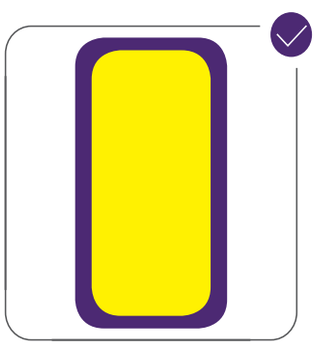

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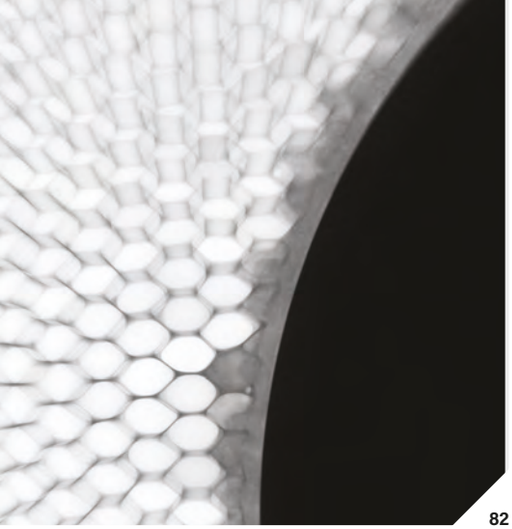

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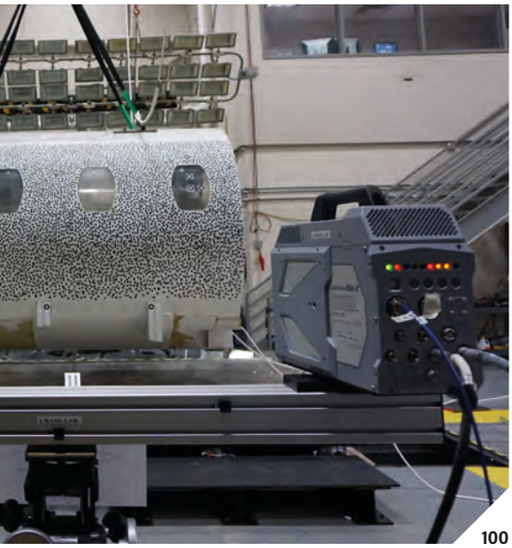

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// DEFINING THE SCOPE OF GROWTH

Our annual flight test roundup at the start of this *Aerospace Testing International Showcase* reveals the breadth of aircraft development programs happening across the world. Indeed, the first challenge when producing the report was defining its scope. The report covers only the major commercial passenger aircraft in development. If we were to consider other sectors and other types of air vehicles and aircraft in the design phase, the report would risk spiraling out of control.

There are many more aircraft development programs and arguably more innovation happening in the defense and space sectors. One need only look at the USA's latest thrust into space using the Space Launch System, combined with SpaceX's Dragon and Boeing's Starliner spacecraft, for evidence of the revitalization and innovation in the space sector. Similarly, there are several sixth-generation fighter jets being developed around the world, such as the UK's Tempest, the aircraft being developed for the USA's Penetrating Counter Air and FA–XX programs, the European New Generation Aircraft and other projects in Russia and Japan.

Then there is business aviation, cargo aircraft, as well as entirely new segments, such as UAS, eVTOL, air taxis and electric and hybrid aircraft. Although it may be said that the commercial aircraft sector is the more conservative area of the aviation market, and that it lacks innovation because of more stringent legislative constraints, the influence of these electric and digital technologies is steadily reshaping commercial aircraft and their systems.

An attempt at a comprehensive and constantly updated flight test report may be a Sisyphean task, but we successfully illustrate the breadth and diversity of the aerospace sector elsewhere in the magazine. The impact of digital and electrical technologies on testing in aircraft development can be seen in the article about acoustic simulation and testing on page 32. More effective testing of aircraft's electrical systems can be read about in the article on page 24, which describes how engineers are eliminating the notorious 'no fault found' message reported while carrying out maintenance. Meanwhile the article on page 18 tackles one of the thorniest of topics for flight test engineers – interoperability of instrumentation and data. The article considers if an ongoing US project will result in standardization of data formats for flight test instrumentation.

"The job of testing aircraft has never been as vital or in demand as it is now"

There is also plenty of innovation and diversity in other articles, which describe the latest tools and technologies for aerospace test engineers. From software analysis of additively manufactured components and hardware-in-the-loop testing systems, to fire and vibration testing, these products are evolving to equip engineers with the means of ensuring that aircraft don't go into a flat spin.

The job of testing aircraft has never been as vital and in-demand as it is right now. The great innovation and change in the sector can only be taken advantage of if one has the right tools. You will find them within these pages.

Ben Sampson, *editor*
ben.sampson@ukimediaevents.com

// The team

EDITOR Ben Sampson (ben.sampson@ukimediaevents.com)

PRODUCTION EDITOR Alex Bradley
CHIEF SUB EDITOR Andrew Pickering
DEPUTY PRODUCTION EDITOR Nick Shepherd
SENIOR SUB EDITOR Christine Velarde
SUB EDITORS Tara Craig, Alasdair Morton

ART DIRECTOR James Sutcliffe
ART EDITOR Louise Green
DESIGN TEAM Andy Bass, Anna Davie, Patrick MacKenzie, Craig Marshall, Nicola Turner, Julie Welby, Ben White

HEAD OF PRODUCTION AND LOGISTICS Ian Donovan
DEPUTY PRODUCTION MANAGER Robyn Murrell
PRODUCTION TEAM Carole Doran, Bethany Gill, Frank Millard, George Spreckley

PUBLICATION DIRECTOR Tom Eames (tom.eames@ukimediaevents.com)
PUBLICATION MANAGER Jag Kambo (jag.kambo@ukimediaevents.com)

CEO Tony Robinson
MANAGING DIRECTOR Graham Johnson
EDITORIAL DIRECTOR Anthony James

Published by UKi Media & Events, a division of UKIP Media & Events Ltd, Abinger House, Church Street, Dorking, Surrey, RH4 1DF, UK; tel: +44 1306 743744; fax: +44 1306 742525; editorial fax: +44 1306 887546

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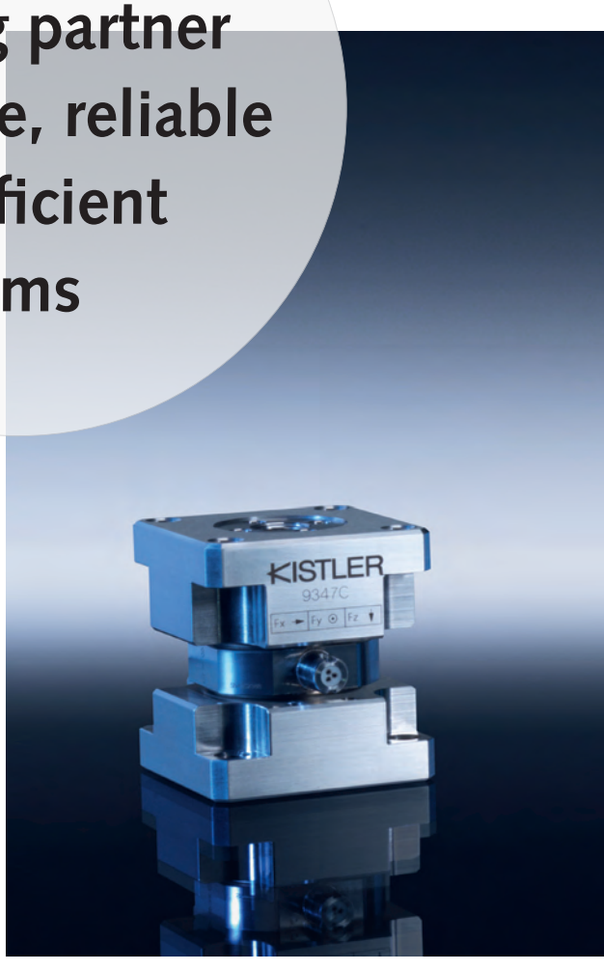

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FLIGHT TEST ROUNDUP

1 // Delta Air Lines became the first US-based airline to fly an A220, formerly the Bombardier C-series, in October 2018

"EIGHT A220 FLIGHT TEST AIRCRAFT HAVE LOGGED 6,867 FLIGHT HOURS OVER 5,435 FLIGHTS"

Aerospace Testing International's annual flight test report reveals there are more new commercial airliners in testing now than there have been for many years

// IAN GOOLD

AIRBUS

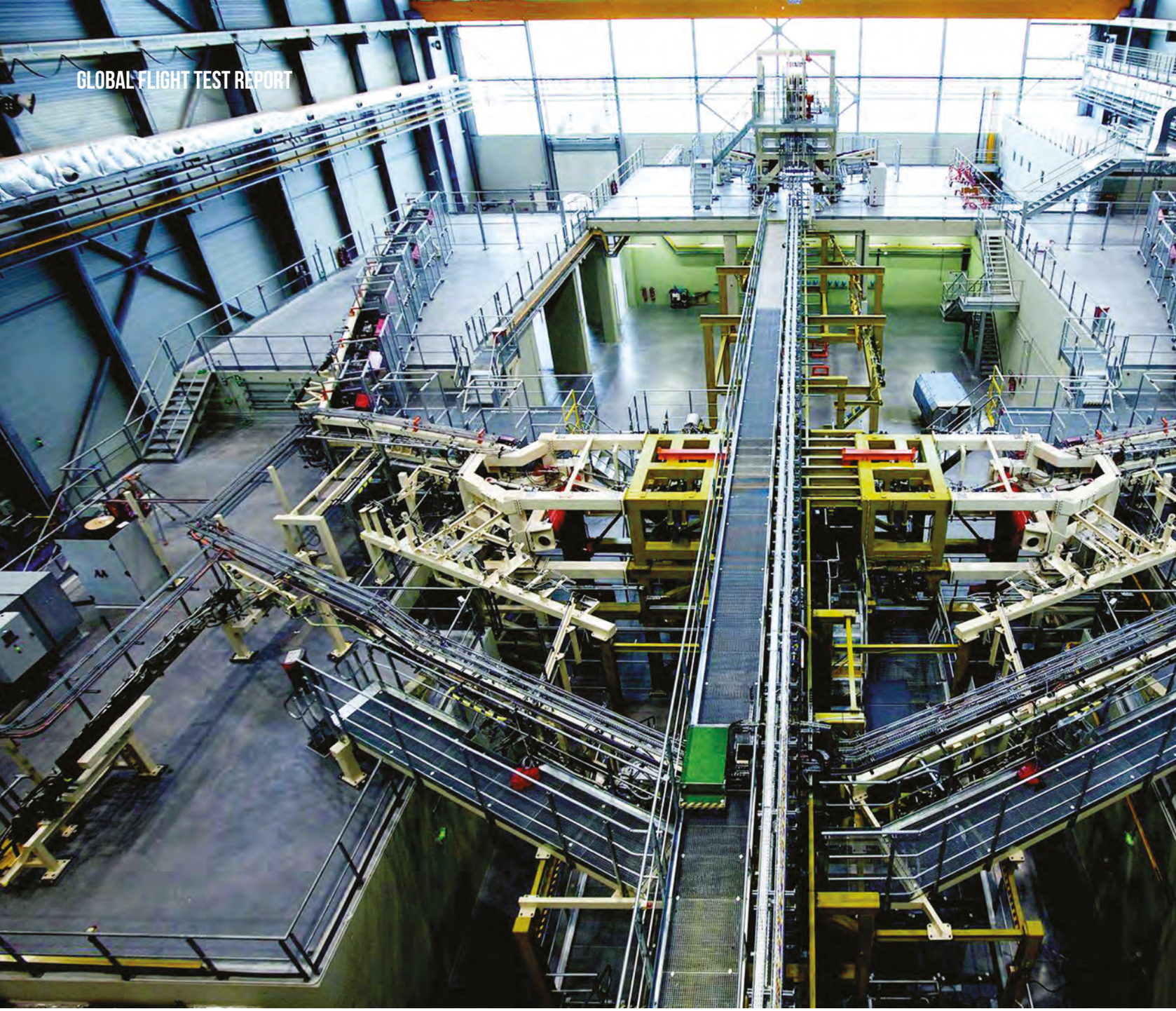
Since Airbus acquired the competing Bombardier's C Series program – now marketed as the A220 – the two entities have been looking at "synergies and integration opportunities for flight test", says Airbus.

A220

Full-scale durability and damage-tolerance testing was completed at the IABG test facility in Dresden, Germany, in 2018. The airframe metallic structure was subjected to 180,000 flight cycles (FC) and residual strength testing to validate primary-structure durability, inspection techniques and intervals, typical repair procedures, and damage tolerance.

Three of the Pratt & Whitney (P&W) PW1500G-JM powered aircraft, A220-100 manufacturer's serial number (MSN) 50002, plus A220-300s MSN55001 and 55002, are being used in flight testing for post-certification activities, software-upgrade development and certification, as well as to investigate in-service 'issues'. Overall, eight A220 flight test machines had logged 6,867 flight hours (FH) in 5,345 flights (including 5,081FH in 4,142 flights by six A220-100s) by September 2018.

MSN50002 was then primarily involved in engine and systems testing, while one A220-300 was principally engaged in avionics-upgrade approval and foreign-certification validation, with flutter



2 // The A350 XWB Iron Bird enabled extensive testing of the aircraft's systems pre-flight *(Photo: Airbus)*

testing planned for late September. Before being retired, the other A220-300 was tasked primarily to complete dual-lane slide certification and cold-/extreme-cold weather testing (in the coming northern winter); it also supported Airbus' marketing activities.

A320NEO

Airbus is supporting P&W's tests of the PW1100G-JM engine for the aircraft, "further improving ... maturity and 'time-on-wing'" with continuous-airworthiness campaigns using A320neo MSN6101. Maturity flight testing in 2019 will use new engine-build standards and MSN6101 for both certification and maturity work.

Meanwhile, A321neo MSN6673 will perform Category III automatic-landing 'Step 2' flying in 2019 to extend the family's "authorized wind envelope". This will remove current auto-land wind limitations that apply to both PW1100G-JM and CFM International Leap-1A engines.

Among the variants, Airbus will not claim a record for a long-range A321LR 11-hour, 4,750nm flight from the Seychelles to Toulouse, France, in March 2018, which carried 178 real and dummy occupants to test cabin-environment and fuel systems.

Airbus has also reorganized A319neo certification, abandoning building the planned MSN6620 for Leap-1A24 flight testing. The work was reassigned to

AIRBUS A320NEO FLIGHT TEST LOG

Model	Engine	MSN*	FC**	FH***
A319neo	CFM	6464	162	471
A320neo	P&W	6101	409	1,181
A321neo	P&W	6673	303	840
A321LRneo	CFM	7877	44	156

**Manufacturer's serial number; **flight cycles; ***flight-hours*
Source: Airbus (August 2018)

2

"AIRBUS HAS BEEN LOOKING AT INCREASING THE RANGE OF THE LARGER A350-1000"

3

3 // A350-1000 during a noise test campaign conducted in Spain *(Photo: Airbus)*

AIRBUS A330NEO FLIGHT TEST LOG

Airframe	FC	FH
MSN1795	217	693
MSN1813	144	499
MSN1819	29	200

Source: Airbus (August 2018)

MSN6464, which was planned to be withdrawn in late 2018 for re-engining with PW1124G-JM units.

Airbus said A319neo deliveries would be in line with "commitments taken with customers". Specifically, the manufacturer told *Aerospace Testing International*: "A319neo P&W certification will happen in due time." The company has also consistently declined to confirm plans for an ultra-long-range (ULR) A321neo with extra fuel capacity. The basic Leap-1A32-powered A321LR had flown in January 2018, leading to a near-100FH test campaign ahead of planned European and US certification and service-entry later in the year.

A330NEO

By September 2018, two A330-900 flight-test aircraft and TAP Air Portugal's first production example had completed about 1,400FH and around 400 flights, as the variant received formal airworthiness approval. Performance and handling-qualities flight-testing of the smaller A330-800, using MSN1836, was expected to begin in late 2018 ahead of certification about six months later.

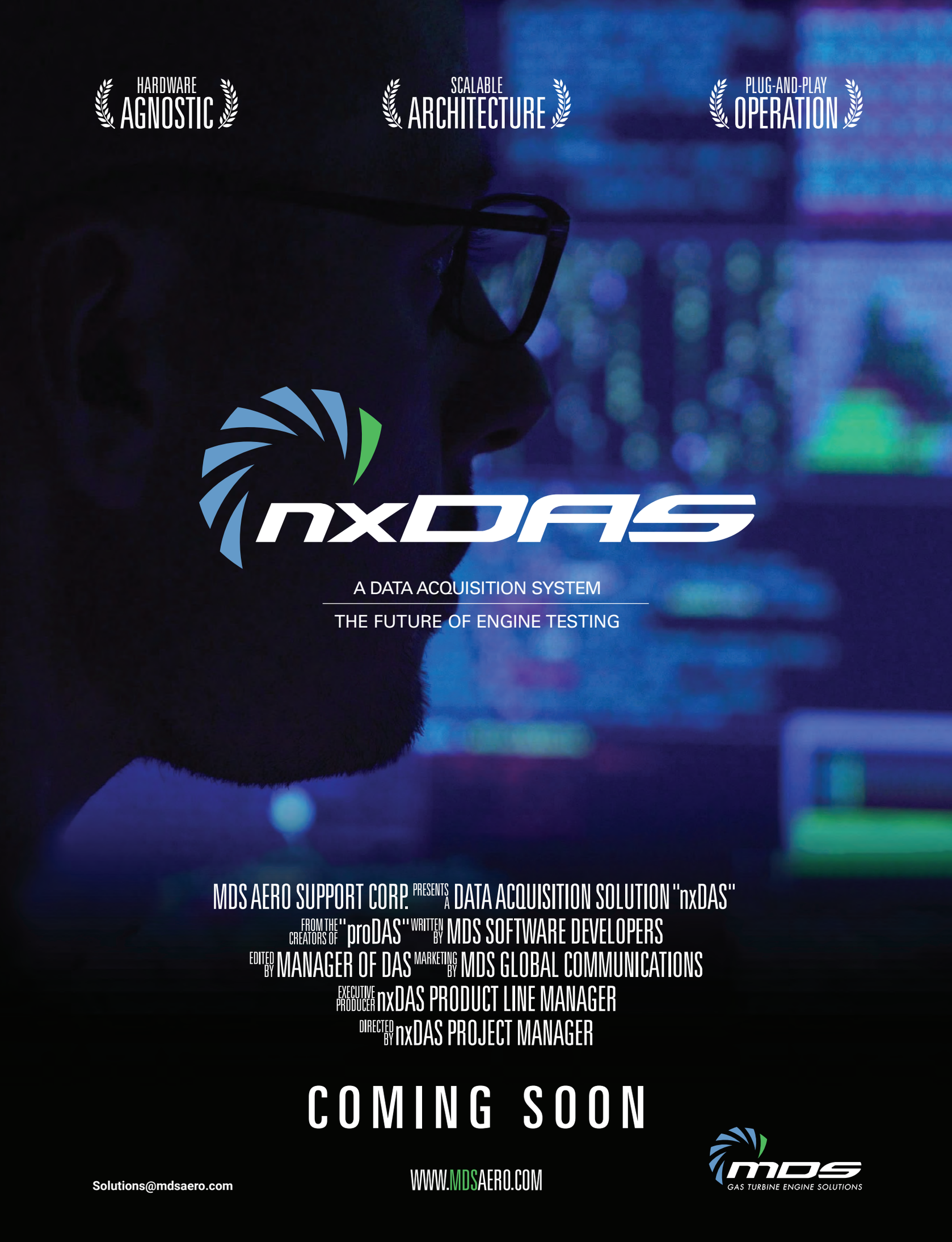
A350

Following flight testing with a redesigned fuel system, the first ultra-long-range A350-900ULR variant – claimed by Airbus to be capable of "flying further in commercial service than any other aircraft" – was delivered in September 2018 to launch customer Singapore Airlines. Testing of the A350-900ULR, which has a 24,000-liters greater fuel capacity, increasing its range by 1,600 nautical miles to 9,700 nautical miles, confirmed the improved performance from aerodynamic improvements, including its extended wingtips.

Airbus has been looking at increasing the range of the larger A350-1000, although it declines to say more than that it will "always consider future improvements in line with market and customer needs". Having previously increased the variant's maximum take-off weight to 316,000kg (348 tons), the manufacturer is understood to be considering an additional 3,000kg (3.3 tons) through introduction of extra fuel capacity to increase range beyond the current 8,400 nautical miles.

BOEING

It was out with the old in 2018 for Boeing as the 777 prototype was consigned to a museum after 24 years, 20,519 commercial flights, and 49,687FH of service. But it was also in with the new, as Boeing prepared for 777-9 ground testing and continued 787-10 development. Also in hand was further progress with the re-engined 737 Max family – including the third and smallest Max 7 (737-7) variant, Max 200, and stretched Max 10 (737-10). The latter two aircraft are expected to enter service in 2020.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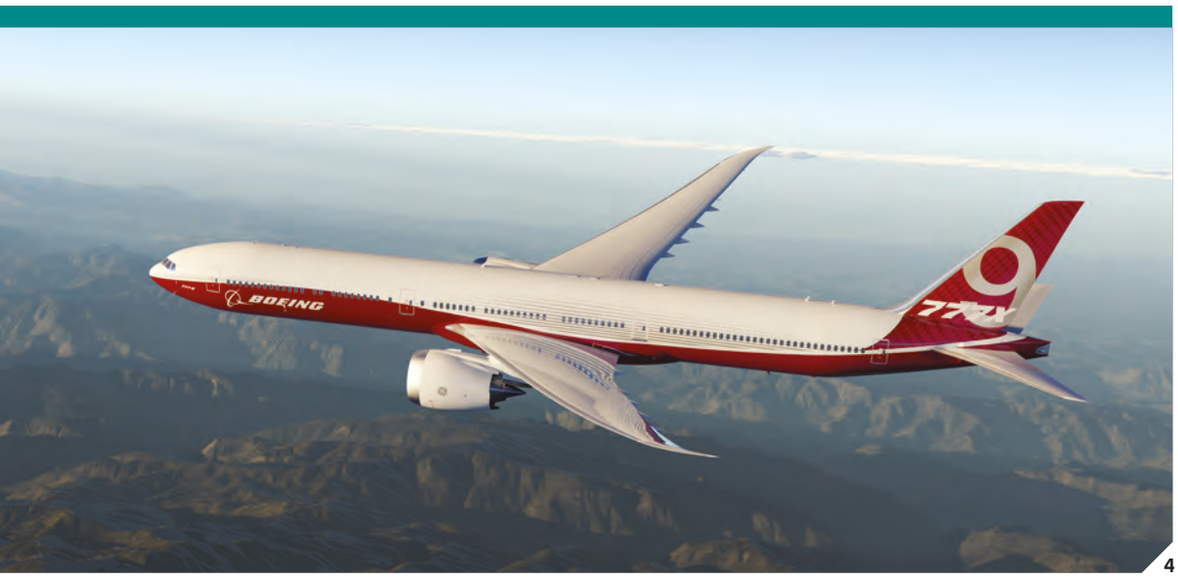

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"SIX AIRCRAFT WILL BE USED IN A THREE-YEAR TEST PROGRAM FOR THE 777-9"

737 MAX

After accounting for 10-15% of deliveries in 2017, re-engined, Leap-1B-powered Max variants were expected to represent 40-45% of 2018 737-family output, according to Boeing. Overall, it expects 60-65% of Max deliveries will be 737-8s, with 737-9s and -10s comprising 30-35%, and Max 7s the balance.

737-10

In January 2018, Boeing completed firm configuration of the 230-seat 737-10, which is 66in (1.6m) longer than the -9 and will incorporate redesigned main landing gear for necessary rear fuselage take-off and landing runway clearance. Over 70% of necessary engineering details required for initial production were complete by September 2018, with Boeing preparing for production in 2019.

737-7

March 2018 saw the maiden flight of the first 172-passenger 737-7 (test-fleet identity 1E001). Designed for operations from high-altitude airports and in hot climates, the variant was expected to receive certification and enter service by early 2019. Second flight test example 1E002 was earmarked for high-temperature and high-altitude flight-validation take-off tests, which are to be conducted in China.

777X

In September 2018, Boeing moved the first 777X (Line Number 9995) into its static-test building ahead of 12 months of trials. The static-test aircraft lacked avionics systems and engines, and its wingtips lacked the folding mechanism planned for production 777-8 and -9 variants. Also set aside for ground-testing is the sixth airframe, which was half complete in mid-2018.

Six aircraft are being used in a three-year flight- and ground-testing development program for the 777-9, with first delivery planned in 2020. Production of airframes 2-6 had begun by August 2018, at which time Boeing had developed 98% of the detail design.

For the folding wingtips, the FAA has set special certification conditions for the aircraft to address worst-case situations. These include crew-alerting, secure locking, gust performance, inflight malfunction, and cross-wind handling.

4 // Boeing's 777-9 features folding wingtips which must meet special certification conditions *(Photo: Boeing)*

5 // Leap-1B-powered 787 Max 8s are expected to represent up to 45% of Boeing's deliveries of 737-family aircraft in 2018 *(Photo: Boeing)*

777-9

Boeing has not publicly released assigned roles for each flight-test aircraft, but the four 777-9s, dubbed WH001 to WH004, will perform a full range of duties including: aerodynamic and brake performance testing, automatic flight, avionics, engine/APU performance, environmental systems, extended twin-engine operations (ETOps), flight-envelope expansion, flight loads, functional and reliability tests, interior systems, primary flight controls, and stability and control.

787

Boeing flew six 787-8 flight test aircraft for 4,800FH, more than three times that for the five -9s, while 787-10 testing required just three test machines and about 900FH. By August 2018, five of the aircraft had been retired, delivered, or were in work to be delivered to customers, except for the fourth example, ZA004, which was stored pending performance-improvement upgrade testing.

787-10

Rolls-Royce Trent 1000 TEN-powered Boeing 787-10s entered service in early 2018, as flight testing involving aircraft ZC001, '002 and '036 was concluded. Meanwhile, certification for General Electric GEnx-1B-engined examples was pending in late 2018 as Boeing awaited updated engine-control software or temporary FAA airworthiness exemption.

COMAC

Launched in 2008 to build what became the single-aisle C919 twinjet, which first flew in 2017, Commercial Aircraft Corporation of China (Comac) inherited the Aviation Industry Corporation of China ARJ21 regional jet that entered service in June 2016. Comac also has a joint venture with Russia's United Aircraft Corporation (UAC) to develop the 280-passenger, 12,000km-range (7,450 miles), CR929

5

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twin-aisle twinjet, which, in late 2018, was in preliminary-design stages.

ARJ21-700

By mid-2018, 11 GE CF34-engined ARJ21-700s, including initial test aircraft, had flown. A third ARJ21, MSN103, completed a 12-day high-temperature operations evaluation, largely aimed at verifying system changes to increase maintenance efficiency and cost-effectiveness.

In March 2018, MSN101 completed crosswind testing in Iceland to obtain clearance for operations in 30kts crosswinds at take-off and 27kts during landing. Following tests of an enhanced flight control system in 2017, flight testing in 2018 was planned to focus on system upgrades and weight reduction.

C919

Ahead of European C919 airworthiness approval, Comac hopes to obtain Chinese certification by the end of 2020, in time for entry into service in the following year – 12 months later than the date given in 2017.

By mid-2018, Comac had completed static and damage-tolerance tests for a composite wingbox project and the aircraft had undergone cabin-pressurization load-limit and whole-aircraft static-load testing.

Also being tested was a Chinese CJ-1000AX high-bypass demonstrator engine, developed as an alternative to the LEAP-1C fitted to initial C919s. It is understood that China plans to build another 24 CJ-1000s for certification work.

A planned 4,200FH test program involves six aircraft, MSN101-106. The first two flew in 2017, and MSN103 was scheduled to fly in 2018, when MSN104 was also to be rolled out.

6 // A Comac ARJ21-700 taking off for crosswind testing at Keflavík International Airport *(Photo: AJW Group)*

7 // An E-190-E2 prototype performing its third icing test *(Photo: Embraer)*

C929

Comac and UAC established the joint venture China-Russia Commercial Aircraft International Corporation (CRAIC) to produce the CR929 twin-aisle twin-engine jet, which will comprise three models: the initial CR929-600, and the -500 and -700 shrink and stretched siblings.

In mid-2018, the CR929 engineering team confirmed finalization of the aircraft's external dimensions and basic aircraft configuration. CRAIC's next milestones were completion of wind-tunnel tests, selection of structural materials, including more than 50% composites, and choice of principal suppliers by mid-2019.

CRAIC has received seven engine manufacturers' proposals, which it planned to have "analyzed, clarified and evaluated in detail" by the end of 2018. In July, CRAIC released a formal request for proposals for the CR929 landing gear.

Construction is set to start in 2021, and the first flight is scheduled for 2023 – two years ahead of service entry. The aircraft is expected to feature "more electric" systems, for braking, environmental control, flight-control actuation and thrust reversing, and to share the same cockpit design as the C919.

EMBRAER E-JET-E2

Development of the 76 to 90 seat E175-E2 – the smallest and last member of Embraer's second-generation E-Jets family – was "right on schedule" in September, said the Brazilian aircraft manufacturer, with initial assembly planned to start before July 2019. Flight testing of the prototype, MSN20006, was expected to follow by the end of the year, with certification and entry into service scheduled for 2021.

That aircraft and second prototype MSN20007 will be used for all of the required aerodynamics, loads, minor-systems compliance, and propulsion tests. The third aircraft, E175-E2 MSN20008 – the first with a cabin interior – will be used primarily for cold soak, comfort and intra-systems tests, and function and reliability (route-proving) flights.

The E175-E2's engine, landing gear, tailplane and wings will require specific tests, although the manufacturer will take credit from the E190-E2 systems commonality and so will not need a dedicated aircraft for systems-compliance demonstration.

Two E190-E2 prototypes remain active. MSN20003 is involved in optional certification campaigns, while MSN20004 is dedicated to global demonstration flying. Three E190-E2s were delivered between April and June 2018 and Embraer expected to supply up to seven more to customers by year's end.

Compared with the E190-E2, Embraer says that certification of the larger E195-E2 – MSN20005 flew in early 2017 – requires "an aerodynamics campaign, tests of systems such as 'firex', environmental and fuel, in addition to specific cabin evacuation and inspection campaigns",

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8 // The Mitsubishi Regional Jet's PW1200G-JM engine being tested on Pratt & Whitney's testbed *(Photo: P&W)*

9 // The first MC-21-300 test aircraft leaves the hangar for its maiden flight *(Photo: Irkut)*

ahead of what it expects to be a 2019 airworthiness approval.

The manufacturer claims that an important aspect of E2-family development has been a focus on product maturity. To exceed typical airworthiness-approval requirements, Embraer created around 600 aircraft-systems maturity tests to include typical operational scenarios not normally fully covered by certification tests.

The procedures were developed from E-Jet (E1) experience and performed during airworthiness-approval flights and dedicated maturity campaigns, such as early-2018 cold-weather operations in North America, during which the aircraft logged more than 100FH and 45FC. By September 2018, E-Jet 2 ground testing had exceeded 50,000 hours.

MITSUBISHI REGIONAL JET

Focused on achieving type certification for the 81 to 92 seat Mitsubishi Regional Jet 90 (MRJ90), Mitsubishi Aircraft (MitAC) had by September 2018 logged over 2,000FH and completed more than 50% of planned flight testing.

The PW1200G-JM-powered machine, Japan's first new commercial aircraft for 50 years, was "making steady progress" toward service-entry, now set (after several delays) for mid-2020. After a series of Japan Civil Aviation Board (JCAB) familiarization flights, MitAC was "working very closely" with the regulator to obtain Type Inspection Authorisation and was expected to release more information "in the coming months".

Four flight test aircraft (MSN10001-10004) had undergone "full envelope testing, including in hot and cold, high and low, and fast and slow environments". The company has been working with US flight-test and type-certification partner Aerospace Testing Engineering & Certification at MitAC's flight test center in Moses Lake, Washington state, supported by teams in Nagoya, Japan and also in Seattle.

Several other machines were in various states of manufacture, including further flight-test examples and the first two (MSN10008 and 10009) scheduled for completion as the smaller, 69- to 80-passenger variant, planned for JCAB type certification 12-18 months after that for the MRJ90.

"THE SUPERJET 75 WILL ENTER SERVICE IN 2022-23 WITH MODIFIED ENGINES AND FUSELAGE"

9

UNITED AIRCRAFT IRKUT MC-21-300

There are three initial MC-21-300 test aircraft. The second aircraft, MSN003, first flew in May 2018 almost exactly 12 months after the first, and a static-test specimen, MSN002, at Russia's Zhukovsky Central AeroHydrodynamic Institute (TsAGI).

Powered by PW1431G-JM engines, the flying MC-21-300s are based at the Zhukovsky Flight Research Institute, near Moscow, where the two single-aisle jetliners are involved in stability and control tests as part of a 1,150FH program ahead of planned certification in mid-2019. An MC-21 equipped with indigenous Aviadvigatel PD-14 powerplants, for which European approval is expected in 2021, is scheduled to fly by mid-2019.

The first aircraft (MSN001) is also being used to assess take-off and landing characteristics, engine operation including inflight restarts, and recovery from deep-bank rolls. The second machine is undertaking controllability checks with various wing configurations, with landing-gear extension and retraction, and testing of onboard equipment. Irkut plans to build three more test machines before it enters serial production of the MC-21-300, including fatigue-test airframe MSN005.

SUKHOI SUPERJET

Sukhoi Civil Aircraft wants the flight deck of its proposed 75-passenger Superjet 75 (SSJ75) to be similar to that of the Irkut MC-21, as parent company United Aircraft plans to the consolidate the two companies' civil-aircraft production. The Superjet 75, which is now in development for service entry in 2022-23, will have modified engines, fuselage and wings, while avionics and some structures will be "unified with the MC-21".

In mid-2018, Sukhoi Civil Aircraft had yet to decide on an engine for its planned SSJ100R 'Russified' variant, which is currently powered by the Franco-Russian PowerJet SaM146, developed jointly with Safran (Snecma). \\


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SHARED GOALS

A standardized programming language for FTI being developed in the USA could improve flight test agility across the entire industry

// AUSTIN WHITTINGTON

Southwest Research Institute (SwRI) is developing software application techniques to improve the agility and cost-effectiveness of the flight tests used to qualify military and civilian aircraft.

The project is being funded by the Defense Advanced Research Projects Agency (DARPA) and the US Air Force Research Laboratory (AFRL). DARPA recently expanded SwRI's contract from US$791,000 to US$2.29m. The new work will build upon the flight test integration effort by applying the constraints technologies to a set of challenges with military ground vehicles. Work will entail SwRI performing technical evaluations of Building Resource Adaptive Software Systems (BRASS) performer solutions against flight test and ground vehicle challenge problems. Additionally, it will help to speed the transition of DARPA BRASS technologies into military aircraft and ground vehicles

Real-time adaptability is a major challenge for military and commercial flight testing. SwRI's DARPA project is an opportunity to explore the BRASS platform as a framework for industry and military adoption of interoperability standards and adaptation techniques. There is a great opportunity with DARPA's BRASS technology to help expedite industry and military adoption of interoperability standards and adaptation techniques.

Flight tests use instruments and networks from many different instrument vendors to test for hundreds of potential problems and prove aircraft are ready for service. Each test instrument typically uses proprietary software with custom 'flight

"SYNCHRONIZING FLIGHT TESTING GOALS FOR DIFFERENT INSTRUMENTS IS A MAJOR CHALLENGE FOR THE INDUSTRY"

2

test constraints' that define the capabilities of the instrument for the problems or situations the aircraft may encounter.

Synchronizing flight testing goals for different instruments is a major challenge. Engineers try to test multiple problems on each test flight, but they are often delayed when a single failure causes a chain reaction of delays to unrelated tests.

To overcome these issues, SwRI will use DARPA's BRASS technology to augment the capabilities of a common flight test constraints implementation that has been developed through the US Department of Defense (DoD) Integrated Network-Enhanced Telemetry program, or iNET.

As iNET's lead integrator, SwRI works with the DoD and aerospace stakeholders to define a Metadata Description Language (MDL), which enables a standardized way to configure hardware for different vendors. A standard language will help test engineers work across devices from different vendors, paving the way for flight tests to better adapt to changing conditions, such as inclement weather or equipment failures.

1 // Research Analyst Austin Whittington (right) is the principal investigator on a DARPA-funded project to improve compatibility of flight test instrumentation

2 // SwRI's flight test technologies laboratory is used to develop a common constraints language for flight test vendors through the Integrated Network-Enhanced Telemetry (iNET) program

If the BRASS techniques prove to be adaptable and sustainable and match the overarching goals of flight test programs, their applicability and effectiveness for the warfighter will be extensive and persistent.

CLASSIFYING AND ADDRESSING FLIGHT TEST PROBLEMS

In the BRASS realm, there are several classes of problems that can be solved or addressed by the constraint satisfaction-type of approach. More specifically, these are problems for which all the parameters and metrics are known and static, and answers can be verified without the information of a particular circumstance.

One class of problems matching these criteria is that of configuration requirements analysis. An engineer may have a set of requirements for an acquisition system, defining the measurements needed, data rates, and other information. In the theoretical world, where a BRASS-powered system has all the capabilities that are foreseen as possible outcomes of the program, there are a few options open to them.

The engineer can validate that the acquisition system that was assembled from available parts is capable of satisfying the requirements, based on the capabilities of the individual components and the system topology. The engineer can get

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a measure of the redundancies of the system in the face of failures by seeing how many sources there are of a particular piece of safety-critical information; and can opt to have the BRASS-powered system build configuration possibilities, drawing from the available devices and equipment available for use at that facility, with a goal of the minimum hardware required to satisfy the requirements.

MAKING DATA-ACQUISITION COMPATIBLE ACROSS VENDORS

A particular problem that is being explored by the SwRI project is the question of what to do when hardware needs replacement. A scenario may present where, in a preflight situation, a data-acquisition unit (DAU) is broken and needs to be replaced. Inventory stock for that DAU is low, so the risk of depriving other concurrent programs which rely on that part is high. The decision could be made to order a new DAU from the vendor, which adds a purchase cost and a significant lead time during which no more tests can be run. Alternatively, there may be another type of DAU, even from a different vendor, which has similar capabilities and is in stock at the facility.

Using requirement analysis techniques, it is possible that the BRASS-powered system can prove that the secondary DAU will satisfy the original requirements that the DAU being replaced was responsible for, regardless of the actual sampling rates and other parameters used in operation. This would save money and time for the program and would avoid putting other programs at risk. These BRASS adaptations can explore beyond what an engineer would be tasked to do, because there isn't a minimum feasibility that would have to be met. In other words, it doesn't have to seem likely for BRASS to explore the possibility. These types of exploratory optimizations and adaptations are generally only done by humans with considerable domain experience and intuition to help guide them, but a BRASS-powered system can explore further and faster with more formal satisfaction of the requirements.

This then leads back into our theoretical world, where the BRASS-powered systems are available and performing as predicted. In addition to the configuration-time adaptations discussed above, there are many points in a flight test program where real-time adaptations are desired, but may not be actually carried out, because of the relatively static nature of running tests and the complex interdependencies between simultaneous flights. A BRASS-powered system could consider the environment of the whole test range and make decisions that either avoided impact to other tests while adapting a single test, or trigger adaptations to maximize the value or minimize the cost of the entire range, depending on the scope of the operation the system is responsible for managing.

> "RECENT EVOLUTIONS IN FLIGHT TEST TELEMETRY MEAN THAT SOME SCENARIOS ARE ACTUALLY ADAPTABLE WITHOUT BRASS"

3 // SwRI develops network-based flight test solutions used to certify aircraft. Synchronizing flight test goals with hardware, networks and telemetry is a challenge

4 // Flight test instrumentation vendors use different constraints and embedded software. SwRI is exploring DARPA's BRASS framework to integrate common software for instrument vendors

SYNCHRONIZING FLIGHT TEST TELEMETRY

Recent evolutions in flight test telemetry mean that some scenarios are actually adaptable without a BRASS system. An example of this is a situation with a test article (TA), which, after encountering strange vibration, requires more safety of flight data to continue the test. In a traditional PCM system, this TA would be configured with a fixed transmission schedule and would just be forced to land. Using an iNET Telemetry Network System (TmNS) system, but still configured with a fixed transmission schedule, a BRASS

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5 & 6 // Instead of being grounded, a BRASS-powered FTI system could increase utilization by autonomously deciding to run alternative tests

system would be able to dynamically reconfigure the radios, considering other transmissions scheduled on that frequency. A more typical iNET system would be able to use the Link Manager to adjust the scheduled bandwidth for that test article and grant the bandwidth rights to be able to send down the necessary data without any reconfiguration.

A more interesting situation is performing a test when another parallel test is grounded, leaving the remaining TA with considerably more available bandwidth for a period of time. The TmNS system can make the adjustments to grant the TA that bandwidth, but there are unlikely to be guidelines on how to adapt for beneficial situations that operators can follow. As such, a traditional system would just continue as if no change had occurred, and the range would lose the cost and value associated with the grounded test.

However, a BRASS-powered system could have knowledge of many relevant parameters to decide on a course of action. These parameters include the current configuration of the TA's instrumentation system, the progress in the testing program and even environmental conditions. This system could advise anything from simply transmitting more data for the existing test, to suspending it to do a more 'lucrative' test to maximize program value. These complex adaptations are far from being implemented, but it is important to highlight the potential of these types of approaches.

FUTURE INTEGRATION

Ignoring the practical limitations of needing people to sign off on letting a computer create and modify test plans, the sky is the limit for what we can adapt to. For instance, take a flight that fails an icing test. A BRASS system, with the knowledge of what instrumentation is equipped and what test points still need to be measured on unrelated tasks, could still gain some value by reconfiguring devices and performing a different test. Going further, BRASS could already have planned for that eventuality by running other tests on the way to the icing site, or even monitoring the weather on the way and redeploying the TA as the system clears to run a test without even making it out there.

Much like the evolved antennas that NASA uses, computer-designed to maximize radiation patterns in ways humans would not have come up with, BRASS could make exotic test shapes and plans that end up saving tens of thousands of dollars and weeks of testing and continue to do so as standards and test platforms evolve across time.

These larger applications may still be years away. Using our modeling techniques, we frame the flight test challenge problem for the performers and bring their adaptive technology techniques and expertise to this domain that many are unfamiliar with. The scenarios we discussed provide reasonable windows for the BRASS adaptive technologies to prove their worth, both in being able to solve the problem and to build the credibility needed to actually be applied. Combining all the performers' techniques will dramatically increase the quality and capabilities of adaptive systems for flight test. \\

Austin Whittington is the program's principal investigator and an SwRI flight test researcher

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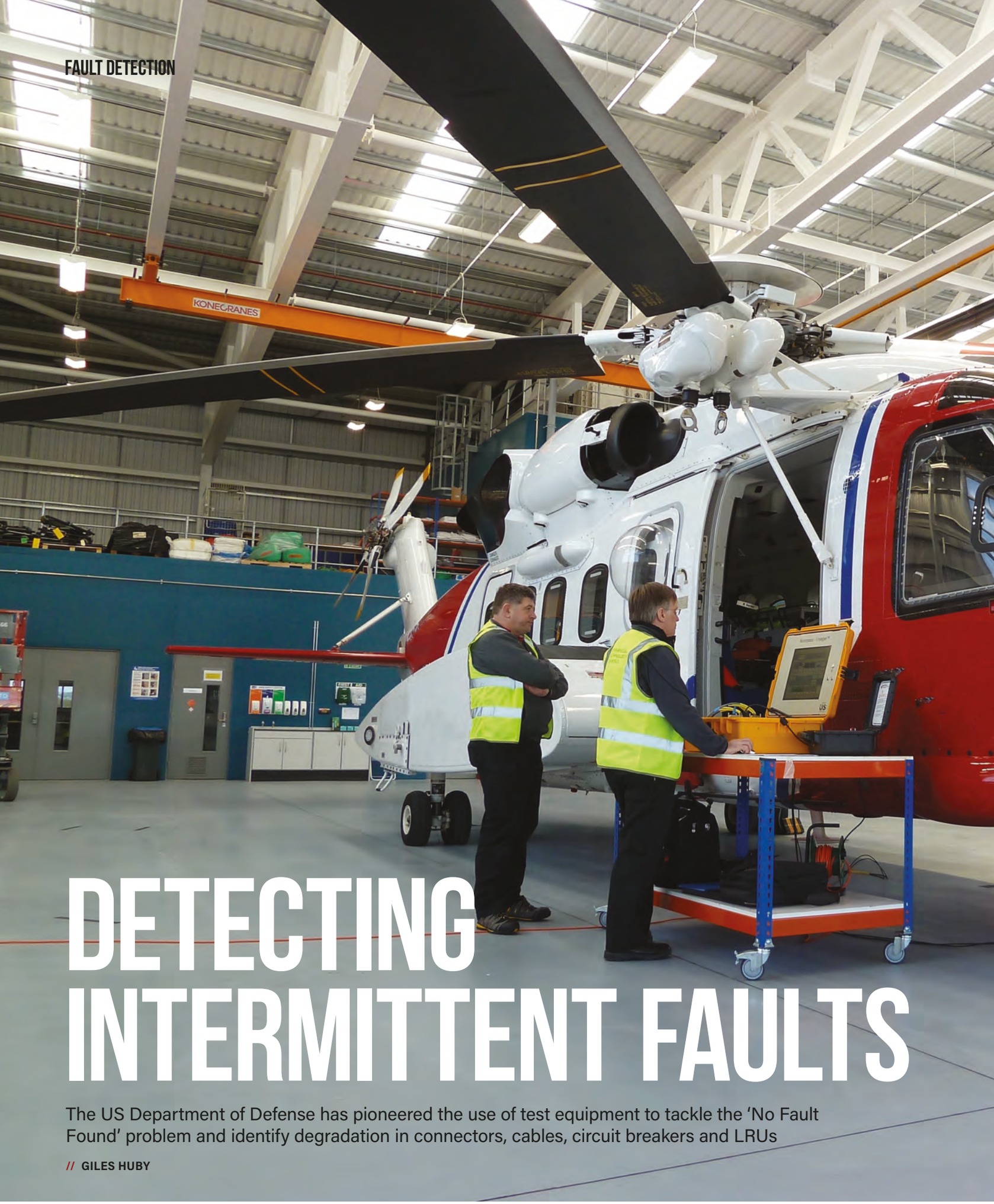

DETECTING INTERMITTENT FAULTS

The US Department of Defense has pioneered the use of test equipment to tackle the 'No Fault Found' problem and identify degradation in connectors, cables, circuit breakers and LRUs

// GILES HUBY

1 // Sikorsky's S-92 is one of several aircraft that has successfully used the portable intermittent fault detector

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"DESPITE THE ENDEAVORS OF MAINTENANCE ORGANIZATIONS, NOT ALL FAULTS ARE REPAIRED ON THE FIRST ATTEMPT"

Whenever we fly we want every component on our aircraft to work perfectly. If faults occur we want them repaired immediately and correctly as soon as the aircraft is on the ground. To this end, aviation maintenance organizations have been making huge strides to improve the effectiveness and efficiency of maintenance, repair and overhaul (MRO). Digital technology is revolutionizing predictive and prognostic maintenance, for example.

However, there is one area where notable advances have not been made for decades. Despite the very best endeavors of maintenance organizations, not all faults are repaired successfully on the first attempt. The problem is particularly widespread in avionics, electrical components and wiring, and in the industry goes by the innocent sounding name of 'No Fault Found' (NFF).

NFF is an unsuccessful repair outcome where the fault diagnosis did not successfully identify the root cause of the reported fault. It happens frequently in circumstances when pilots report a fault to the maintenance technicians who, on investigating the problem, discover the symptom has disappeared. How do you successfully repair a fault when you can't reproduce the symptom?

In most cases the technicians will replace the line replaceable unit (LRU) that is believed most likely to be the cause – based on the guidance in fault isolation manuals and/or of experienced colleagues. The removed LRU is sent for repair and, if it is indeed faulty, the LRU repair organization should be able to detect and repair the fault.

Meanwhile the aircraft goes flying again with the newly fitted LRU. Two possible scenarios may now follow, with the impact of each depending on whether the replaced LRU is the genuine root cause of the fault.

2 // The RAF Chinook fleet was one of the first in Europe to use Voyager Intermittent Fault Detectors for testing wiring

3 // The Voyager Intermittent Fault Detector is used to find problems with wiring and interconnection components

"US DOD ANALYSIS CONCLUDED THAT THE PROBLEMS WERE COSTING US$2BN IN REPAIR REWORK EVERY YEAR"

SCENARIO 1: WHEN THE SUSPECTED LRU IS THE SOURCE OF THE FAULT

A fault's symptom is reported to the maintenance organization by the aircrew. The root cause of the reported fault is in LRU 'A'. It is correctly diagnosed as the cause and is removed and replaced. The aircraft goes flying again with the replacement LRU fitted. The symptom does not return.

The rejected LRU 'A' is sent for depot repair. The three most likely outcomes at the depot are:

1. The actual root cause is detected and isolated correctly and a repair is conducted.
2. An unrelated fault is detected, isolated and repaired. The LRU is returned through the supply chain and causes the original problem to occur again when fitted to another aircraft.
3. No fault is detected, so no repair is carried out: Fault not Found (FNF).

Individual LRUs that repeatedly circulate round the FNF cycle are called rogue LRUs.

SCENARIO 2: THE SUSPECTED LRU IS NOT THE SOURCE OF THE FAULT

A fault's symptom is reported to the maintenance organization by the aircrew. LRU 'A' is incorrectly diagnosed as the cause and removed and replaced. However, the actual root cause of the reported fault is a short inside a wiring harness connected to LRU 'A'. The aircraft goes flying again with the replacement LRU fitted: the symptom returns. At the next fault investigation LRU 'B' is replaced. The cycle continues until the wiring is fully investigated by engineers.

The original rejected LRU 'A' is sent for depot repair. The two most likely outcomes at the depot are:

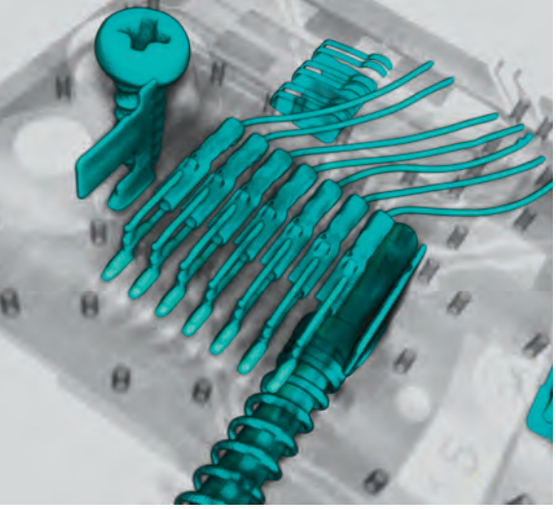
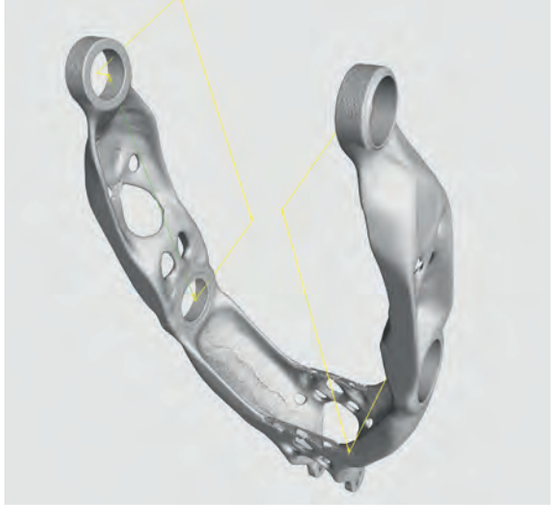
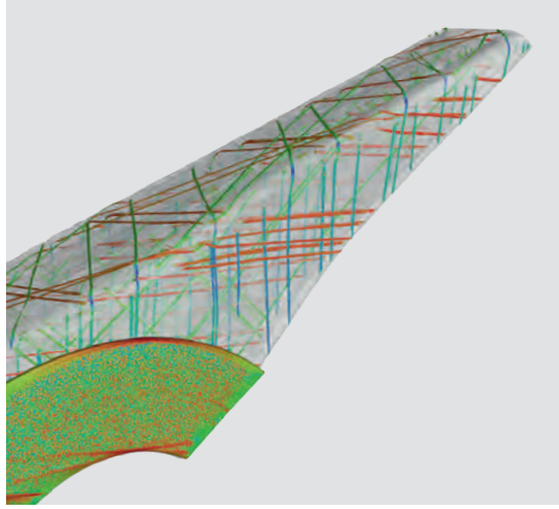
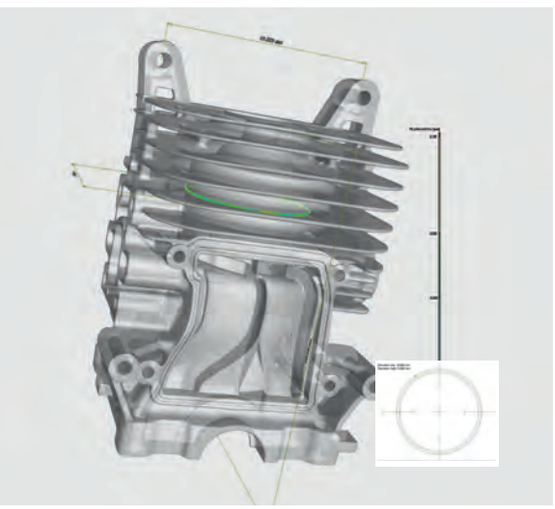
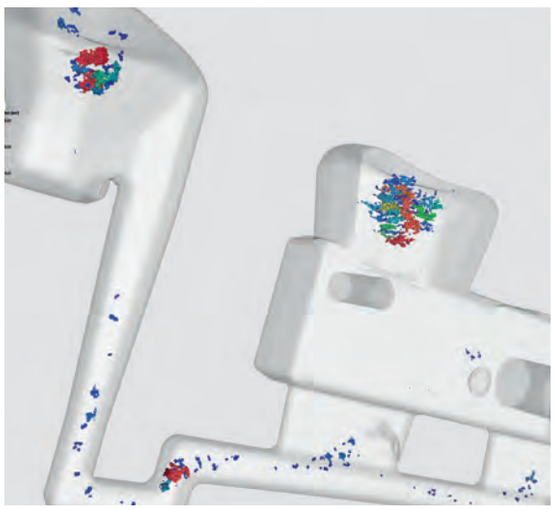
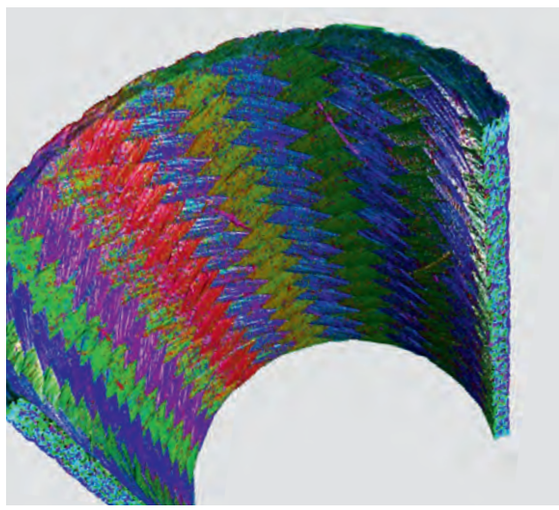
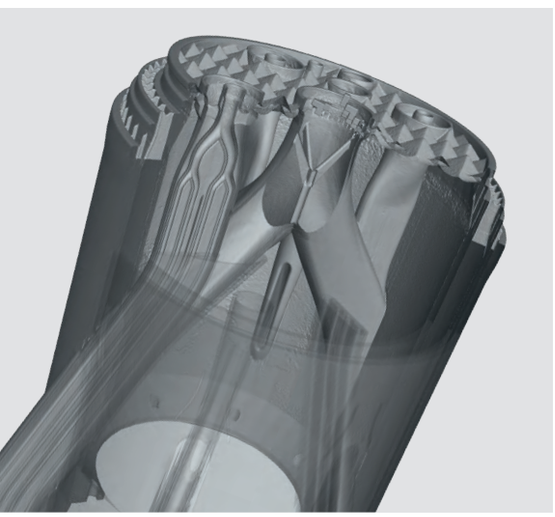
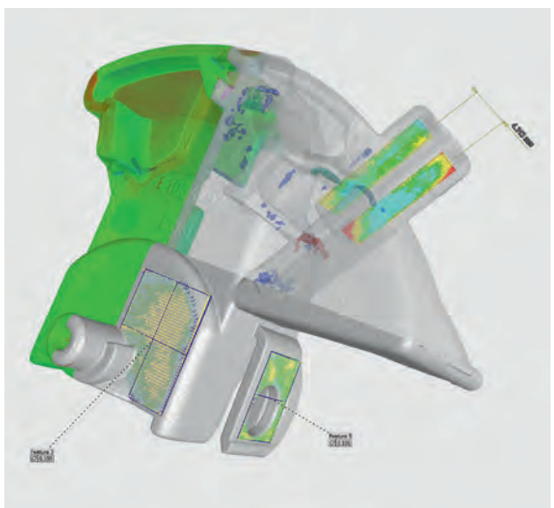
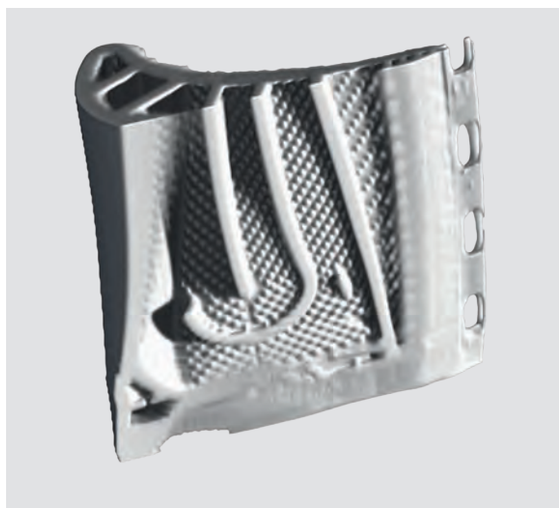
1. An unrelated fault is detected, isolated and repaired. It is returned through the supply chain, ready to be fitted to a different aircraft.
2. No fault is detected so no repair is carried out: NFF.

Individual aircraft's systems with faults that cause repeated, erroneous LRU rejections – which then repeatedly circulate round the NFF cycle – are called rogue systems.

THE IMPACT OF ROGUES

NFF is often used as a catch-all phrase across both scenarios, so it is important to distinguish between NFF and FNF to ensure the best maintenance solutions are applied. Repair and maintenance data can be analyzed to distinguish between NFFs and FNFs and to quantify which rogue LRUs and rogue systems are having the biggest impact on operational reliability and on MRO costs.

Several years ago the US Department of Defense (DoD) conducted an analysis that confirmed they were spending huge sums on repeating repairs because they weren't fixing faults Right-First-Time, on repairing LRUs that didn't have anything wrong with them (NFF), and on repeated repair attempts of LRUs that did have something wrong with them but which kept resulting in NFF (in reality, FNF).

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4 // The US Navy uses portable intermittent fault detectors to test LRUs on the F/A-18

The US DoD analysis concluded that these problems were a major driver of poor weapon system readiness and were costing over US$2bn in repair rework every year.

INTERMITTENT FAULTS: THE LEADING CAUSE

The US DoD's analysis concluded that the primary reason for the extent of the NFF cost impact was the prevalence of intermittent faults. These intermittent faults are caused by degradation in connectors, cables, circuit breakers and LRU chassis because they are vulnerable to mechanical aging effects and to their immediate operating environment, namely vibration, temperature cycling, maintenance disturbance and ingress of dirt or fluids. When this happens the interconnection integrity breaks down, exacerbated by corrosion and vibration, and the system begins to exhibit intermittent faults.

Back on the ground, the technicians can't reproduce the fault because the environment has changed completely and because their test equipment and procedures aren't designed to detect and locate intermittent faults.

THE DIFFICULTY IN DETECTING INTERMITTENT FAULTS

Sample rates and digital averaging techniques used to filter out noise have been developed in digital test equipment to improve numerical accuracy in measuring circuit attributes such as resistance. However, the combination of measuring at a single point-in-time, sampling rates and digital averaging results in intermittent faults being missed completely or masked mathematically. It's the testing equivalent of trying to photograph lightning – to get the best shot you have to decide which part of the sky it will happen in and when to press the shutter.

To maximize the chance of capturing that image you would need to look at all of the sky all of the time, perhaps by using video cameras. Similarly, to maximize the chance of capturing an intermittent fault event you would need to test all the test points all the time. The test equipment needed would have to be optimized to detect changes on every test point simultaneously and continuously.

The US DoD recognized the relationship between NFF, intermittent faults, the environmental factors and the intermittent fault detection shortcomings of conventional test equipment.

It concluded that test equipment that detects and locates intermittent faults would be the main weapon with which to tackle the NFF problem, and in 2012 the Joint Intermittence Testing Working Integrated Project Team (JITWIPT) was established to drive the initiative. Facilitated by the US National Center for Manufacturing Sciences, JITWIPT members are drawn from each of the US armed forces, the US Coast Guard and selected industry partners.

In 2015 JITWIPT introduced the MIL-PRF-32516 performance specification for intermittence testers, and tested several types of test equipment against the specification in January 2016. The Intermittent Fault Detection (IFD) test equipment from Universal Synaptics Corporation (USC) scored full marks in the evaluation – including the detection of all sub100ns intermittent faults across multiple test points.

USC's IFD rack-mounted tester product, the IFD and Isolation System, or IFDIS, can test for intermittency, shorts and continuity faults on thousands of test points and is already used extensively for the testing of LRUs on the USA's F-16 and F/A-18 fleets.

USC and its Scottish partner Copernicus Technology knew that wiring and interconnection components are also major factors in the NFF problem. The two companies therefore jointly developed a portable IFD tester for testing wiring and interconnection components both on and off the aircraft – the Voyager Intermittent Fault Detector (VIFD). VIFD models have 128, 256 or 512 test points. They have the same test functions as the IFDIS and are also available with integral spread-spectrum Time Domain Reflectometry and L/C/R (inductance/capacitance/resistance) characterization functions.

"INTERMITTENT FAULTS CAN BE CAUSED BY DEGRADATION IN CONNECTORS AND CABLES"

The IFD tester family can therefore be used to reduce downtime and costs by tackling the NFF and FNF problem across the entire avionics repair chain. First, rogue LRUs can be tested by IFDIS and, after having the IFDIS-detected faults repaired, their mean time between unscheduled removal, also known as time-on-wing, increases enormously across the fleet. Second, the wiring and interconnects of rogue systems can be tested by VIFD to reduce the time taken to troubleshoot intermittent faults on aircraft and to prevent serviceable LRUs from being incorrectly sent for repair.

Third, scheduled IFD testing can be used for the prognostic and health management of critical harnesses – integrity faults can be dealt with or monitored as appropriate and the resulting data used to inform maintenance optimization and life-extension.

5 // The USDoD is steadily increasing its use of IFDIS for testing LRUs on F-16 and F/A-18 fleets

"IT REMAINS TO BE SEEN WHEN SOLUTIONS FOR INTERMITTENT FAULTS WILL BE ADOPTED"

CASE STUDIES

IFDIS testing has been a key feature of testing F-16 radar LRUs by the US Air Force for several years and the US Navy has introduced it for testing F/A-18 LRUs. These programs began by focusing on testing rogue LRUs identified from maintenance data. The rogues had undergone depot ATE (automatic test equipment) testing on multiple repair visits but were testing NFF. Eventually they had been returned for repair so often they were quarantined as unrepairable.

IFDIS testing on the LRUs' chassis isolated intermittent faults in virtually all the rogues. Approximately 70% of them were repairable and could subsequently be returned to use. The fleet average time-on-wing for each LRU type that undergoes IFDIS testing has increased by over 300% in all cases and, because the LRUs stay fitted to aircraft for longer, repair hours and MRO costs go down significantly. To date the US DoD support savings have been measurable in the hundreds of millions of dollars, motivating it to procure several additional IFDIS systems. Several other follow-on projects are underway with IFDIS and VIFD on multiple US DoD fleets to support the work and recommendations of JITWIPT.

The VIFD (previously known as the Ncompass-Voyager) has been successfully used on a multitude of aircraft types from the Sikorsky S-92 to the Eurofighter, as well as on trains and armored vehicles.

An early customer of VIFD testing was the RAF's Chinook helicopter fleet. VIFD testing was used to test a system's wiring and interconnects for a safety investigation and immediately revealed the presence of intermittently faulty circuit breakers and switches, and EMC vulnerability in a safety-critical cable. Furthermore, analysis of the Chinook fleet's MRO data had identified the system whose reliability had the most adverse impact on fleet mission success rates. There were several aircraft with rogue systems of this type and multiple LRU replacements were not improving the system's fault rate on these aircraft.

VIFD testing of system wiring quickly revealed system wiring integrity issues, with multiple test points affected by excessively high resistances and/or intermittence. The IFD test duration per aircraft was 25% of the time needed for the standard test of the entire system's wiring (over 400 test points), and repair of the VIFD-detected faults resulted in an overall fault rate reduction of 40%. As with the IFDIS examples, the faults detected using VIFD had all been undetected when using standard testing methods previously.

THE FUTURE

After its recognition as a problem in a handful of LRU testing projects, the US DoD maintenance community now recognizes intermittence as a failure mode. Furthermore, IFD testing is becoming an integral part of its avionics and aircraft maintenance capabilities. In particular IFDIS testing has been made a standard test method for certain LRUs on the F-16 and F/A-18 fleets, while VIFD is starting to be used for aircraft fault-finding purposes.

The JITWIPT's IFD testing strategy aims to make readiness improvements and maintenance cost improvements across multiple fleets that will be impossible to ignore. After that it remains to be seen how quickly the global aviation, defense and transport sectors will follow the US DoD's example in adopting test solutions to tackle intermittent faults. \\

Giles Huby is managing director of Copernicus Technology

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EVOLVING AIRCRAFT DESIGN AND NOISE MITIGATION AT SOURCE

Acoustic simulation tools are being developed to help reduce the noise generated by the next generation of commercial aircraft and urban air taxis

// CHARLOTTE CLARK AND ANA LUISA MALDONADO

1 // Arup's SoundLab has been used to study how people perceive aircraft noise differently

Since the advent of the turbojet and turbofan engines in the 1960s, regulatory bodies in the aviation industry have been driving reductions in noise from aircraft by imposing ambitious noise targets for the certification of aircraft. Consequently aircraft and engine manufacturers have been investing in extensive R&D programs to deliver further improvements. High bypass ratio (BPR) engines, introduced in the 1970s, resulted in substantial noise attenuation, with a bigger engine radius, a longer distance between the rotor and the stator, and a proportionally smaller nacelle. Since then, aircraft noise fell by approximately 4dB per decade until the 1990s and around 2dB per decade after that.

To meet the demanding 2050 noise reduction targets, such as ACARE, new technological breakthroughs are needed (Figure 3). The aircraft of the future will differ greatly from current tube-and-wing types. For instance, one of the proposed concepts, the hybrid wing body (HWB), will be more aerodynamic and offer effective noise reduction due to the airframe shielding the engine noise sources.

Electric propulsion, including both electric and hybrid electric aircraft, is another way to reduce noise, emissions and fuel burn. Hybrid electric aircraft are being designed for short-haul operations.

Fully electric aircraft are also being rapidly designed for urban air mobility and include vertical take-off and landing aircraft (eVTOL). Fully electric aircraft for long-haul flights do not exist yet, mainly due to battery technology constraints.

Electric propulsion offers engineers increased flexibility to distribute motors

2

> "HUMAN RESPONSE TO NOISE IS INFLUENCED BY ACOUSTIC AND NON-ACOUSTIC FACTORS"

2 // Air taxis require greatly reduced noise levels to operate in urban areas

3 // Trends in aircraft noise reduction for long-range travel

around the aircraft and devise more efficient designs. This supports the development of transformational prototypes, with different noise levels and signatures.

This wide variety of novel aircraft requires new assessment tools. In the first instance, a simulation tool is needed to examine newly proposed aircraft, engines, flight procedures and other conditions or configurations for which measurement data is not available.

However, their noise signature might differ considerably from traditional aircraft concepts and even though the noise levels are reduced, the spectral content of the noise signature could increase the impact on health. This will require a deeper understanding of how the noise from the next generation of aircraft will affect communities.

NOISE PREDICTION AND AURALIZATION TOOLS

Airports calculate aircraft noise levels using traditional tools, based on noise-power-distance (NPD) curves, which are derived from measured data. Thus they do not lend themselves to assessment of novel aircraft technology or operating procedures for which measurement data unavailable.

Furthermore noise levels alone don't tell the whole story. Auralization, which is the process by which source noise predictions are turned into audible sound, is a very powerful tool in understanding how noise is perceived by communities. It is particularly important for novel aircraft types, as their noise signature differs significantly from traditional ones.

At engineering consultancy Arup, auralization is performed in the SoundLab, allowing stakeholders and members of the public to make up their own minds by experiencing the noise environment instead of interpreting decibel charts or noise maps. SoundLab has a proven record of informing the design of major infrastructure projects in the UK.

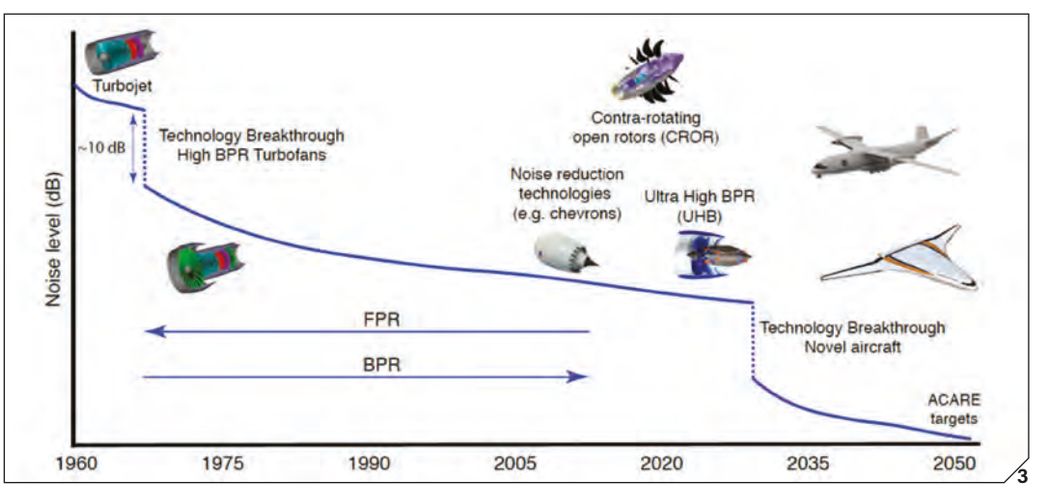
The desire to take SoundLab demonstrations for aviation to the next level has led Arup to look for ways to couple high-quality simulated aircraft data with auralization. The use of simulation tools developed by NASA seemed the perfect choice for this.

NASA has developed a suite of codes, the Aircraft Noise Prediction Program (ANOPP2), which enable noise simulation of novel aircraft types and operations. ANOPP2 can provide aircraft simulations based on atmospheric conditions, flight properties, observer location, ground condition and airframe/engine properties. The codes predicts the noise of advanced aircraft concepts to assess noise reduction technologies, configurations and operations through subjective testing. NASA has also developed the NASA Auralization Framework (NAF), which enables the auralization of the simulated noise generated using ANOPP2. Talks are now underway between Arup and NASA to develop a long-term collaborative relationship around the simulation and design applications for the future of air travel by combining NASA's suite of codes with Arup's sound demonstration capability.

NASA researchers are expected to benefit from an expanded fleet of aircraft noise models developed in cooperation with Arup. In turn, Arup will be able to evaluate proposed aircraft, engines, flight procedures and other conditions or configurations for which measurement data is unavailable. This will represent a major step forward, allowing both parties to optimize for maximum operational efficiency while minimizing the environmental impact when planning airports for cities and regions.

FACTORS AFFECTING RESPONSE AND PERCEPTION

Human response to noise is influenced by acoustic and non-acoustic factors. The



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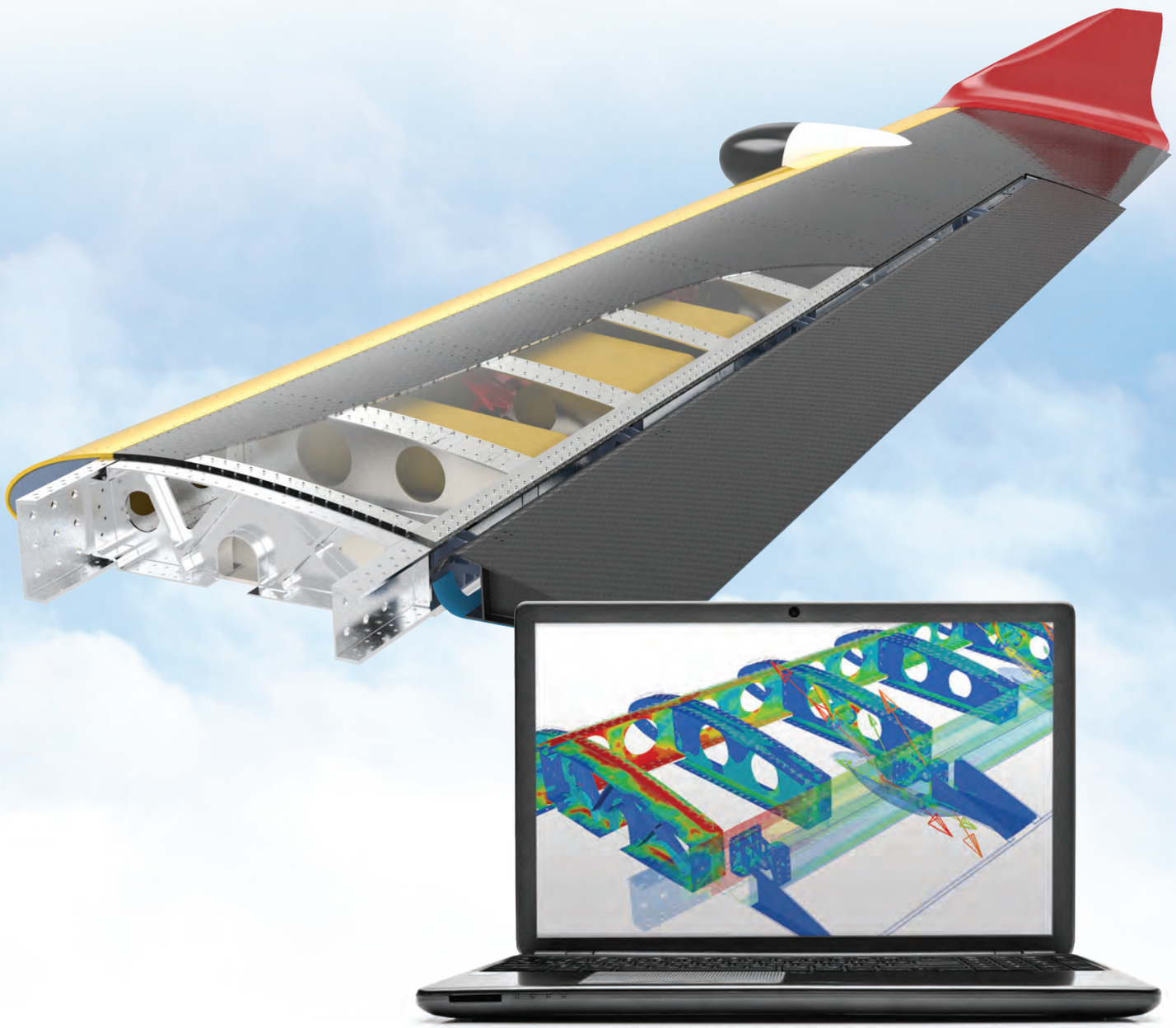

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perception of an aircraft sound event will depend on acoustic factors such as the sound level, the frequency spectrum of the sound and whether it contains particular features such as tones and amplitude modulation, the rise and fall times of the event, the duration of the event, and the level of masking or ambient sound.

Non-acoustic factors are those other than noise levels alone that affect the way communities perceive noise. According to the World Health Organization, they play an important role in the human response to noise and include the fear associated with the noise source, interference with activities, ability to cope, noise sensitivity, expectations, mistrust of the operating authorities, anger, attitudes to the source – both positive and negative – and beliefs about whether noise could be reduced by those responsible.

According to studies, human response to noise is also influenced by the rate of change at an airport with respect to noise and operational procedures. The propensity for multiple acoustic events to cause disturbance such as annoyance and sleep disruption will depend on the sound level, the overall number of events, the distribution and timing of the events, the context in which they are experienced, and a range of attitudinal factors about the noise source and operator.

The London Heliport Study provides an example of how non-acoustic factors can affect public perception. It identified a bias against helicopters, which were perceived as being louder than they actually were because of non-acoustic factors, including a feeling among local residents that helicopters offered them no benefit.

We have a reasonable understanding of how exposure to existing sources of aircraft noise affects the health and quality of life in communities surrounding airports. Exposure response functions, showing the relationship between noise exposure and health or quality of life, have been defined for impacts such as sleep disturbance and cardiovascular disease. The development and operation of new aircraft will similarly need to consider potential health and quality of life impacts on the surrounding communities.

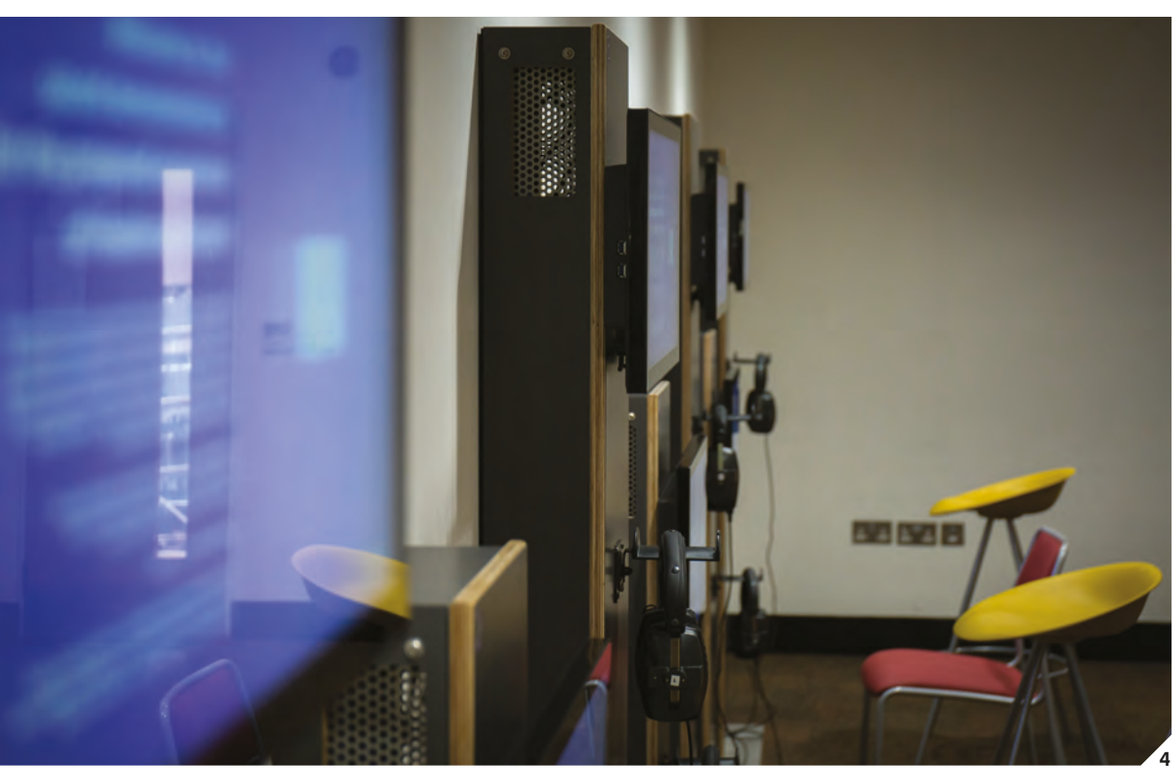
However, there is a limit to which the existing evidence can be applied to estimate the effect of new aircraft types and modes of operation on health and quality of life. It will be necessary to develop new evidence, but how can this be done if the aircraft are not even operating?

One method for building this knowledge is to use auralization of simulated sound or recordings of actual aircraft in a laboratory setting. Arup has been using SoundLab to carry out listening tests during which participants gave feedback on a range of existing aircraft sounds in terms of whether they noticed differences in the sounds and whether these could potentially lead to a valuable break in aircraft noise over a longer period of time.

Similarly SoundLab can also be used to allow people to experience new aircraft types or to evaluate the redesign of airport operations through a holistic experience. This approach not only informs the design of new aircraft but also enables experiments to be conducted on the perception and tolerance of different aircraft sounds.

Subjective data, for example annoyance ratings, or objective measures such as blood pressure, on health and quality of life can be collected in a laboratory setting, linking the auralization to standard health assessment methodologies. This approach would help to identify auralization worthy of further testing in the field and identify sounds that would not be tolerated by local communities, building knowledge on the potential health and quality of life impacts of new aircraft while they are in development. This knowledge could also feed into certification for new aircraft.

"NASA HAS DEVELOPED THE AIRCRAFT NOISE PREDICTION PROGRAM TO ENABLE NOISE SIMULATION OF NOVEL AIRCRAFT TYPES AND OPERATIONS"



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4 // Auralization simulation tools are being developed that enable the noise of aircraft to be tested using people before prototypes are built

TOOLS FOR THE FUTURE

The coupling of simulated aircraft noise data to SoundLab provides a powerful tool, representing a major step forward in shaping the design of new aircraft, infrastructure and airspace. The ability to design in this way will help to minimize impacts on health and quality of life without incurring great expenditure on development costs and prototyping. \\

Charlotte Clark is an associate and Ana Luisa Maldonado is a consultant at Arup

CERTIFIABLY CHEAPER

TLG Aerospace has used analysis software to achieve faster and cheaper certification for its clients' aircraft

// PRASHANTH SHANKARA

When Wayne Tygert, Boeing's chief program engineer for the 787-10, said in 2017 that his engineers were aiming to carry out "the most boring flight test program we've ever seen" for that aircraft, he was describing a goal most engineers desire at the start of testing. Nevertheless, boring isn't the first word that comes to mind when describing something that took 900 hours across three test aircraft, thousands of regulations, upward of 4,000 documents and millions of dollars.

The 787-10 is a simple midsection extension of the already certified 787-9 to accommodate 40 more passengers. The original 787 Dreamliner took eight years from application to certification, clocking 4,645 flight hours, more than 200,000 hours in FAA experts' time and a much higher certification cost.

Getting an aircraft certified, whether new or modified, is a long, expensive, bureaucratic process. From the largest aircraft in history down to small two-seaters, every plane needs to prove airworthiness and compliance to regulatory authorities before operation.

Certification costs around US$1m for primary category aircraft, which have up to three seats, US$25m for a general aviation aircraft and hundreds of millions of dollars for a commercial aircraft. Certification delays can cost millions of dollars and can make or break the profitability of an aircraft.

The news is full of mentions of program delays, missed delivery dates, cost overruns and safety issues due to designs not meeting certification requirements and requiring expensive redesign and flight testing. So how can companies reduce certification cost and time?

WHAT IS CERTIFICATION BY ANALYSIS?

With a combined 45 years of experience in design, development and certification of aircraft, Robert Lind and Andrew McComas of TLG Aerospace are no strangers to this problem. Occupying one floor of an unassuming, six-story building on Seattle's Lake Union, their modest office belies the experience and expertise that has racked up a client list that reads like a who's who of modern-day aviation. TLG Aerospace has helped numerous customers receive FAA certification in the USA at a low cost and in a short time – and with surprising efficiency.

1, 2 & 3 // For airplanes where structural flexibility is important, a coupled aerodynamic and structural certification-by-analysis approach is needed

FAA certification for aircraft has three stages: design certification, production certification and airworthiness certification, the approval to operate the aircraft.

The process is similar for other regulatory agencies worldwide. The FAA requires certification purely by test or by analysis validated by test. The industry calls it certification by analysis (CBA). These analyses are made using a full vehicle model that is otherwise validated by flight test over a specified range of the flight envelope, as agreed in advance by the certification authority. The full vehicle model includes:

Aerodynamics: A combination of computational fluid dynamics (CFD), low-order methods, wind tunnel and handbook analysis validated by pressure and strain measurements in flight test;

Structures: Finite element analysis (FEA) and handbook calculations validated by ground vibration testing (GVT) and static load in ground test;

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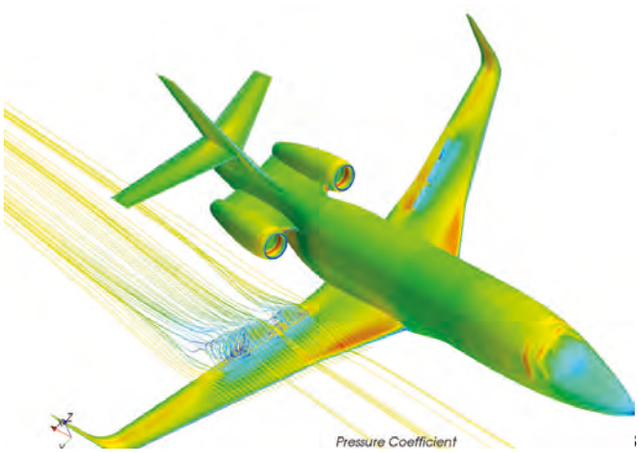

Mass properties: CAD and weights bookkeeping validated by weighing;
Flight controls: Laws of flight control validated by integrated simulation and flight test.

The integrated full-vehicle model has to be validated by flight test and must be shown to be accurate or conservative. Mostly the certification authorities' role is to ensure that the analysis will yield a safe result. The OEM will mainly be concerned with limiting conservatism to avoid excess weight and missed performance.

"SIMCENTER STAR-CCM+ HAS CONTRIBUTED TO NUMEROUS FAA-APPROVED CERTIFICATES"

THE TLG APPROACH TO CERTIFICATION WITH CFD

Lind, director of engineering and FAA-approved designated engineering representative (DER) for flutter at TLG Aerospace, says, "What has changed is the balance between how much analysis you can do and how much you can use in the certification process.

"This is a really exciting development in my 30 years in the industry. As CFD codes and computers have become more capable, we can certify faster and more cheaply".

Most of Lind's work involves getting customers to type certification with analysis. As one of the four resident DERs, he can sign for certain certification functions on behalf of the FAA. TLG uses Simcenter STAR-CCM+ from Siemens PLM Software for CFD analysis and NASTRAN for FEA to develop full-vehicle certification models for loads, flutter and handling qualities, modeled appropriately for the entire flight envelope.

Andrew McComas, engineering manager and aerodynamicist at TLG, says, "We use Simcenter STAR-CCM+ in a certification environment that is different from design. We don't use CFD to get an answer that the FAA signs off on. We use it to build a full-scale aero/structure/controls model so that we can simulate vehicle response and produce loading and handling information".

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"CFD IS SUPPLEMENTING TESTS AT SOME CONDITIONS AND REPLACING TESTING AT OTHERS, LEADING TO HUGE SAVINGS"

4 & 5 // Certified with TLG Aerospace: (Right) 737NG split scimitar winglets; (Left) Falcon 2000 business jet

6 & 7 // Certification by analysis at TLG started with the aerodynamic database generation, mapping the results to NASTRAN and the generation of the final aeroelastic model

When a new aircraft is to be certified, an aerodynamic database is required. To build the entire analysis database would require data for hundreds of thousands of conditions to be available in a short time. The aerodynamic properties of the vehicle are calculated at design and at flight envelope extremes using CFD. The results are mapped to a reduced-order aerodynamic model within the aeroelastic process. TLG will calibrate the aeroelastic model to develop full-vehicle aeroelastic solutions that are underpinned by the rigid CFD. The final aeroelastic model will reproduce full-vehicle integrated and distributed aerodynamics in rigid mode and will yield a converged aeroelastic solution in seconds.

The predictions are now in place to show that regulations are met at certain conditions. Flight testing then validates the analysis models. This validation may be limited to something less than the full flight envelope so as to reduce risk in flight testing. Once validated, the analysis models can be used to show compliance at other flight conditions. Having a high-fidelity pre-flight test model will significantly reduce the amount of post-flight test model adjustments and calibrations that are required.

REDUCING CERTIFICATION COSTS WITH SIMCENTER STAR-CCM+

Most of TLG's work involves getting customers to type certification in a timely, cost-effective manner. But where do the savings come from? McComas credits Simcenter STAR-CCM+ and Amazon Web Services (AWS) for this breakthrough in certification cost reduction. "Simcenter STAR-CCM+ runs robustly, accurately and repeatedly with simple processes and best practices. Those features have given companies the confidence that the code can be used as a source for aero database generation," says McComas.

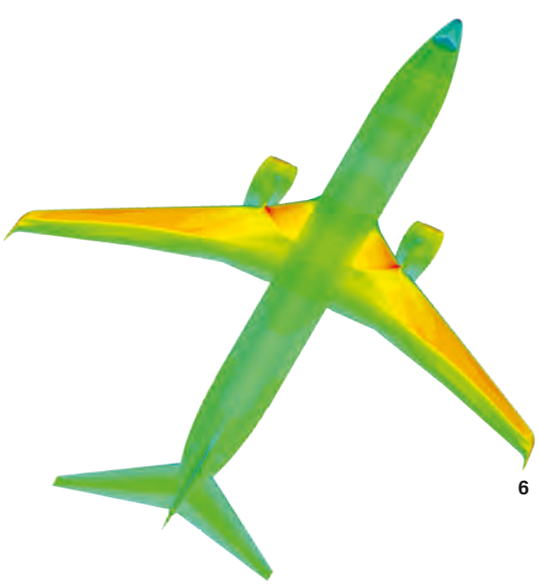
"Elastic computing from AWS with Siemens' Power-on-Demand licensing helps run multiple simulations on multiple computing clusters simultaneously on the cloud in a secure way.

"If we did not have the Power-on-Demand licensing model, we wouldn't have the capability to take full advantage of elastic computing resources and would incur the large cost of annual licenses."

In short, the entire aero database is built in a shorter time with cheaper licensing. The additional benefit? Reducing wind tunnel tests.

CFD OR WIND TUNNEL?

With experience in over 100 wind tunnel test campaigns, at low and high speeds, support from TLG comes with a strong experimental background. But far from having fallen out of favor, wind tunnel testing is still used for aero database development for new aircraft



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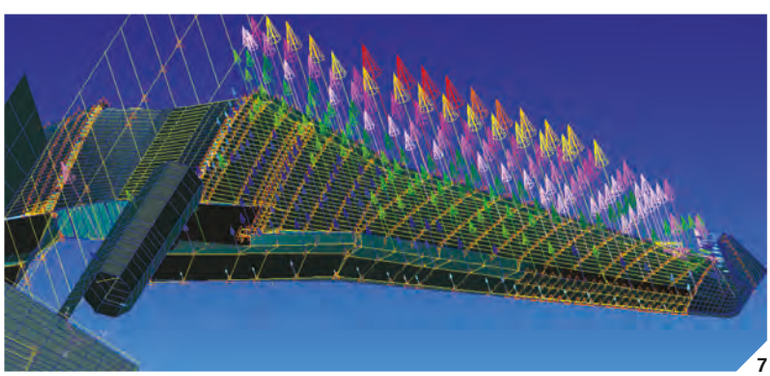

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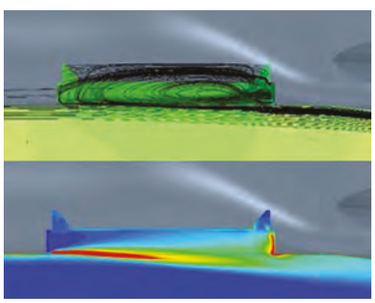

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8 & 9 // (Above) Flap effectiveness in Simcenter STAR-CCM+ validated against OEM test data; (Right) Cavity resonance analysis in STAR-CCM+ – non-impact assessment

configurations. However, CFD is supplementing tests at some conditions and replacing them at others, leading to huge savings.

Figure 10 is a notional comparison of legacy CFD codes and Simcenter STAR-CCM+ compared with wind tunnel testing as seen by TLG. For a low investment, Simcenter STAR-CCM+ can reduce and replace some testing requirements. Considering the use rate and model cost for wind tunnel tests, this translates into significant savings in time and money.

Wind tunnel testing is still best suited for incipient separation regimes such as high angle of attack and sideslip-handling analysis. CFD works best for moderate angles of attack and for detailed flow-field investigations. "Large databases can be run in STAR-CCM+ today at a fraction of the cost and schedule of legacy methods and wind tunnel testing. That was not possible only a decade ago", says McComas.

With elastic computing and cloud licensing there is no technical limitation to running large numbers of CFD cases simultaneously. TLG is also able to regularly run large, fully detailed simulations, with most models running in under an hour, no matter their size, something that was not possible before.

Using elastic computing with AWS, TLG saves 75% of the total cost per CFD simulation. The technology behind this is Amazon EC2 Spot Instances, an Amazon offer to use unused computing capacity on the AWS cloud at deep discounts.

IS CFD A ONE-TRICK PONY FOR CERTIFICATION?

The answer is a resounding 'no'. Modifications and additions to existing type certified aircraft will affect regulations. Taking older airframes to the limits of the flight envelope with new modifications is hazardous, expensive and time consuming. The FAA allows CFD as a means to show the compliance of the original aircraft hasn't changed due to modifications. Companies like TLG have adopted this wholeheartedly and use CFD to generate supporting data and arguments to show compliance.

"In the past, engineers unquestionably had to go to for any modification. Now CFD gives you the data to try to eliminate some test requirements," says McComas.

Other applications suitable for the use of CFD in certification include pressure loading on secondary structures, fairings, antennas and radomes, ice accretion, air-data system location, internal flows, winglets and beyond.

An example scenario is if a new radome is fixed to an aircraft. To comply with regulations, the manufacturer has to prove that if the structure comes off, it will separate safely without impact. Breaking off a radome in a flight test would be too dangerous. Similar challenges exist in proving icing on the new structure doesn't affect compliance and operational safety.

McComas says, "The only feasible option here is to use a validated analysis to show the structure meets safe separation criteria. For TLG, Simcenter STAR-CCM+ has all the necessary tools built in to do these calculations without other third-party software."

The onslaught of innovative aircraft such as drones and air taxis, military aircraft, the born-again supersonics and others, similarly benefit from certification by analysis in terms of enabling cost and time reductions.

At TLG Aerospace, the 'C' in CFD stands for certification. "Simcenter STAR-CCM+ has contributed to the receipt of numerous FAA-approved certificates. It has a role in every single certification program at TLG," says McComas.

It is unlikely that CFD will ever completely replace wind-tunnel testing. Computers evolve, software evolves, licensing evolves and therefore the role of CFD in certification is only set to increase over time to supplement and complement flight testing.

For now, companies like TLG have found a reliable workhorse in CFD for certification – one that can do the heavy lifting of proving compliance at the extremes of flight envelopes, reduce the number of flight test conditions, enable test to lower loads and predict potential testing hazards. Flexible licensing and elastic computing are further solidifying the case for certification by analysis.

"We can now bid on projects that have greater scope, be more competitive, pass on the savings to our customers and do much more with our dollar," concludes McComas.\\

Prashanth Shankara is marketing manager at Siemens Product Lifecycle Management Software

10 // Table showing a notional comparison of wind tunnel versus CFD as seen by TLG Aerospace

	Model costs	Usage rate (per hour)	Engineers (per hour)	Productivity (conditions/day)
Low speed wind tunnel	$165k	$600	X2	800
High speed wind tunnel	$315k	$4500	X3	600
Legacy CFD	$15k	$250	X1	20
Simcenter STAR-CCM+	$15k	$100	X1	80

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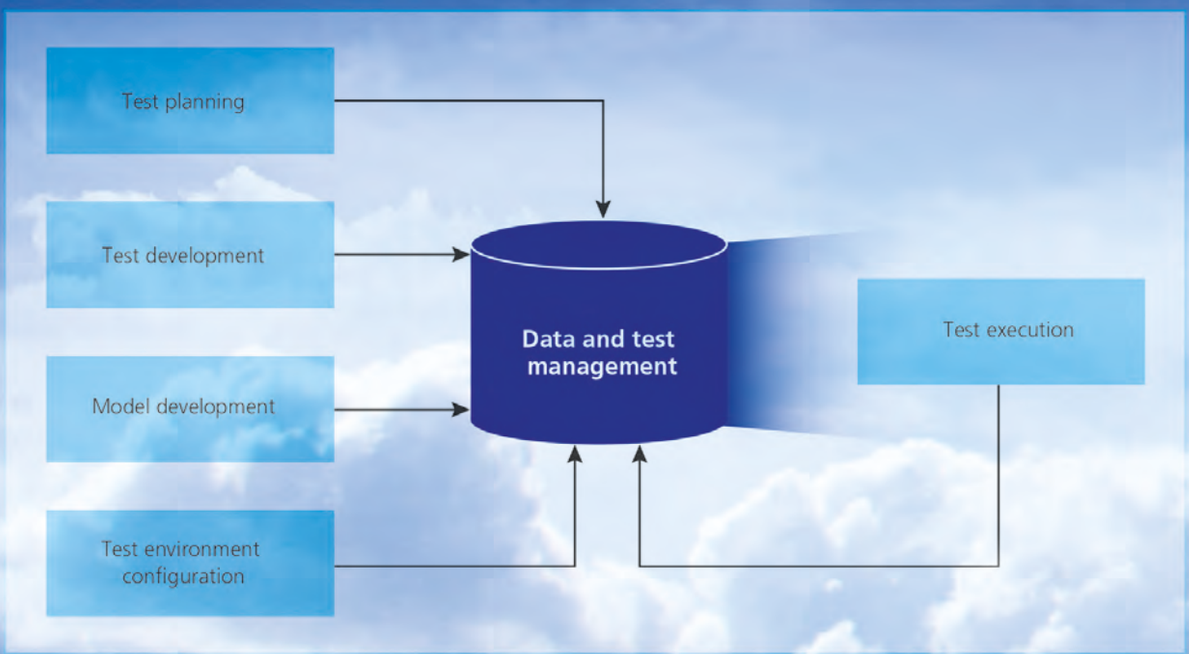

OPTIMIZING VIRTUAL TESTING

A centralized and well-organized approach to virtual testing can reap efficiency rewards in a test program

// ANDREAS HIMMLER, SÖREN REGLITZ AND JANN-EVE STAVESAND

Methods for virtual testing in the aerospace industry cover a growing range of test executions carried out during the development and testing of avionics systems. Hardware-in-the-loop (HIL) simulation plays an important role, being the most industry-proven method of virtual testing. New demands arising from the evolving architectural design of electrical/electronic (E/E) systems and from process engineering conditions have their effects on this well-known method.

In recent years most companies have focused on questions regarding the evaluation and implementation of methods for virtual testing. However, it has become more important to seamlessly integrate virtual testing into the overall development process.

For instance, a company's test strategy might stipulate a combination of methods, such as software-in-the-loop (SIL) and HIL simulation, to benefit from the advantages of both in the same test process. In such a case, efforts concentrate on the optimization of the overall process, from test specification to test execution, as well as on the test result evaluation and its alignment with methods for virtual testing. To coordinate and manage the design, implementation and test process, it is beneficial to store all test and simulation data centrally using a data and test management tool that reduces complexity for an improved overview.

PROCESS-ORIENTED TESTING

Most of the functionalities of advanced avionics systems are safety-related, and the development and verification has to be planned and executed with appropriate thoroughness. The methods used for

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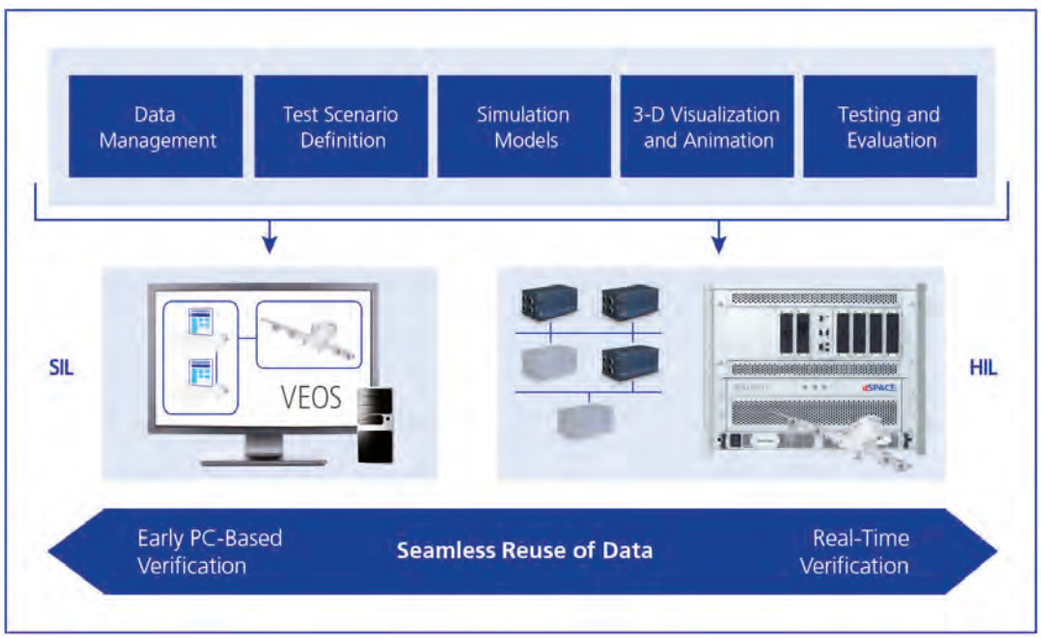

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1 // Centralized data and test management during virtual testing can help integrate it into the development process

2 // Reusing artifacts from SIL to HIL simulation supported by a suitable toolchain

development have to meet these requirements and have to be suitable to transfer the standards' generic process descriptions to real applications.

To efficiently structure and manage the development processes for E/E systems while complying with standards, the whole process from specifying and executing the test to evaluating the results, has to be considered. The tools and verification environments have to be integrated into an overall process. For example, using a high-end simulator is only one aspect of many. The simulator also has to be integrated into an overall verification process to address the new demands. The integration requires a toolchain that can be adapted to various processes and applications used by different users. The toolchain also has to enable users to efficiently customize the process for testing functional safety. Furthermore, the tasks and activities within these processes have to be optimized. This can be achieved by automating them, which minimizes human error. This requires interfaces between, and support by, suitable tools.

The model for the verification process introduced by the SAE guideline ARP4754A describes the general verification workflow recommended for aircraft systems, including the required inputs and generated outputs. Development tasks preceding the verification process include the formulation of requirements according to the associated development assurance level

"THE SIMULATOR ALSO HAS TO BE INTEGRATED INTO AN OVERALL VERIFICATION PROCESS"

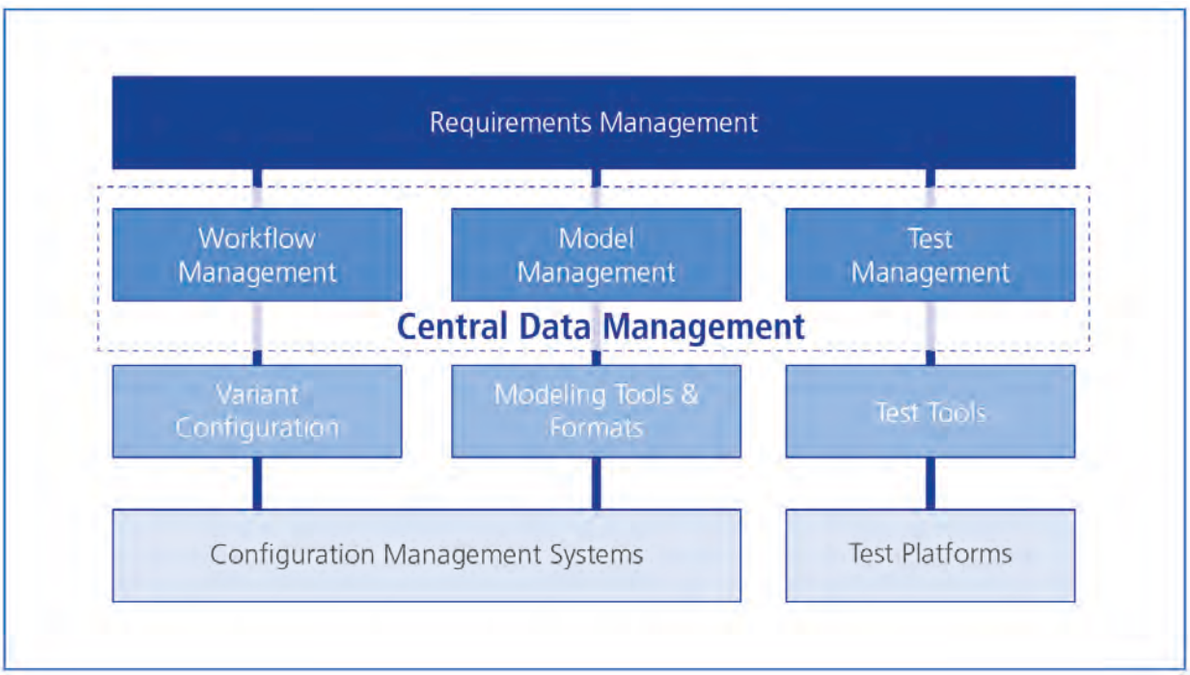
of the function or item as well as its design process, which results in a testable implementation. The verification process is applied iteratively at different integration levels, such as the item, system and aircraft integration levels.

Each of the applied verification methods requires specific inputs and generates outputs that have to be managed and linked to the overall development process to establish traceability between requirements and test results, reproducibility of the verification task, and reusability of the related artifacts, such as simulation models and test scripts, for subsequent verification phases. Other outputs defined by ARP4754A include a specific set of verification data to provide evidence that the verification process was completed. The guideline introduces verification matrices, plans, procedures and summaries to use as evidence. This evidence is one of the requirements for later certification credit.

The integration of a central data management system in the development and verification process of aircraft systems provides essential support to efficiently manage the previously described verification data. It offers the necessary interfaces between all tools involved in the various processes, such as requirements engineering, configuration management and test automation tools.

SEAMLESS REUSE OF ARTIFACTS

During the development of controllers for complex avionics systems, a large number of artifacts, which originate from previous development steps, should be reused whenever possible to reduce modeling and model integration time. Examples of these artifacts include component and system-level models. Furthermore, artifacts from previous test steps can also be reused if a standardized test automation interface is used for all test phases. This includes test designs, test cases, and even partial or full test implementations. Today these artifacts are rarely reused throughout the entire development process, because the modeling and testing tasks at each development level are performed by users from different departments or even people outside the organization. The parties involved might not necessarily have an



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3 // Example of the functionalities provided by a central data management system

"SYSTEMATIC DATA MANAGEMENT IS KEY TO SEAMLESS INTEGRATION"

overview of or access to all potentially related workflow artifacts from upstream or for downstream processes.

Moreover many companies have already invested heavily in creating simulation models, suitable model parameterizations, test libraries and user interface panels for virtual testing scenarios. These investments are often mostly focused on HIL simulation as it is the most established verification method with regard to virtual testing. The goal must be to incur investment costs only once in the development process and also to use the results for SIL simulations. A main objective of using SIL simulation is to frontload the HIL function tests to an earlier development phase. This helps increase the test coverage as soon as possible. Therefore well-established HIL tools have to be used for operation control, such as test automation, to make earlier SIL simulations possible. This increases the efficiency of back-to-back-testing significantly throughout the whole test process.

TEST ARTIFACT CENTRALIZATION

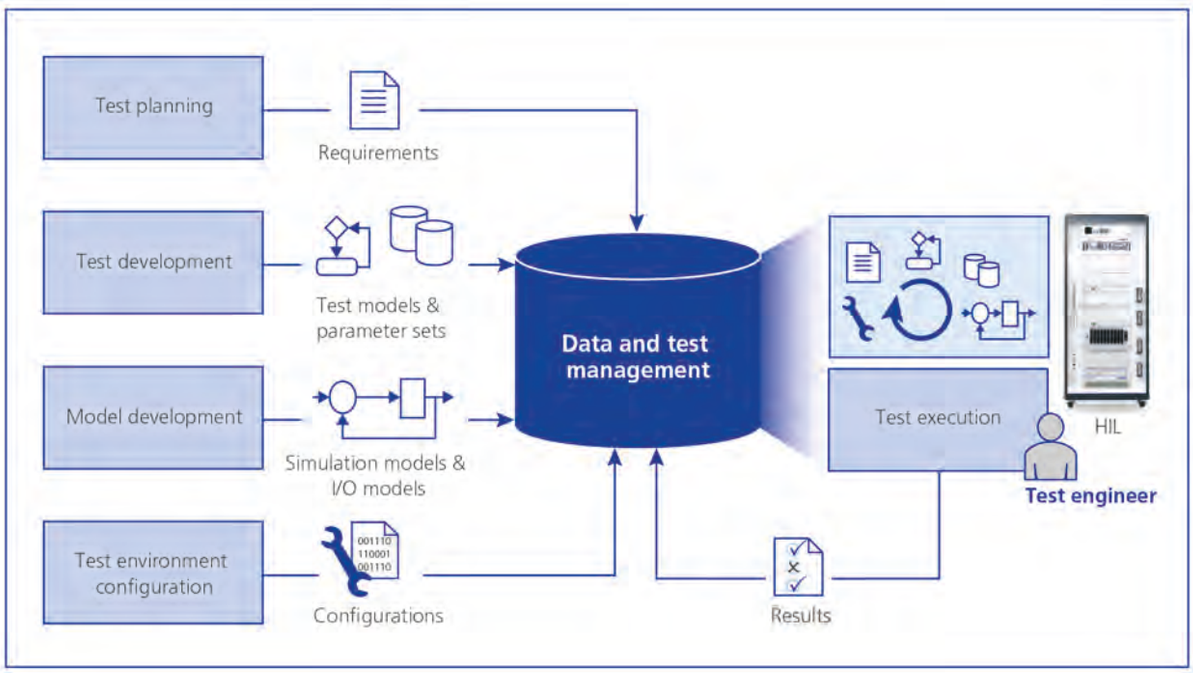
Systematic data management is key to the seamless integration of different simulation-based test environments, such as SIL and HIL. The artifacts that were created during tasks throughout the development process have to be managed centrally with comprehensive tool support that has to cover various aspects.

First, the artifacts have to be available to many roles throughout the verification process, such as test designers, test developers and test engineers on HIL test benches. Second, there has to be version and variant management for the artifacts so that data consistency can be ensured throughout the entire process. For example, a specific variant of a test case might be valid for only a single version of a test object.

Moreover, different data is generated in various tools, departments and teams. The collaboration of these parties has to be managed in an interdisciplinary manner and supported by a tool. Often the processes between the cooperation partners, either inside or outside an organization, are not explicitly defined, so guidance by a tool can reduce transfer losses. The adoption of established processes throughout the development cycle is associated with enormous efforts. Consequently the goal of implementing a central data management tool is to change these processes as little as possible and to link that tool to other existing tools. For example, the central data management tool has to provide all necessary interfaces to, for example, IBM Rational DOORS (Dynamic Object Oriented Requirements System), Microsoft Team Foundation Server, MATLAB or Microsoft Excel to manage requirements, models, and test cases in the process (Figure 3).

The proposed approach is that the data management tool supports the established processes and tools while providing the central administration of the data and linking – for example, development artifacts to test cases and results. This is necessary because there are different users and different needs throughout the collaborative work process.

For example, when performing tests as a verification method according to ARP4754A, test developers need tools to efficiently create, handle and implement a large number of test designs. Meanwhile test engineers require support for the automated and manual execution of test cases. To meet these requirements while maintaining efficiency and process reliability, many artifacts that are created when working with discipline-specific tools, such as test automation, model development and configuration tools, have to be made available in a central location (Figure 4).



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In addition to the centralization of artifacts, challenges arise in the exemplary HIL test process introduced above:
- Efficient test planning, development, preparation and execution;
- Traceability between requirements, tests and test results;
- Variant-dependent test execution;
- Explicit and dedicated support for the various roles in the test process.

This means that the solution for the collaboration of the various roles in the test process must provide comprehensive test management with an interface to requirements management as well as test planning, test selection and test execution.

At the same time, it also needs to be possible for the user to manage and connect all relevant data at a central location so that variant dependencies, test parameterization and the configuration of the HIL system can be implemented as efficiently as possible.

By linking test designs, test cases and related implementations such as test scripts to requirements, a central data management tool considerably helps achieve complete requirements coverage during the test planning process. In addition, full traceability also enables developers and testers to easily identify all related artifacts whenever a requirement is changed and to adapt them if necessary.

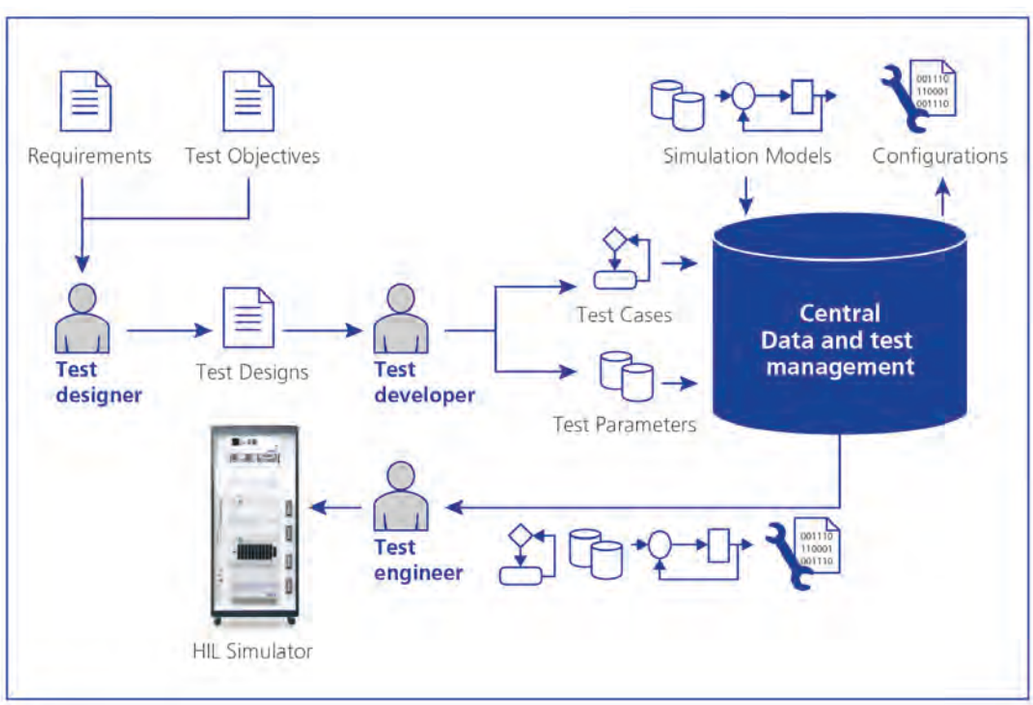
The central data management tool also makes it possible to set baselines to a specific point in time to capture the current configuration of all related workflow artifacts. These artifacts could include, for example, requirements, models, test designs, test cases, tests scripts and test results.

All roles in the design, implementation and test process should have access to the artifacts they need to perform their assigned tasks. This includes, for example, model development, test development or test execution (Figure 5). This makes it possible to use the artifacts immediately to execute the tasks and reduces the risk of errors originating from manual work steps. \\

Andreas Himmler is business development manager, Sören Reglitz is a product engineer and Jann-Eve Stavesand is team leader process consulting with dSpace

4 // Exemplary HIL test process with involved roles and related artifacts stored in a central data and test management tool

5 // Centrally managing and providing artifacts from different processes to specific roles



5

BEYOND FLIGHT TEST INSTRUMENTATION

1

A turnkey FTI solution with close support from providers drastically improves the efficiency of flight tests, particularly for new players and disruptive aerospace projects

// GHISLAIN GUERRERO

For about a decade the aerospace industry has been evolving toward being a more open sector. More than a thousand startups have appeared and they are willing to play with the big established companies.

From new space and future hypersonic jets, flying taxis and unmanned combat air systems (UCAS), to light aircraft and civil helicopters, there are many new and exciting platforms and concepts in planning that should come to fruition in the years to come. Likewise, the established aerospace companies, such as Airbus, Boeing and Rolls-Royce, are announcing new platforms.

All these companies are aiming to disrupt the market. But with nearly everything yet to be built, they are in the development phases of projects, from design to test.

DISRUPTIVE DEVELOPMENT

The flight test phase is particularly crucial when working on a disruptive project, where getting to market quickly is often critical to success. Both small companies and large ones are faced with increasing certification requirements for aircraft. The complexity of flight testing can be tackled better with the help of experts from flight test instrumentation (FTI) providers.

The industry is at a turning point, where Zodiac Data Systems (ZDS) has an important role in providing assistance to any aerospace platform manufacturer. The company is offering complete COTS-based and tailored end-to-end instrumentation systems and providing close and expert support to flight test teams before and throughout their entire test campaigns.

Established major companies have traditionally hosted expertise for the integration of FTI within their companies. As a consequence, many instrumentation vendors have mainly produced equipment dedicated to acquiring, recording, transmitting, displaying and processing data, while integration inside the aircraft was left to the OEMs. However, ZDS's understanding of flight testing needs extends to expertise in system integration, thanks to decades of close partnering in military and civil test programs. These programs include not just jets and wide body aircraft, light and heavy helicopters, missiles and launchers, but also automotive instrumentation and satellite communication.

1 // Stratobus, Thales Alenia Space's stratospheric balloon

2 // Ruggedized 2 x 3in (5 x 7.5cm) Zodiac XMA DAU

FULL SYSTEM AND ADVICE

ZDS has developed COTS units for its end-to-end solution with a design driven by the required standards. The XMA is a field-proven modular data acquisition unit (DAU) designed to perform signal conditioning and acquire, process and stream synchronized data with high timing accuracy of typically ±100ns. Various levels of ruggedization and reduced intrusiveness enable integration

2

3

3 // Irkut's MC21 during its first flight, equipped with the ZDS flight test system for video and data.

"THE FLIGHT TEST PHASE IS CRUCIAL WITH DISRUPTIVE PROJECTS"

in any environment. The wide variety of modules available enables the acquisition of any type of signal, such as from analog or digital sensors, serial interfaces and avionics buses. Coupled with ZDS's modular data recorder (MDR), which is the most-used FTI video and data recorder, the XMA sets a new standard in terms of FTI flexibility, while keeping field-proven top-quality metrology performance.

ZDS' FTI creates a fully standard compliant solution that can handle synchronous and asynchronous data through the same dataflow from air to ground without any impact on existing infrastructure. The instrumentation's integration with existing FTI architectures on board is seamless, thanks to its ability to handle various data formats. It has standard and specific legacy data output formats such as IENA and DAR (the original FTI network packet format introduced by Airbus and Boeing) and follows the latest IRIG106 standards (Inter Range Instrumentation Group), such as TmNS (Telemetry Network System).

In addition to these competencies, ZDS offers a range of sensors, cameras and cabling. In particular Thales Alenia Space has taken advantage of this offer for the Stratobus program, a very challenging autonomous high-altitude pseudo-satellite set to fly at an altitude of 20km.

ZDS is also developing new technologies. Its end-to-end solutions are being enhanced with wireless technologies such as Bluetooth, wi-fi, UWB (ultra-wideband) and the development of smaller equipment. Reducing the intrusiveness and power consumption of FTI is crucial, especially for smaller platforms such as UCAS and flying taxis. The wireless transmission of data on board raises the challenges of time synchronization, datalink availability and system configuration but also offers unprecedented flexibility to adapt the FTI or reach remote areas.

GROUND STATIONS

A full end-to-end FTI system is not complete without the telemetry downlink and related ground station. Taking advantage of its worldwide leadership in satellite communication and strong position in telemetry and data acquisition for launchers, ZDS has developed its own portfolio of ground station solutions based on various sized multiband antennas, suitable for any test vehicle. A ground station also includes multiband receivers, radio frequency, intermediate frequency and/or baseband recorders and various tools enabling decommutation, real-time visualization, post-processing and replay. ZDS can provide full fixed, mobile or shipborne stations with antennas having diameters up to 11m (36ft).

Above all, the flight test engineer's experience with a ZDS FTI system is enhanced by using a single platform for the whole system's management. The eZ Software Suite enables the user to configure, calibrate and monitor the whole system (on-board & ground segments). The software features automatic wizards for first-time setups. Productivity tools can then be used to improve the setup, while advanced discovery features make architecture changes easier.

The eZ Software Suite offers data processing, data analysis and various import/export capabilities to interface with third-party software. Live monitoring is made available both on board the aircraft and at the ground station.

ZDS provides instrumentation engineers with a full turnkey solution. In addition, using its long experience and the best practices of its large portfolio of customers worldwide, the company can tailor FTI to fit a program's needs in the best way. Such discussion has been particularly fruitful in the unique case of the Thales Stratobus.

DEDICATED ASSISTANCE

The duration of flight test campaigns is often a critical factor in their management. Technical training on the equipment and software tools enables flight test teams to attain in a short time the technical readiness needed for a test campaign. ZDS has a Flight Test Training & Integration Center where sessions are conducted on onboard and ground systems.

Each test vehicle is unique, so each FTI is tailored. To mitigate risks during integration, a similar architecture is installed and tested in the Flight Test Training & Integration Center before delivery. Any configuration of up to 60 FTI components can be integrated at the center and tested. Telemetry datalink experts are also available to consider specific needs and analyze budgets. If necessary, ZDS teams can go for on-site characterization of a datalink and even perform tests with antennas and a dedicated helicopter or aircraft in a ZDS specialized facility.

Once the system is delivered, ZDS sends experts to the customer's site to provide support. This is a big help for flight test teams.

KOPTER'S EXPERIENCE

As a young aeronautical company, Kopter has been looking for strong partnerships

4

5

4 // Zodiac's MDR (Modular Data Recorder)

5 // French Institute, ISAE-SUPAERO's Vulcanair P68 Observer pre-flight

"TRAINING ENABLES FLIGHT TEST TEAMS TO ATTAIN IN A SHORT TIME THE TECHNICAL READINESS NEEDED"

since its foundation in Switzerland in 2007. It was founded with the aim of developing, manufacturing and supporting a new generation of turbine helicopters. With this vision in mind, Kopter launched the SH09, aiming at delivering a helicopter with high performance, large cabin/cargo space, excellent modularity and modern electronic systems. The SH09 also aims to offer the highest standards of safety, performance and comfort, combined with the lowest operating costs possible.

The need for close collaboration in a very dynamic and time-constrained environment is paramount. "Very agile development and strong commitment are a must with our company," Tim Niggemann, chief engineer flight test instrumentation at Kopter, explains.

Development of the SH09 led to the production of several prototypes aimed at reaching certification in the second half of 2019. ZDS was selected to provide the instrumentation on the third prototype, following the need for easy-to-install and efficient instrumentation.

Michele Riccobono, Kopter's executive vice president technology, says, "ZDS is very committed to supporting us and meeting our challenging timeline. The company proposed a complete turnkey solution for our FTI system."

ZDS provided an end-to-end system to Kopter, composed of onboard acquisition, recording, processing and live display, as well as the ground station part composed of antennas, receivers, recording systems and displays for live monitoring currently being installed. It is all managed through the eZ Software Suite.

SCALABILITY

Kopter's need represents a midsized FTI system. ZDS equipment has long been integrated in various-sized architecture, such as the Airbus A350, with more than 80 XMA units or UAVs hosting a single all-in-one box system.

ISAE-SUPAERO (France), a world leader in aerospace engineering higher education, was recently equipped with a new twin-engine aircraft for its flight testing educational and research activities. It was equipped with a light architecture, containing a single XMA, system management and data analysis software, transmitter and receiver. It was fully designed and integrated by a ZDS team.

Medium-haul aircraft need a much bigger installation. While it requires a deeper understanding of needs, the testing of the FTI's configuration plays an important role. For the Irkut MC21 flight test program, ZDS experts contributed from sensor selection to final FTI integration. The validation of the entire FTI system was conducted at the ZDS Flight Test Training & Integration Center and was followed by a full training seminar for Irkut's engineers prior to system delivery.

Scalability also comes at the equipment level. The XMA family covers the very specific needs of missiles and space launchers. Meanwhile recording capacities extend from micro-dataloggers to high-speed recorders such as the MDR-GT, which offers storage of 20TB with 12Gbps sustained writing speed.

TOWARD A NEW ROLE

The setting of an instrumentation configuration, the integration of FTI equipment and even the definition of requirements for the acquisition are increasingly being delivered by equipment providers. Young companies are already willing to rely on providers to lead the development of FTI to help enable the success of their venture.

A contributor to the standards evolution (IRIG106 Ch10, Ch7), ZDS offers high-quality equipment that it is constantly developing to follow the manufacturers' community needs. While safeguarding expertise in customizing specific FTI building blocks, the company can fully accompany manufacturers during the whole flight test phase.

The shared experience of ZDS and its customers opens a new perspective. The expertise and skills gathered by the people who have been working on highly technical solutions can contribute to the success of the high-performance aerospace platforms that will shape the sky of tomorrow. \\

Ghislain Guerrero is business development director with Zodiac Data Systems

ZODIAC DATA SYSTEMS

WE ARE TELEMETRY™

ACQUIRE | RECORD | TRANSMIT | TRACK | RECEIVE | PROCESS | REPLAY

As a world leader in telemetry, Zodiac Data Systems is the only provider offering the entire IRIG106 & CCSDS datalink from data acquisition to decommutation and display for flight testing.

With the courtesy of Lockheed Martin, Airbus Helicopters, Boeing, Thales Alenia Space / E.Briot

GLOBAL SALES
5, Avenue des Andes - CS 90101 - 91978 Courtaboeuf Cedex - FRANCE
Tel.: +33 1 69 82 78 00 – Email: sales.zds@zodiacaerospace.com

USA
11800, Amber Park Drive - Suite 140 - Alpharetta, GA 30009 - USA
Tel.: +1 770 753 4017 – Email: sales.zds@zdsus.com

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PRECISION AT DISTANCE

The latest videoscopes are able to measure more precisely at greater distances, broadening the range of applications in test and inspection

// LIAM HANNA

Videoscopes fulfill a critical role in visualizing damage and assessing safety in aerospace inspections by enabling inspectors to image hard-to-access locations in less time. Advanced videoscopes also enable the easy integration of 3D measurement into the inspection workflow by featuring stereo measurement capabilities.

Videoscopes have been a mainstay in safety inspections of aircraft for many years. Complex areas such as turbines can get damaged in places that are not visible from the outside, but are essential to safety.

ALL EYES ON PARALLAX

Stereo measurement functions similarly to how our own depth perception works. Our brain is constantly calculating distances based on parallax, which is the change in the position of objects relative to each other when seen through the other eye. When looking at the main image on this page, our brains know that the background has not moved, even though the object appears to shift. This shift is inversely proportional to distance – the closer something is, the greater the apparent shift when viewed by alternate eyes. Parallax enables us to measure how close an object is, based on apparent changes in position from one image to another captured from a different position. Videoscopes use the same fundamental principle to make measurements. Instead of a brain and two eyes, videoscopes use a CCD imaging sensor, a processor and lenses in a scope tip adaptor. The tip adaptor has two lens systems at a known, fixed distance from each other and uses parallax to determine the distance to an object (Figure 2).

WIDER FIELD, GREATER DEPTH

When using super-wide-field stereo measurement on Olympus's Iplex NX (Figure 3), users can benefit from a large field of view and depth of field. These expanded capabilities mean that it is possible to measure defects from farther away than with conventional videoscopes and therefore measure larger flaws. The Iplex NX can produce accurate measurements at distances from 4 to 60mm (0.2-2.5in), resulting in a four-fold increase in measurement area over what was previously possible.

> "VIDEOSCOPES ENABLE EASY INTEGRATION OF 3D MEASUREMENT"

In addition to measuring larger defects, super-wide-field stereo measurement provides users with another important benefit – speed. It can take several minutes to position a videoscope to get a reliable

1 // The Olympus Iplex NX Videoscope

2 // Expanded measurement capabilities on Olympus's Iplex NX enable detailed measurements from greater distances

3 // By using a dual-lens measurement tip, videoscopes can calculate parallax and use this effect to carry out measurements

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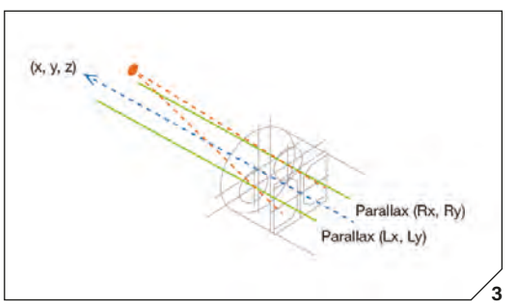
"VIDEOSCOPE TECHNOLOGY IS NOW SO ADVANCED THAT THE PRECISION OF POINT MATCHING IS NO LONGER LIMITED BY PIXEL SIZE"



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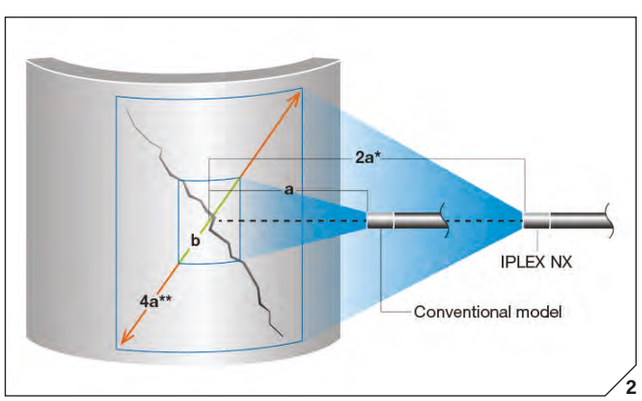

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measurement, and because the Iplex NX can measure defects from a significantly increased distance range, inspectors spend less time taking measurements.

IMPROVING ACCURACY AT LONG DISTANCES

Stereo measurement relies on the selection of two pixels – one chosen by the user and one chosen by the videoscope on the alternate stereo image. Measurements are based on the change in angle, which means that with increasing distance the absolute error increases, even though the relative error stays constant. This fundamental issue is inherent to any visual measurement system.

There are two ways to compensate for this distance issue and enable precision at greater distances. The first is to use one-to-one matching between the measurement tip and the CCD. While the Iplex NX features high-quality lenses, no lens system is perfect and variations between stereo tips are inevitable. For this reason, calibration of the combination of CCD and stereo tip results in a higher level of precision. The calibration finds these variances and incorporates them into the measurement algorithm, thereby improving accuracy.

All the measurement tips for the Iplex NX are calibrated using a control scope and test block. However, to improve precision even further users can also carry out a calibration of a specific combination of a videoscope and measurement tip.

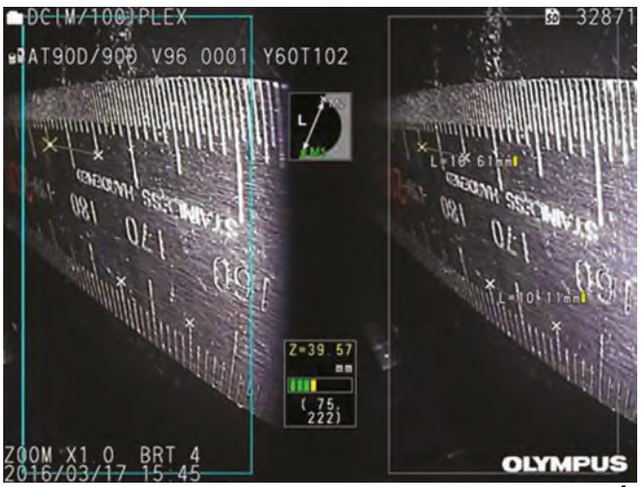
The second way to compensate is to improve the scope's ability to pick the correct matching point. Videoscope technology is now so advanced that the precision of point matching is no longer limited by pixel size; other aspects such as lens quality and aperture size play a more important role.

The high lens quality of the measurement tips on the Iplex NX makes it possible to find the best point for measurement between pixels. The Iplex software enables this so-called sub-pixel matching, where it is possible to select points that lie between pixels. This increased precision in setting up the measurement adds considerable accuracy to outcomes – especially at much greater distances.

MEASURING EVERYTHING, EVERYWHERE

Thanks to the combination of bright, intelligently adjusting illumination and robust measurement capabilities, Iplex NX can carry out measurements of a range of surfaces and features that traditionally have been challenging or impossible for videoscopes to achieve.

An example of this is the measurement of angled objects. Any object that is captured at an angle toward or away from the CCD can be challenging to measure. While the image may look fine, the actual measurable area can be very small. Standard videoscopes often have inflexible LED illumination for the phase



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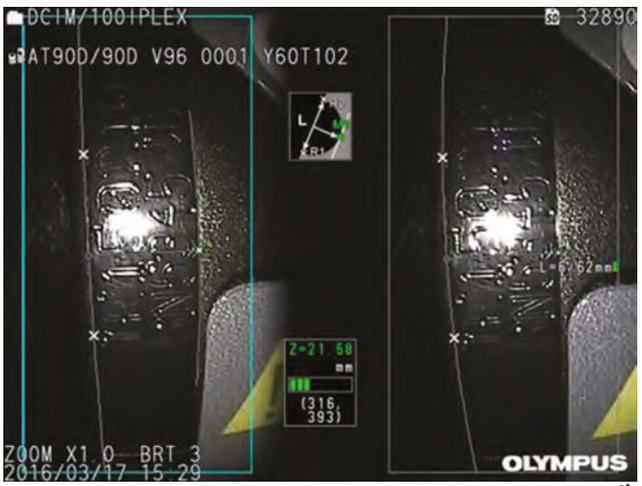

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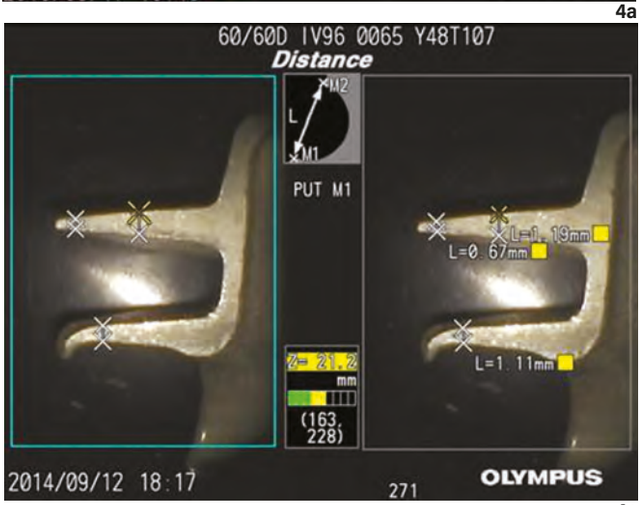

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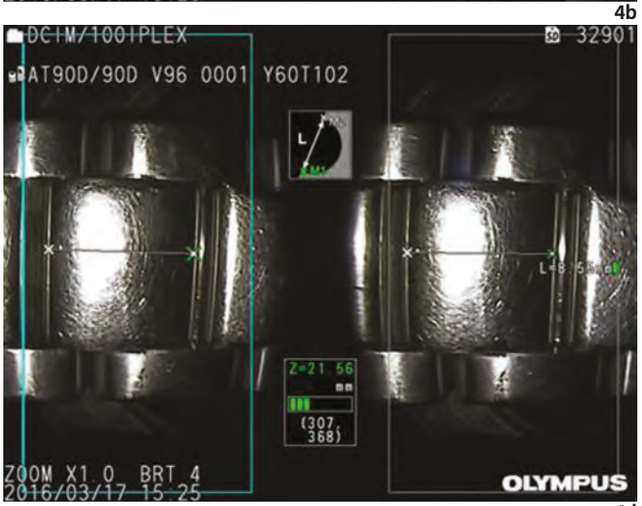

4d

4 // Features such as angled surfaces (a), dark spaces (b), narrow features (c) and reflective surfaces (d) are challenging when accurate measurements are needed

grating pattern projection, which is not adjustable to allow measurement.

Super-wide-field 3D stereo measurement allows objects to be illuminated entirely with a high level of detail and contrast retained which allows for better results under the same conditions.

Measurement of dark areas is another key challenge. When an object is too dark, it is common for many videoscope systems to display an error message such as: "Measurement error. Please rotate the tip or move closer for better results."

The measurement fails, even though the objective is close. This means that large dark spaces and high absorbency materials cannot be inspected accurately. In these situations, Olympus's bright but intelligent illumination enables the measurement feature to achieve accurate results, even at greater distances.

Components such as gear teeth and blades can have very small surface areas when seen from certain angles. When a surface area is too narrow to project grating patterns, it means that measurement of the target is not possible with standard videoscopes. Using super-wide-field 3D stereo measurement, the component's distal end can be measured accurately under the same conditions.

A final challenge for many conventional videoscopes is glare or halation. A range of reflective materials, including metals, glass and oily/wet surfaces are highly reflective.

Unfortunately, imaging these types of surfaces using other videoscopes results in bright areas, or lack of color in certain patches that cannot be measured. Therefore, measurement of defects on these types of surfaces cannot be achieved.

With the Iplex NX, measurement is possible under these conditions as a result of PulsarPic process technology, which automatically adjusts the laser illumination by intelligently increasing or decreasing brightness and contrast depending on surface conditions. The PulsarPic technology facilitates simple and accurate measurement even when working in the most extreme conditions.

PRECISION DELIVERED

With super-wide-field 3D stereo measurement and outstanding resolution, it is now possible to use videoscopes for making precise measurements from greater distances than ever before.

Reliable measurement environment data, individually mapped for each Iplex NX, in combination with more pixels and the ability to look between them, delivers a greater level of precision and helps inspectors to see and measure in places where measurement has traditionally been extremely difficult to accomplish.

In conclusion, it is a robust measurement tool that helps to save time and reduce cost in aircraft inspections. \\

Liam Hanna is senior product and application specialist RVI at Olympus Europa

Industrial Videoscope IPLEX NX

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Great Images Get Great Results

The IPLEX NX is Olympus' new feature-rich flagship industrial videoscope that delivers new levels of excellence in image quality, manoeuvrability and user friendliness to help locate flaws that were previously undetectable and streamline inspections in even the most difficult-to-reach areas.

The IPLEX NX combines industry-leading high pixel count CCD imaging, an ultra-bright laser diode light system, and Olympus' PulsarPic processor to reduce signal noise and deliver clear, bright images.

With the IPLEX NX, operators can measure flaws and defects that are 4x larger than is possible with conventional videoscopes.

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- **Expanded measurement capabilities**
- **Enhanced efficiency of inspection**

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BURNING BRIGHTER

A small, family-run test house is establishing its expertise in fire testing through industry-leading research and a customer-focused approach to service

// BEN SAMPSON

Northern Ireland-based Resonate Testing performs complex fire and vibration testing for aerospace clients throughout the supply chain. The company, which was formed in 2016 out of the propulsion integration business Nacelle Systems Consultancy (NSC), is rapidly carving itself a niche in the global aerospace testing market as a leader in the area of multi-condition, bespoke propulsion fire testing for R&D and Qualification.

The small, family-run test laboratory, which is located on a greenfield site on the transport corridor between Dublin and Belfast, is fast gathering an exciting rostrum of global clients and research partners, such as Bombardier, Curtiss-Wright, the FAA and the UK's National Composites Centre.

Aerospace Testing International talked to Resonate Testing's principal engineer and owner, Tom Mallon, about how the requirements for fire and vibration tests are changing, the technology shaping the area and how to meet customers' needs.

CAN YOU DESCRIBE HOW A TYPICAL FIRE TEST IS CONDUCTED?

We test anything from composite structures to engine valves based on the industry accepted parameters – a temperature of 2,000°F (1,090°C) and a heat flux density of 4,500 BTUs per hour within the flame.

Depending on the designation and hazard minimization requirements, the test article must withstand a fire test of either 5 or 15 minutes, but this can take up to four weeks to set up.

The level of complexity for a fire test varies from simple exposure to a flame to the top tier of testing, which introduces vibration, air flows, pressure differentials and mechanical loading to simulate the in-service environment. Much of what we do is bespoke and with an in-house design and fabrication capability we are able to respond to our customers' often changing requirements. It's our job to guide and to respond to our customers' needs from initial planning to final report, to ensure they get what they need for their project up to full product qualification.

1 // Propulsion systems fire testing can involve multiple airflows and pressure differentials

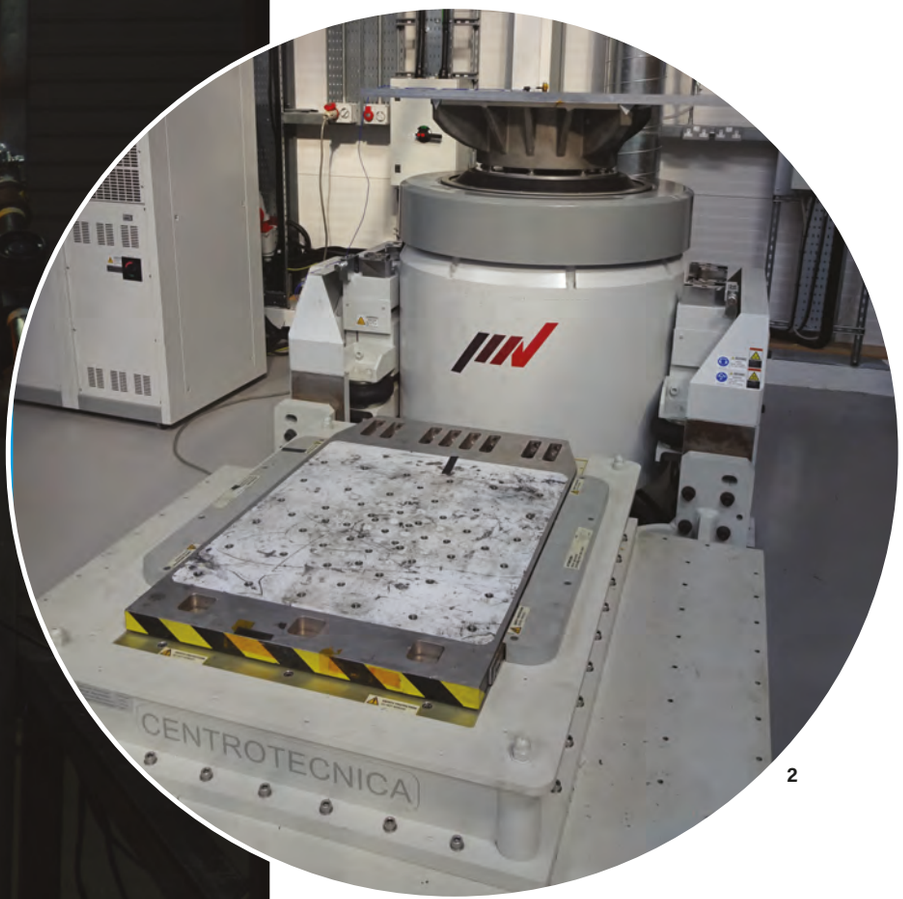
2 // Resonate conducts vibration tests on a range of products from asthma inhalers to aircraft seating

WHAT TESTING CAPABILITIES DO YOU OFFER CUSTOMERS?

We have great experience in design, qualification, validation and verification, inherited from the engine build-up work we did in the consultancy. That helped us when we physically built and equipped our own laboratory, enabling us to really understand the specifications, the variances and the best practices. We've seen what the industry was doing and what it will be doing.

Our unique offering to the market is primarily propulsion systems fire testing. We take the complex work with multiple airflows and pressure differentials that need to be replicated during a fire event. We're the only ISO17025 UKAS accredited lab equipped with kerosene burners in the UK. We also offer aircraft interiors-based material flammability and combination seat burn tests.

1



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Aside from the fire lab we have a high spec vibration laboratory with 54kn shaker table capable of testing across multiple engineering sector requirements and also offer a range of environmental testing capabilities based around the RTCA DO160G standard.

But we're the new boys in the field, so we're innovating and trying hard to make life easier for our customers. For example, we're one of very few companies in the world offering live streaming of testing.

WHAT DO YOUR CUSTOMERS VALUE ABOUT YOUR COMPANY?

We know it's not just the regulations; it's their interpretation that is important to our customers. Having seen the variation in the quality of laboratories and reporting, we know that customers have nothing until they have the report. We understand how essential it is that customers can demonstrate compliance. Our ability to provide support during test planning, test execution and the production of the test report are key to our proposition. We won't do your work, hand over the data and push you out of the door. We're genuinely looking for repeat customers and to develop a loyal customer base.

"WE KNOW IT'S NOT JUST ABOUT REGULATIONS, IT'S THEIR INTERPRETATION THAT IS IMPORTANT TO OUR CUSTOMERS"

HOW IS FIRE TESTING CHANGING?

The industry is moving away from the use of propane toward kerosene. We participate in and lead several working groups on temperature measurement. We can see that the move away from propane is a seismic shift. People's fears will be realized – components that have previously passed are more likely to fail when tested with kerosene.

While propane burners have been used for decades, experiments in France a few years ago showed that testing with propane is not as severe as testing with kerosene. Certification bodies such as Transport Canada and ANAC (Brazil's National Civil Aviation Agency) have since said they don't want to see testing with propane. The FAA will formalize their position with an advisory notice within months.

While EASA uses the ISO2685 standard which as it stands does allow propane, many believe that the document has issues. But because of the global market and to keep costs down, we're seeing a move to kerosene-based testing. We recognized this and chose only to install kerosene burners.

Fire testing is also becoming more sophisticated, with the application of airflows, pressure differential, fluid flows, external mechanical loading and other conditions, often with multiple conditions in the same test with changing variables during the test. And all of these parameters need monitored real time. The days of simple burner tests are long gone!

WHAT IS CHALLENGING ABOUT CONDUCTING FIRE TESTS?

The challenge is that you are using burners that were originally designed 40 years ago. It's not a scientific piece of equipment. It's fundamentally a kerosene heater similar to that which is used in a home. Controlling the equipment to produce an optimized flame at temperatures of up to 2,000°F (1,093°C) within a tight tolerance and trying to meet a heat flux of 4500 BTUs per hour is a difficult task. The flame has to be optimized to prevent over testing – it's a task that can take several days. The industry norm to require post-test calibration, particularly for full qualification tests, causes people to add extra conservatism into the test – potentially adding unwelcome weight and cost to the final assembly.

WHAT ARE THE LATEST TECHNOLOGIES IN FIRE TESTING?

We've done a lot of work to map the legacy burner and optimize it as much as possible. The FAA has devised a sonic burner with the intention of achieving a uniform, highly repeatable flame for use in testing. We've recently examined that burner, mapping its temperatures and BTUs, and modifying it in partnership with National Research Council of Canada, to assess its equivalence to the legacy burners.

HOW IS VIBRATION TESTING CHANGING?

We test a wide range of products from many industry sectors – anything from asthma inhalers to aircraft seating. The classic industry qualification vibration profiles are constantly being modified to include discrete frequency band applications and increased *g* levels. Extended vibration exposure is being driven by the need for increased reliability in the field, so we are seeing higher and

3 4

"COMPONENTS THAT HAVE PREVIOUSLY PASSED WILL START FAILING WHEN TESTED WITH KEROSENE"

3 // Kerosene burners are also used for aircraft interiors as well as propulsion components

4 // Tom Mallon, principal engineer and owner of Resonate observes a test

significantly longer validation and verification testing. The drive for more sophisticated testing is also increasing, with exposure to operating environments during vibration testing becoming a potentially mandatory capability that test houses will have to provide in the future. In short, we'll be seeing more severe profiles, longer duration and increasing sophistication for enhanced reliability testing in the future. I think the next step for most test providers will not be simply larger shakers, but the increased use of synchronized tables, capable of accommodating larger parts, or greater lengths of installed systems.

WHAT'S CHANGED IN TESTING DURING YOUR CAREER?

All technology-based industries are revising their qualification standards either at the direction of their customers or as a risk mitigation. In our modern world reliability issues become public very quickly, leading to reputational as well as financial damage. The result of this can be that a greater emphasis is put on testing for reliability with customers becoming ever more risk averse and wanting to test more. It's a great time to be in testing as long as you can stay independent and away from predatory venture capitalists.

WHAT HAS BEEN YOUR MOST IMPORTANT PROJECT TO DATE?

We work with companies of all sizes in the supply chain, and every test is important to them and therefore to us too. But recently the vibration testing we carried out for Curtiss-Wright on Data Acquisition Units was impressive. The DAQs will be used in aircraft and spacecraft data measurement systems, some of which will fly to the International Space Station. We're frequently testing at the tail end of an aircraft's certification process which is always a critical time when no-one can afford any gremlins!

WILL YOU BE TESTING LITHIUM-ION BATTERIES IN THE FUTURE?

Yes, it's an enormous topic, it's 80% of all the FAA fire test conferences we go to. To my knowledge no one has joined the dots between automotive lithium-ion batteries and the ones we want to use in aircraft. We're getting enquiries from the automotive sector and there is certainly an opportunity for convergence and cross pollination to drive better testing approaches in this area. It's certainly an area where we want to develop capability.

WHAT OTHER PLANS ARE THERE FOR RESONATE'S FUTURE?

We're busy and getting busier, especially internationally where we are bidding on new work opportunities on civil aviation projects from North America to Europe to Russia.

The vibration side of the business is picking up and we're about to expand our capacity in environmental test chambers for combined conditions across temperature variation, humidity, altitude and vibration, along with expanded fabrication capabilities. And the work that our test-house manager Dr Mary Kelly has done to lead an international review of temperature measurement and with the FAA is keeping us in the forefront of testing development. There's plenty of work ahead as we continue to establish and grow Resonate! \\

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1

THE CHALLENGE OF SHORT-DURATION RANDOM VIBRATION TESTING

Displaying a smooth control trace on the power spectral density can be dangerous if it hides what is really happening during the test

// JADE VANDE KAMP

Random vibration tests are one of the best ways to validate reliability for a mechanical product. They generate a power spectral density (PSD) that identifies resonances across a frequency range.

Aerospace organizations often want to test a very high value piece of equipment at extremely high levels of random vibration for a very brief period of time. These short-duration, high-amplitude tests are representative of launch and take-off events. The goal is a realistic test that will identify any reliability issues but won't damage the equipment. Ideally aerospace test engineers want to see a smooth control trace on the PSD that stays within an established tolerance range. These types of vibration tests typically have very tight tolerances (±1.5dB). This means that the statistics of averaging FFT power values makes it nearly impossible for all lines to be within tolerance over a short period of time. IDOF (instant degrees of freedom) calculations, discussed below, are a statistically valid way to provide smooth lines and have a PSD within tolerance, if appropriate, in a brief testing period.

THE ESTIMATION ERROR PROBLEM

The underlying problem is that a PSD is created by separating time-domain data into a series of frames, moving to the frequency domain by calculating the FFT for each frame and then averaging the power values of the FFTs. In a PSD there are two sources of error – control error and estimation error. Control error refers to the discrepancy between the actual PSD of the data (signal) and the desired demand PSD. Estimation error refers to the discrepancy between the estimated, plotted PSD and the actual PSD of the signal.

The inherent nature of randomness means that there is statistical variance in the PSD, creating estimation error that is reduced as more data frames are captured and contribute to the calculation. This takes extra time, something engineers don't have in a short-duration test.

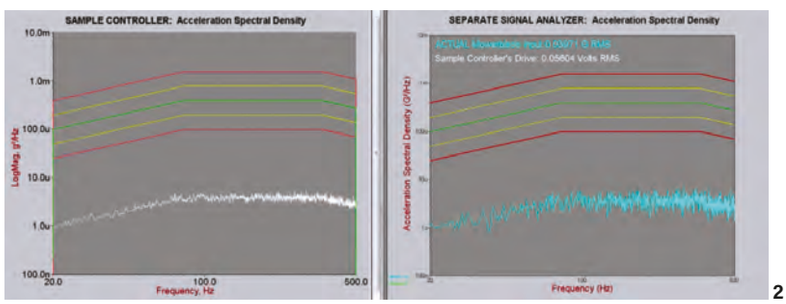
One approach to avoiding an initially jagged, high-variance display plot is to simply suppress the PSD display until traces are sufficiently averaged. But while unpleasant early randomness is hidden,

1 // Random vibration tests are used to test launch vehicles and payloads

THE STATISTICAL NATURE OF A PSD

The power spectral density (PSD) of a Gaussian random waveform is computed using an FFT. The FFT is a linear transform and it is given a Gaussian input. As a result, the output of the FFT at each frequency line is a complex number, with a Gaussian real part and a Gaussian imaginary part. These are squared and added together to get the magnitude, so the square magnitude of the FFT output is a chi-squared distributed random variable with two degrees of freedom (DOF). To compute an averaged, random PSD, F frames of time data are measured, an FFT for each frame is calculated, and the square magnitudes are averaged. As a result, the averaged PSD of a Gaussian waveform is a chi-squared distributed random variable with 2F DOF.

"THE GOAL IS A REALISTIC TEST THAT WILL IDENTIFY ANY REALIBILITY ISSUES"



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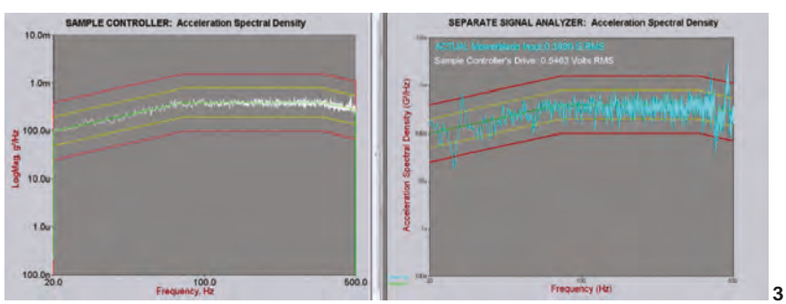

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this blank-display method also hides what is actually happening on a shaker early on in a test. This can include out-of-tolerance conditions, which is clearly a dangerous situation for the test.

DATA MULTIPLICATION

A more common but equally dangerous approach to achieving an attractive PSD for short-duration tests is data multiplication. It involves starting the test at a low level and as the test ramps up, multiplying the low-level data by a scaling factor and presenting it as full-level data. The process assumes that a device under test's (DUT) mechanical behavior at the high level mimics that at the low level. Unfortunately that is not true.

The mechanical world is not linear. Resonances will typically shift in both frequency and amplitude when signal levels change. Data multiplication masks changes occurring at the product resonances, so the test engineer is unaware of potentially damaging vibration energy levels. Multiplying low-level data is inaccurate and misleading.

The white PSD (Figure 2) is generated by a test controller at a low-level, early stage, while the blue PSD comes from an independent signal analyzer. Both show essentially the same behavior.

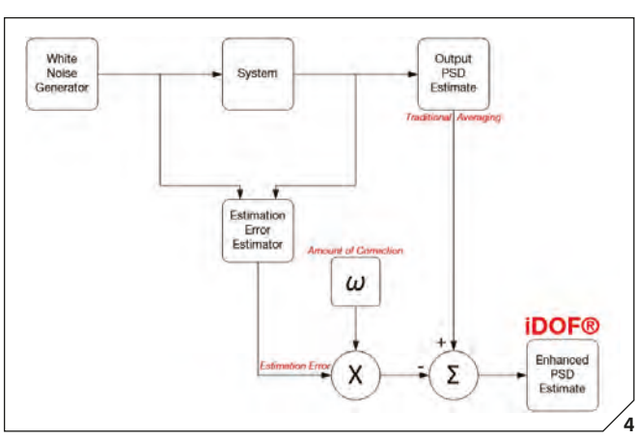
Figure 3 shows a white PSD created for full level by data multiplication, while again the blue comes from an independent signal analyzer. In this case the graphs are dramatically different. The data multiplication graph does not show the resonant peaks, including some that are well beyond abort limits. An engineer viewing the white PSD can't see what is really happening during the test and is left with the false impression that it is staying within tolerance.

This lack of visibility into testing reality can result in undertesting, which means that the DUT could pass the test but fail during field use, or overtesting that damages the DUT with vibration energy beyond required test levels. Overtesting error is especially significant if it results in avoidable damage to unique and extremely expensive components or payloads.

RESETTING THE AVERAGE

To accurately display what is happening in the real, non-linear world, the PSD averaging should be restarted or reset with every change in level. All the PSD data is discarded and averaging starts over from the beginning. The advantage of this approach is that it displays exactly what is happening on the shaker. A major disadvantage is the time required for averaging a sufficient number of frames. So if the trace is within a 1.5dB tolerance at the low level, it will take some time to get back within that tolerance. If your test requirement is that all lines of resolution must always be within 1.5dB, this method is not going to work.

Note that high PSD estimation variance during the start of a test, or a change in level, does not mean there is anything wrong with the PSD estimation method.



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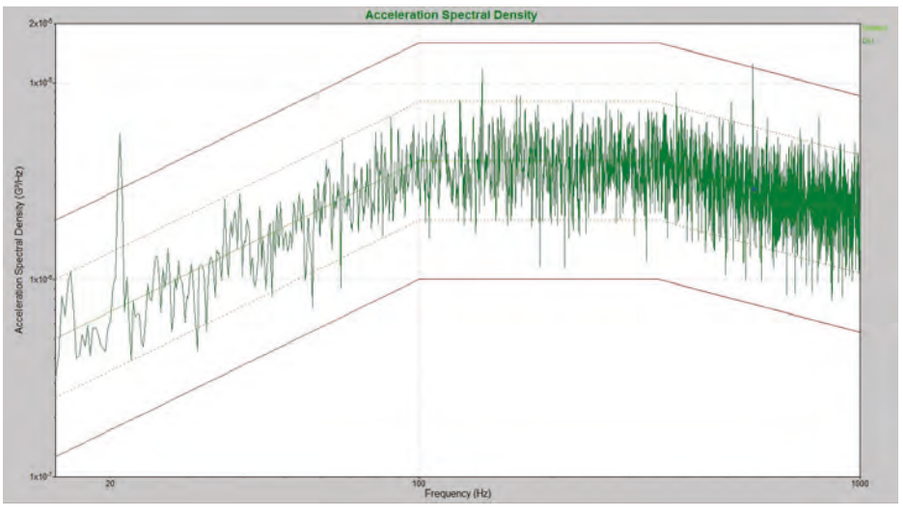
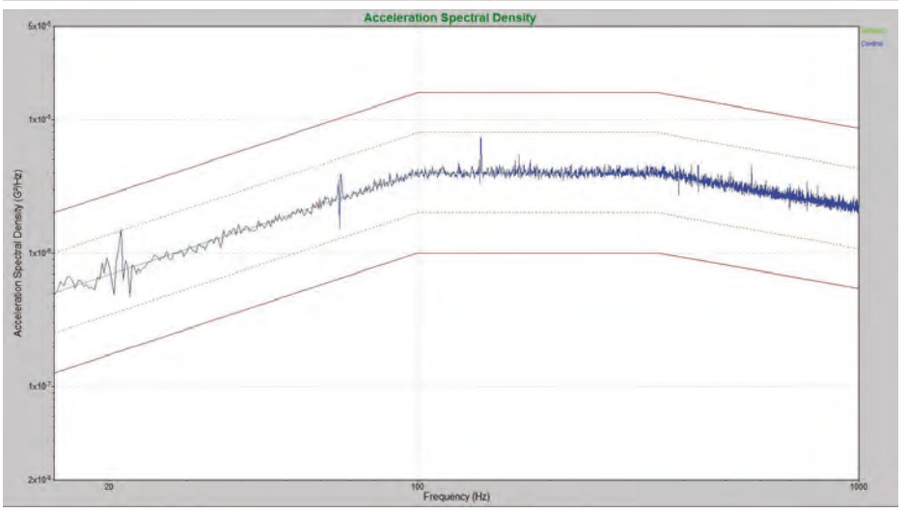
2 // Sample controller PSD at 20dB below level, compared with a separate signal analyzer

3 // Sample controller PSD at full level generated by data multiplication, compared with a separate signal analyzer

4 // An iDOF functional diagram



5 // PSD generated by a separate signal analyzer



6 // PSD generated using iDOF, with resonances clearly visible

> "RANDOM VIBRATION TESTS OFTEN OPERATE ON EXTREMELY VALUABLE EQUIPMENT AND MUST BE COMPLETED WITHIN A SHORT TIMEFRAME"

Volatility is a natural and expected characteristic of a random signal. The variance is only reduced as more frames of similar data are calculated and averaged into the PSD.

iDOF

Fortunately there is a statistically valid approach to quickly creating an accurate PSD. In a random test, the variance is based on a chi-squared distribution. Using this statistical understanding, the variance can be calculated and taken out of the PSD plot, essentially removing the estimation error (see box, The Statistical Nature of a PSD). This approach delivers a smooth but accurate PSD, preserving control error so that an engineer has an accurate view of the DUT's behavior.

iDOF is an optional module in the VibrationVIEW software suite. It uses an advanced, patented algorithm to deliver accurate, low-variance PSD estimates during vibration testing. These estimates are calculated much more quickly than those using traditional averaging. iDOF removes the estimation error while displaying the control error, which is the true difference between the PSD of the signal and the demand PSD.

With iDOF, control error becomes visible much sooner than with traditional averaging. For example, 10 frames of data can be processed with the iDOF algorithm to produce a PSD estimate comparable to traditional averaging with 100 frames. This enables the fast detection of changing responses, such as shifting resonances (for example due to a product beginning to fatigue), without using long averaging times – critical in short-duration tests.

iDOF does not touch the controller itself, so it does not affect the signal being sent from the controller to the system. iDOF calculations are applied to the estimation of the signal and clarify the estimation of the signal's PSD. Hence, the control trace more clearly displays the true control signal, with less raggedness.

After a change in level, iDOF quickly reduces the variance of the PSD estimate, and does so without using the low-level data or some other trick. Thus, iDOF quickly exposes any lines truly out of tolerance without masking resonances, and without requiring the time necessary for traditional averaging.

Figure 5 shows the PSD from a signal analyzer using traditional averaging for a test at full level, while Figure 6 shows the PSD using iDOF, also at full level. The iDOF PSD preserves and displays the resonances and vibrations experienced by the DUT while also greatly reducing the raggedness of the plot. The estimation error has been confidently removed while actual vibrations and deviations from demand due to control are clearly displayed.

We can conclude that by using iDOF, a test engineer is able to verify that the control PSD is maintained within tolerance throughout the entire test and can make an informed decision on how a test is affecting the DUT. Most importantly, the engineer can stop a test before the energy from a vibration resonance inflicts damage on an expensive, hard-to-replace DUT. \\

Jade Vande Kamp is the training and education manager at Vibration Research

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VIBRATION RESEARCH

1

OPTIMIZING ADDITIVE MANUFACTURING PART TESTING

Industrial and academic partnerships have devised a practical and efficient workflow able to discern how additive manufacturing parts deviate from their nominal designs

// PHILIPPE YOUNG, NICK BRINKHOFF, STEVE PILZ, ALBERT TO

The growth of additive manufacturing (AM), or 3D printing, in aerospace has brought advantages over traditional approaches to designing and manufacturing parts. The use of AM methods solves many of the common challenges of prototyping or manufacturing complex designs requiring considerable weight reductions. AM also allows for structures like lattices to be built within or as part of the component, which would not be possible with any other traditional manufacturing technique.

Computer-aided engineering (CAE) is particularly valuable for designing parts for AM. Simulation tools such as finite element (FE) analysis provide methods of virtually testing designs before manufacturing begins. In combination with topology optimization, weight reductions can be targeted around where typical loadings on the part are not critical.

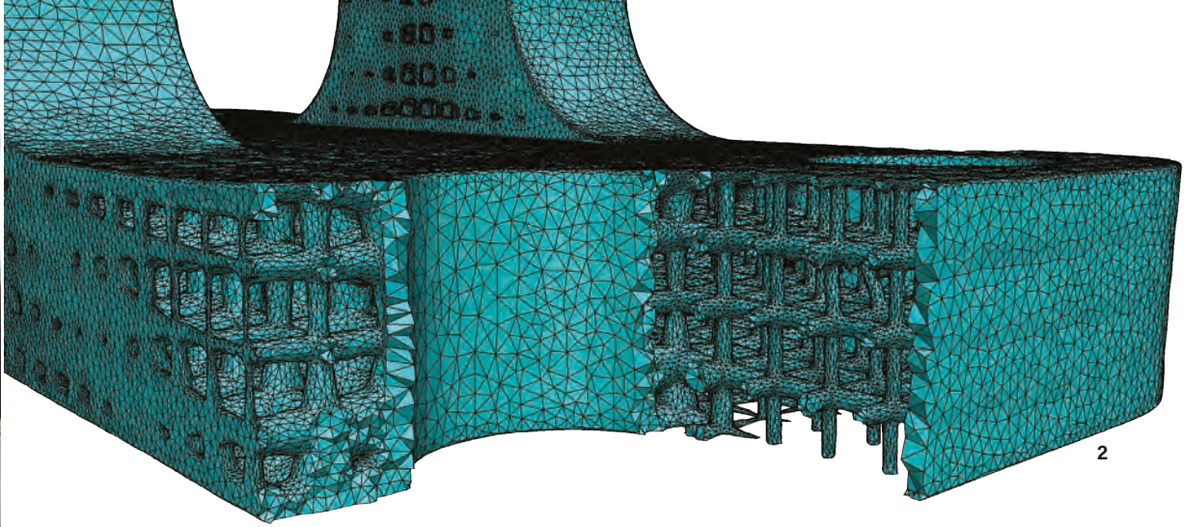
Post-manufacture, a common technique to inspect the components is with scanning. As AM parts can often have complex external and internal geometries, computed tomography (CT) scans, for example, allow for the part to be comprehensively inspected. This method enables potential problems in the AM process to be identified and rectified early in the design process. While many companies use AM, scanning and simulation, they typically lack a straightforward workflow that links them together. Synopsys' Simpleware software removes this problem by creating meshes from CT scans.

North Star Imaging (NSI), Synopsys, Ansys and the University of Pittsburgh have collaborated on a project to develop a proof-of-concept workflow for going from a 3D CT scan of an AM part to a solved FE simulation. While this workflow was tested on a lightweight bracket, NSI, Synopsys and Ansys have also applied the research to prototypes by Moog, bringing new levels of confidence to the overall testing process.

REDESIGNING AEROSPACE PARTS

Researchers at the University of Pittsburgh are investigating simulation-based analysis and design methods for AM by using Ansys software's homogenization and structural optimization tools to redesign a typical bracket geometry. An early proof-of-concept was created using lattices to save part weight. Ansys tools were used for the lattice structure and design validation

1 // Additively manufactured parts are becoming more commonplace in the aerospace sector



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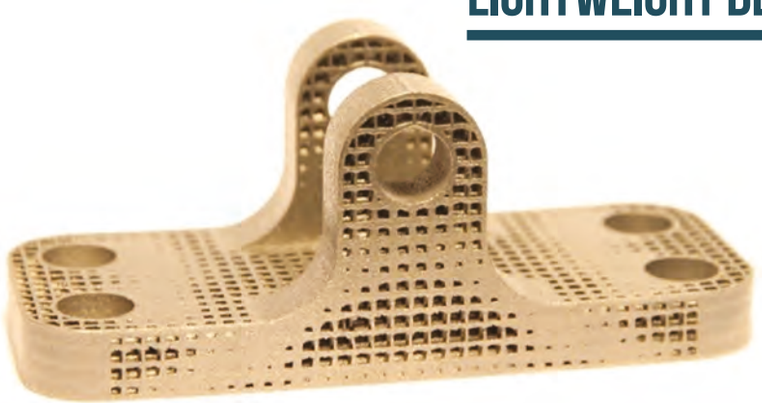
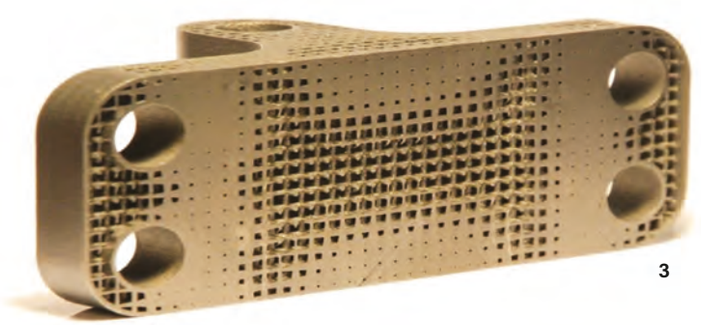
"THE MODELS DEVELOPED ARE EXPECTED TO IMPACT LIGHTWEIGHT DESIGN FOR THE AEROSPACE INDUSTRY"





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carried out on a homogenized model prior to manufacture using a titanium alloy (Ti_6Al_4V) in an EOS direct metal laser sintering (DMLS) powder bed AM machine (Model M290). Prof. Albert To from the University of Pittsburgh has discussed the goals of this work:

"Currently, there is a great need for these methods because past design tools were developed for traditional manufacturing and do not account for manufacturability requirements and the unusual microstructure and properties of AM parts.

"As a step toward this goal, my research group has been developing an AM-friendly lattice infill optimization method and process-microstructure modeling of different AM metals.

"The models developed are expected to not only impact lightweight design for aerospace industry, but also enable support structure design to reduce residual stress and distortion."

It was possible to use the AM part to compare the as-designed and as-built parts. The key questions here were about whether there were any design differences present between the two parts and how the differences between them may affect real-world performance.

CAPTURING THE PART GEOMETRY

The titanium and aluminum brackets were received, scanned and reconstructed by North Star Imaging. There are several software applications and scanning methods that can here be used to verify a part's integrity.

3D imaging using subpiX software enabled engineers to gain good contrast and obtain a clean surface. As the part was relatively large, it required low magnification of 1.5x. This low magnification allowed for defocusing of the tube at 220kV and 700µA. The high-power tube settings and pixel binning of the detector allowed the scan to be acquired at 30fps, with dozens of frames averaged for an excellent signal-to-noise ratio. The completed scan was done in less than two hours with projections acquired every quarter of a degree.

CT DATA PROCESSING

Once the scan data was obtained, it was processed and prepared by the Synopsys Simpleware ScanIP software for export to simulation. One of the advantages of working with CT as well as with the other types of imaging data is the capability to capture the 'as-manufactured' aspects of a design. This capability enables realistic models to be generated. Simpleware software was used to segment the part from surrounding air space using thresholding and localized techniques.

An optimized 3D surface was exported as a high-quality STL and a volumetric FE mesh, removing the need to rebuild the mesh in a simulation solver.

INSPECTION AND SIMULATION

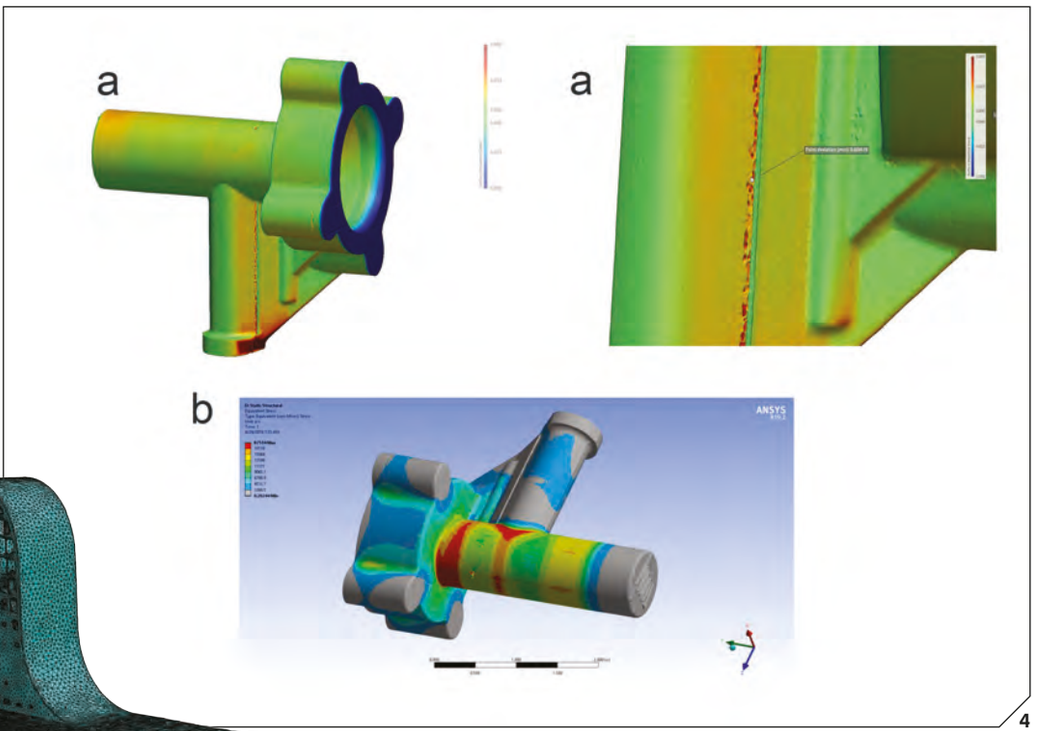
The goal of this next stage was to compare the image-based STL model from the Simpleware software with the original CAD design. This was achieved by aligning the two parts using landmark and automatic registration tools.

A deviation analysis tool in the Simpleware software identified key differences between the CAD and as-manufactured models, including a bend in the base of the bracket that was likely caused during extraction of the component from the AM machine. In addition, broken struts were detected in the lattice, an error linked to the performance of the power bed arm during AM. It is worth noting, however, that this was the earliest version of the part design. The analysis enabled the researchers to detect errors and handle them for future iterations, reducing the risk of future manufacturing issues.

The volume mesh was imported to Ansys Mechanical from Simpleware software in a native format. The Ansys simulation team was able to rely on the accuracy achieved from the scan to the image-based model, when evaluating how the virtual part performed in specific conditions. A structural simulation was carried out on the original CAD design and the scanned part in Ansys

2 // High-resolution mesh of the additively manufactured titanium bracket built for the University of Pittsburgh

3 // Examples of the additively manufactured titanium alloy bracket built for the University of Pittsburgh project



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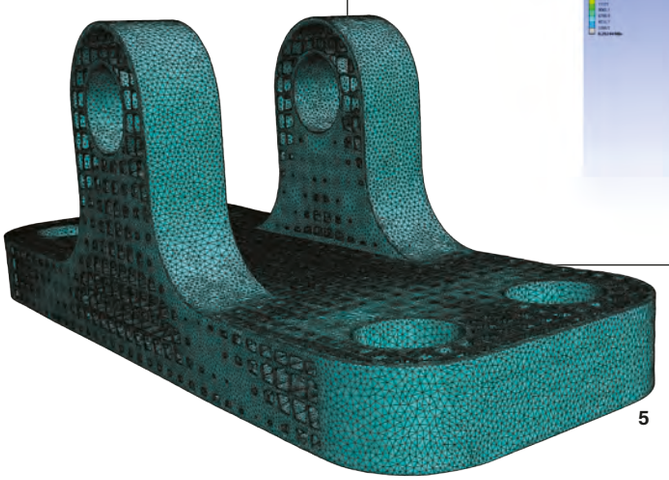
4 // Deviation analysis between CAD and CT data in Simpleware software (a) and simulation of maximum principal stress in Ansys Mechanical (b)



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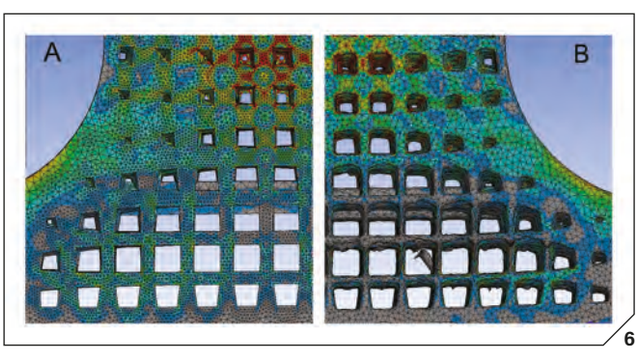
5 // Image-based segmentation and meshing in Simpleware software

"DESPITE THE VISUAL DIFFERENCES, THE PRINTED COMPONENT STILL PERFORMED WELL AND MET TESTING REQUIREMENTS"



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6 // Comparison of CAD (a) and scan model (b) stress in Ansys Mechanical

Mechanical to solve loading problems. Results showed that, despite the visual differences between the parts, the AM component performed well and met testing requirements.

CASE STUDY: MOOG

Having successfully developed a workflow, it was then applied for an industrial client. Moog is a designer, manufacturer and integrator of precision motion control products and systems that are used in the automotive sector, military and commercial aircraft, and many other industries.

Typically, Moog will create a conceptual design and perform simulations in Ansys Mechanical prior to printing on a Renishaw AM250 laser powder bed fusion (LPBF) printer. In this project, Moog worked on optimizing the design of an impulse pressure manifold for a specific material and hydraulic fluid configuration. As with the bracket, the manifold was CT-scanned by North Star Imaging before segmentation and reconstruction in Simpleware software.

3D image processing in Synopsys Simpleware software enabled visualization of pores, cracks and residual powder from the AM process, and comparison of the as-built part from the original CAD design to identify geometric deviations, such as part porosity. An FE mesh was then exported from the CAD and segmented CT data to simulate maximum principal stress in Mechanical. Results showed that, between the CAD and image-based model of the AM part, there was a 23.18% increase in maximum principal stress, likely due to cracks and pores in the as-built geometry. The workflow therefore enabled Moog to quantify the fitness-for-purpose of AM parts and evaluate performance uncertainty.

Paul Badding, mechanical design section head at Moog, says, "The Simpleware model reconstruction provides an essential solution to assess the usability of an AM-produced part. The effect of a defect or geometry deviation in a critical location can be quantified. Based on a comparison to the nominal CAD geometry, the impact on structural integrity and fatigue life can be evaluated. This workflow provides a key solution to determine the disposition of an AM produced part with deviations from the nominal design."

The proof-of-concept results with the University of Pittsburgh and the work with Moog show the promise of image-based methods for linking AM and simulation. The comparison of the CAD- and image-based models meant unexpected defects could be identified early and factored into future design iterations. This approach could reduce manufacturing errors for parts planned for aerospace applications.

The presented solution enables complex AM parts to be analyzed to assess their as-built performance against what was originally intended. Understanding what level of differences are acceptable, both geometrically and structurally, will provide valuable feedback when designing parts for AM, especially in metal. \\

Philippe Young is R&D director for Synopsys Simpleware software, Nick Brinkhoff is product manager at NSI, Steve Pilz is lead product manager, additive manufacturing at Ansys, Albert To is director of the Ansys AM Lab at the University of Pittsburgh.

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MODULAR RANGE RE-TRANSMISSION AND DATA INTEGRITY CHECKOUT SYSTEM

An upconverter that can be mated with existing telemetry processing stations offers extended functionality for range flight test operations

// MARK McWHORTER

1

1 // The LS-96-M2 Data Re-Transmission System

Visualizing pictures of a beautifully styled VIP aircraft with bathrooms, wooden furniture in the dining area and luxurious lamps providing a warm and natural atmosphere makes one wonder how it can all be realized. What has to be done to get these parts designed, produced and finally qualified to international aerospace requirements? Or what does it take to get an air-to-air missile fully qualified for combat?

Although not immediately apparent, advanced telemetry systems are an integral part of the development process for both comfortable air passenger environments and precision munitions. Without the innovative products and expertise deployed for flight testing from the international telemetry community, such aeronautical achievements would not be realized.

Building off of the proven success of the LS-28-DRSM, Lumistar has designed a complementary product that when mated with the DRSM allows for a suite of new capabilities in a very small envelope.

The new LS-76-M2 Series upconverter is a standalone dual-channel IF (intermediate frequency) to RF (radio frequency) tunable upconverter module with multipath simulation capabilities. The LS-76-M2 will accept a single IF signal at 10-200MHz and upconvert to any tunable frequency from 200MHz to 7GHz. When the LS-76-M2 is mated to the LS-28-DRSM, as shown in Figure 1, the resultant LS-96-M2 system creates new applications using the receiving, modulation, upconversion, and data quality measurement capabilities.

MODULAR DATA RE-TRANSMISSION SYSTEM APPLICATION

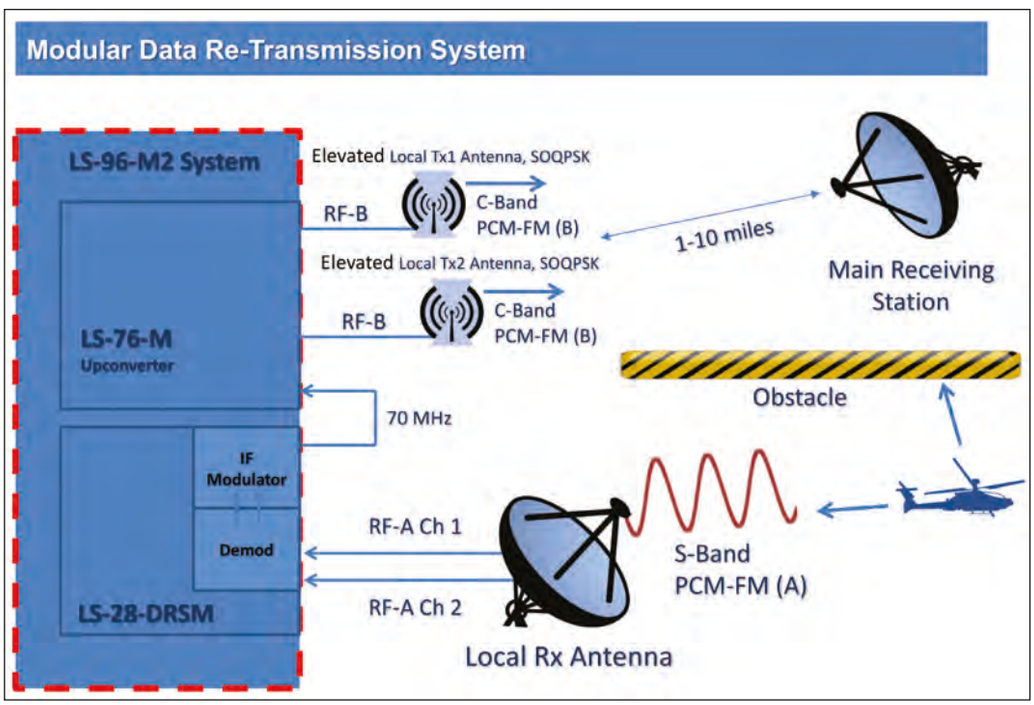
Many of Lumistar's range customers have consistent problems receiving good bits from RF datalinks that are not line-of-sight at various times in a typical ConOps range flight test. One typical example is when the target airframe is at preflight check and typically obscured from the distant main receiving station or stations by hangars, buildings or trees (Figure 2).

The LS-96-M2 can be placed locally on the flight line and will receive the preflight telemetry, and process it down to clock/data outputs. These clock and data signals are fed to the LS-28-DRSM's onboard dynamic IF modulator, where the data can be modulated to one of many formats. The modulated output, necessarily at the same data rate, is then fed to the input of the upconverter module of the LS-96-M2, where it is first split into two streams and then unconverted to RF. The LS-96-M2 allows for upconversion from 200MHz to 7GHz at a power output of up to +20dBm. The output from each unconverted channel can be fed to a typical high-gain directional transmit antenna that is placed at an elevated location at the local site, and pointed directly to the range receiving infrastructure site.

Conversely, a directional receive antenna that can be identical to the transmit antenna can be placed at the receiving station, and the RF brought into the system at the distant site for demodulation and data processing.

MODULAR LOOPBACK RANGE TELEMETRY CHECK-OUT SYSTEM

A second application for the LS-96-M2 system is a complete modular loopback range telemetry check-out system. In this application (Figure 3), the identical LS-96-M2 unit is configured differently than as shown in Figure 2. The internal IF modulator feature inside the LS-28-DRSM can generate a test pattern signal, typically



2 // The LS-96-M2 Data Re-Transmission System application

at 70MHz, which can be configured to provide data rates up to 40Mbps from internally derived data patterns.

The test pattern signal can be PRN, frame simulation, user-defined or external-derived data. The data can be modulated with any appropriate format.

Once modulated, the 70MHz is cabled over to the LS-76-M2 modular upconverter and translated up to any RF frequency between 200MHz and 7GHz. The RF can then be fed to a boresight antenna at power level up to 20dBm without the need for external amplification.

This antenna can be situated in such a way as to return the RF back to the main range infrastructure receiving antenna(s). The received RF signal is routed back to the dual RF inputs of the LS-28-DRSM, or to any range telemetry receiving asset, then demodulated and bit errors collected.

The modulator section in the LS-28-DRSM can be configured to provide Doppler simulation and injected white noise. Therefore, the range telemetry check-out system is able to create RF profiles that could be expected to be encountered in real-world scenarios.

MULTIPATH SIMULATION

In addition to Doppler and additive white noise, the system also employs a multipath simulation capability. Each unconverted RF signal can be dynamically attenuated at

LS-76-M2 SPECIFICATIONS

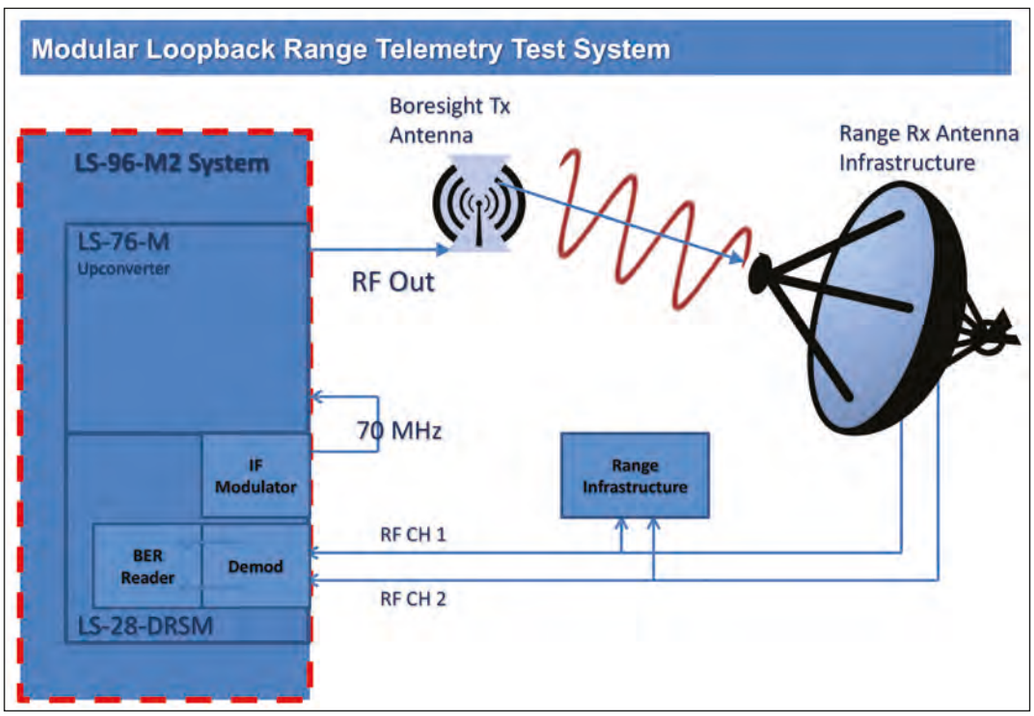
Typical RF upconversion frequencies:	215-320, 400-1150, 1435-1535, 1710-1850, 2200-2395, 2185-2485, 4400-4950, 5091-5150, 5091-5250 *(custom frequencies are available)*
Number of upconversion bands:	Up to 5 plus IF pass-thru
RF tuning step size:	50kHz steps (typical); 100Hz upon request
Maximum input signal non-damage:	+30dBm
IF input frequency:	70MHz typical, Variable from 10MHz to 500MHz
RF output:	Variable; +20dBm to -96dBm; each channel separately controllable
Output fading:	Software controlled; 20kHz adjust rate; 14bit resolution
VSWR:	1.5:1 typical or better
Frequency accuracy:	0.002ppm (internal)
Input/output impedance:	50Ω
IF inputs:	Two inputs; SW selectable; linear and AGC Auto
User inputs/outputs:	Total of 12 Custom IO available
DC input power (calculated):	9-42 V DC; 28W
Control interfaces:	232/422/485/USB/10 or 100Mbps Ethernet

the RF frequency of propagation. Known multipath profiles, such as standard waveforms, previously recorded multipath profiles, or user programmable multipath, can be generated. The multipath depth is greater than 90dB, and the fade rate is greater than 20kHz.

LS-76-M2 UPCONVERTER DESIGN AND CAPABILITIES

The LS-76-M2 upconverter used in the LS-96-M2 modular range re-transmission and data integrity check-out system uses advanced design and technology. The unit is capable of withstanding harsh environments, including resistance to vibration and shock. It is ideally suited for applications where size, weight and power are key design considerations.

The unit provides standard RF upconversion bands of 215-320, 400-1150, 1435-1535, 1710-1850, 2200-2395, 2185-2485, 4400-4950, 5091-5150, and 5091-5250MHz, plus an IF band pass-thru. RF tuning resolution is typically 50kHz, however tuning steps as small as 50Hz are possible. The maximum IF input signal is 1W. The IF input frequency, which typically will be in the 70MHz range, can be varied from as low as 10MHz to 500MHz. If a specific IF input frequency is required, Lumistar can be consulted for details. The unit boasts a powerful RF output at 20dBm, which is more than sufficient power to provide re-transmission over several miles using directional antennas. Lumistar is able to provide specific 'Link Analysis Support' if it is needed to ensure your line-of-sight communications link.



3 // The LS-96-M2 Range Loopback Range Telemetry test application

Each channel has separately controllable attenuation over a >90dB range, thus providing independent multipath attenuation simulation characteristics for dual-polarity systems. The upconverter provides this fading via software control, up to a 20kHz rate, 14bit resolution, using analog variable attenuation. Thus no break in the data stream occurs during fading events. The frequency accuracy is better than 0.002ppm. The upconverter operates from a DC power supply 9-42V DC and consumes around 26W.

The LS-76-M2 can be used as a highly configurable dual-channel upconverter, or when mated with its sister product (the LS-28-DRSM) it can provide range re-transmission or line check-out functionality that is highly useful for range flight test operations. \\

Mark McWhorter is vice president of sales amd marketing with Lumistar

MODULAR TELEMETRY

Lumistar's LS-28-DRSM Modular RF/Digital Telemetry System can stand alone as a fully integrated telemetry processing station or can mate with other Lumistar products to meet extended requirements.

The modular unit supports up to six bands of dual channel RF signals, multiple digital demodulation formats, bit and frame synchronization, diversity combining, three stream data recording, decommutation, IRIG and network time synchronization and Ethernet UDP data broadcasting. Software displays include Spectrum, O-scope and Constellation patterns. Hardware and firmware options support many uses.

The modular unit supports many error correction schemes, such as Viterbi, Reed-Solomon, LDPC, STC, Best Source Selection, and Adaptive Equalization. An added feature is the modular unit's versatile IF Modulator, which can produce many data waveforms used in typical system test scenarios, including Doppler and Multipath simulation.

Other features include spectrum sensing, data re-transmission, and digital communication system data link analysis.

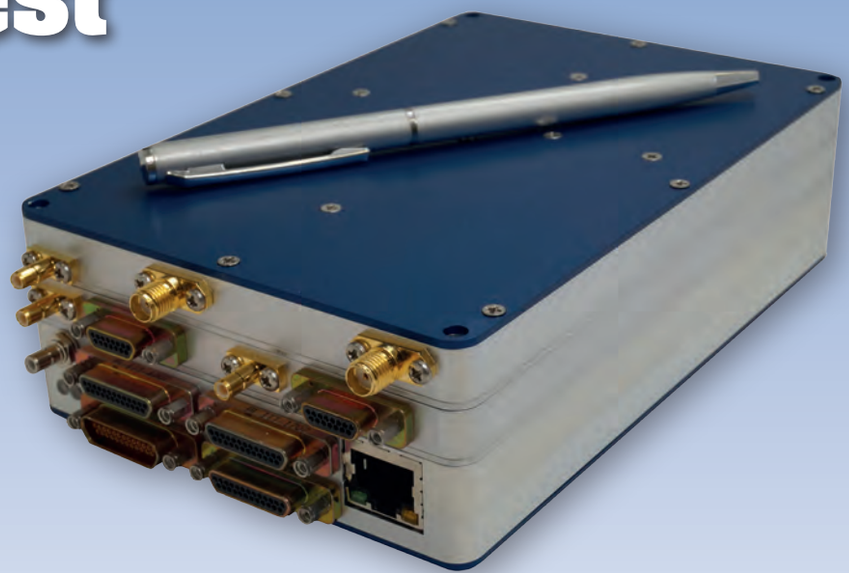
All of these capabilities are included in a small modular unit under 41in^3 (670cm^3) 2 lb (0.9kg) and consuming just 45W at 10-40V DC.

Beyond the excellent RF performance, at the heart of the modular design is a flexible and extensible multicore DSP engine that can assume any one of 12 "personalities". The unit is constructed via four hardware slices: RF, IF, DSP and control processing.

Adding to the unit's design flexibility, it can be constructed using only two or three slices when requirements demand different hardware configurations without RF capabilities. Owing to the open-ended firmware-based architecture of the LS-28-DRSM series products, many more personality-based applications are conceivable and achievable.

Telemetry Ground Systems for Flight Test

- RF and IF Receivers
- Downconverters
- Track Receivers
- Diversity Combiners
- Bit Synchronizers
- Decommutators
- Data Recording
- Network Telemetry
- Data Simulation
- RF Telemetry Test Transmitters
- Data Retransmission Systems



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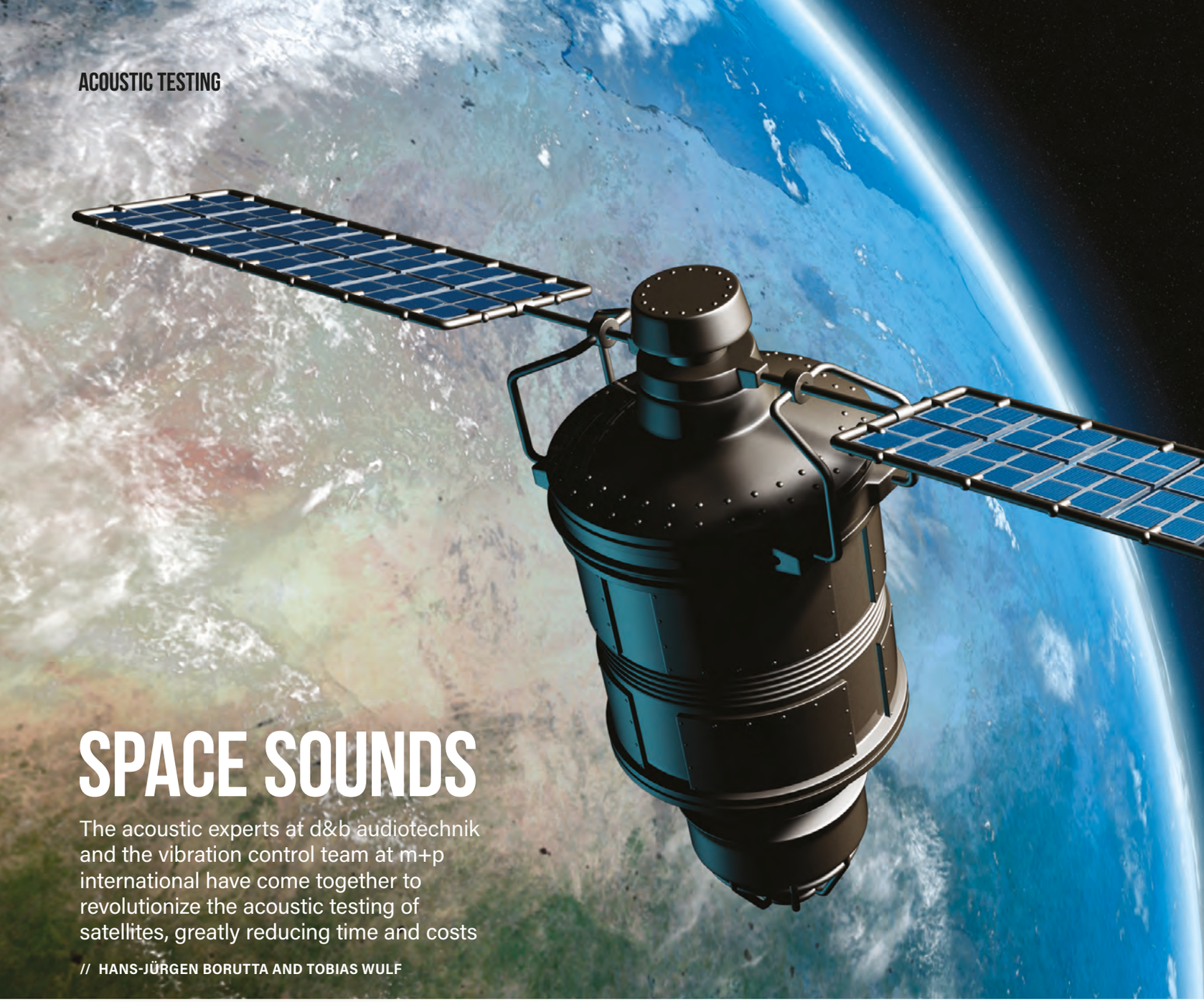


SPACE SOUNDS

The acoustic experts at d&b audiotechnik and the vibration control team at m+p international have come together to revolutionize the acoustic testing of satellites, greatly reducing time and costs

// HANS-JÜRGEN BORUTTA AND TOBIAS WULF

When satellites are launched into space they are subjected to very high mechanical, thermal, electromagnetic and acoustic forces that may cause damage to electronic circuits, as well as to other components, thus jeopardizing their functioning. Satellites therefore undergo extensive stress tests before any space mission starts. To test their acoustic durability, satellites are often placed in a reverberant acoustic test facility (RATF), where they are subjected to extremely high sound pressure levels – the sound intensity and frequency range applied in this 'torture chamber' simulate real-world launch conditions.

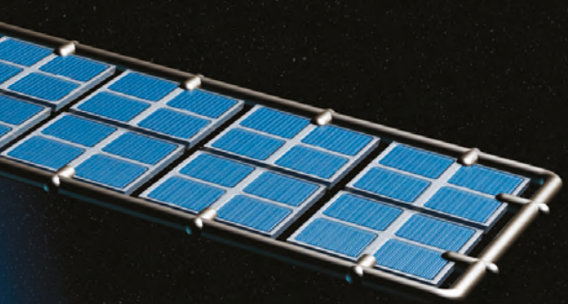
As this testing procedure is complex and very cost intensive, experts have for many years investigated alternative technologies that could produce similarly meaningful results with reduced efforts. Hence d&b audiotechnik, based in Backnang (near Stuttgart, Germany) and m+p international Mess- und Rechnertechnik, headquartered in Hannover, Germany, have decided to combine their unique expertise to present their Direct Field Acoustic Control System (DF-ACS) as an attractive alternative.

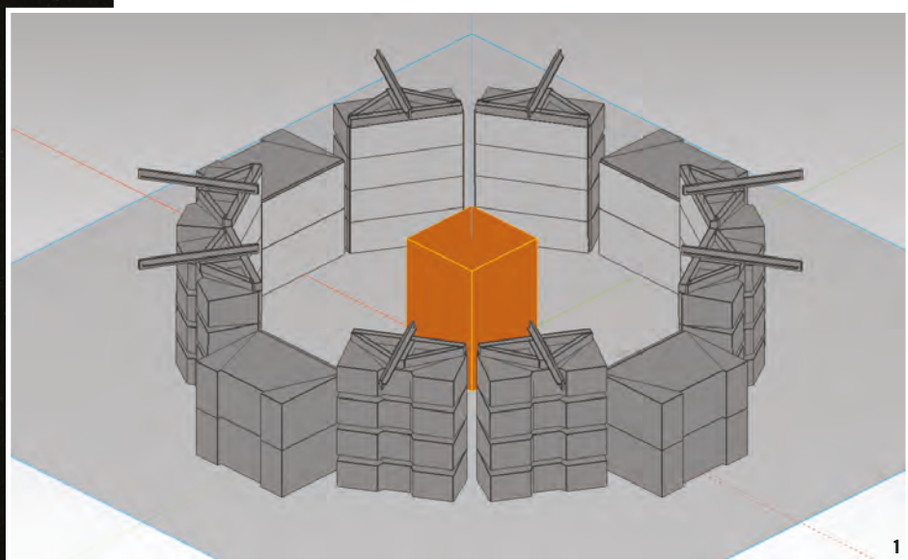
d&b audiotechnik's responsibility in this partnership includes loudspeakers, amplifiers and simulation software. The renowned manufacturer has decided to use its most powerful loudspeakers to meet the challenging requirements. The GSL8 array module is part of the SL series of loudspeakers. Its high Q factor offers a clear benefit for satellite testing: the high rear attenuation helps to avoid any unnecessary excitation of the environment.

"A challenge with satellite testing is to ensure the required homogeneity of the sound field," d&b application support specialist Boris Rehders explains. "In the area around the test object, the field must be absolutely homogeneous even at extremely high levels. We need to reproduce frequencies in the range 18Hz to 12.8kHz – which means the bass area is extended far into the low range."

The d&b SL series also includes powerful subwoofers. As many as three loudspeakers per module emit sound to the front (2 x 21in) and rear (1 x 21in), resulting in a kidney-shaped radiation pattern.

Various aspects need to be considered to reproduce low frequencies with the required sound levels – excessive load would cause the moving coil to hit and damage the magnet. Also, the applied current needs to be monitored and limited if necessary as the moving coil could otherwise overheat and the copper wire might melt. The relevant parameters are monitored by the amplifiers, which are part of the d&b system and controlled if it is required.





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"THE SATELLITE IS SUBJECTED TO A 146DB SOUND PRESSURE FIELD"

1 // The loudspeakers are arranged in a circle around the test object to create a sound pressure field

TEST SETUP

Described by terms like 'loudspeaker-based direct field' or 'direct field acoustic excitation', the test setup is based on d&b loudspeakers that are circularly positioned around the device to be tested. The distance between the loudspeakers, the control microphones and the satellite is critical to achieve the required homogeneous sound pressure level. The test setups so far implemented by d&b and m+p international include 8 x 4 GSL8 plus 4 x 2 modified SL-SUB while 20 d&b D80 four-channel amplifiers are used to drive the output.

The test period during which the satellite is subjected to the 146dB sound pressure field is in most cases only one minute – an additional build-up time of one or two minutes is necessary for the system. The entire test preparation and setup may require a few days.

The test setup is simulated in advance by means of software. "The device to be tested is less than 4m [13ft] (near field) from the loudspeakers, so it does not make sense to use simulation programs, which only calculate valid results for the far field," explains Rehders. "We are therefore constantly adapting the software to optimize the simulation processes for this special task."

NATURAL PARTNER

m+p international Mess- und Rechnertechnik has decades of vital experience in the field of measurement and control technology, developing and manufacturing test and measurement systems for vibration testing, vibration analysis, data acquisition, process monitoring and test stand automation.

Products manufactured by m+p international meet the most sophisticated standards in terms of quality and reliability. The company's quality management system has been certified according to ISO 9001:2015; and it has a global coverage with subsidiaries in the USA, UK, France and China, plus representatives in another 30 countries. With its measurements systems, m+p international is considered the market leader for reverberant chamber excitation – large test rooms with high reflection characteristics that are designed for special measurement purposes.

The proven m+p VibRunner measurement hardware platform is used for satellite testing as it is an ideal tool for dynamic measurements and vibration tests where precise and efficient testing is a top priority. Each m+p VibRunner mainframe accommodates up to 24 input channels with A/D converters (24bit resolution, up to 204.8kHz sample rate). Several m+p VibRunner mainframes can be daisy-chained to implement higher channel counts. An Ethernet interface is used for communication with the controller PC.

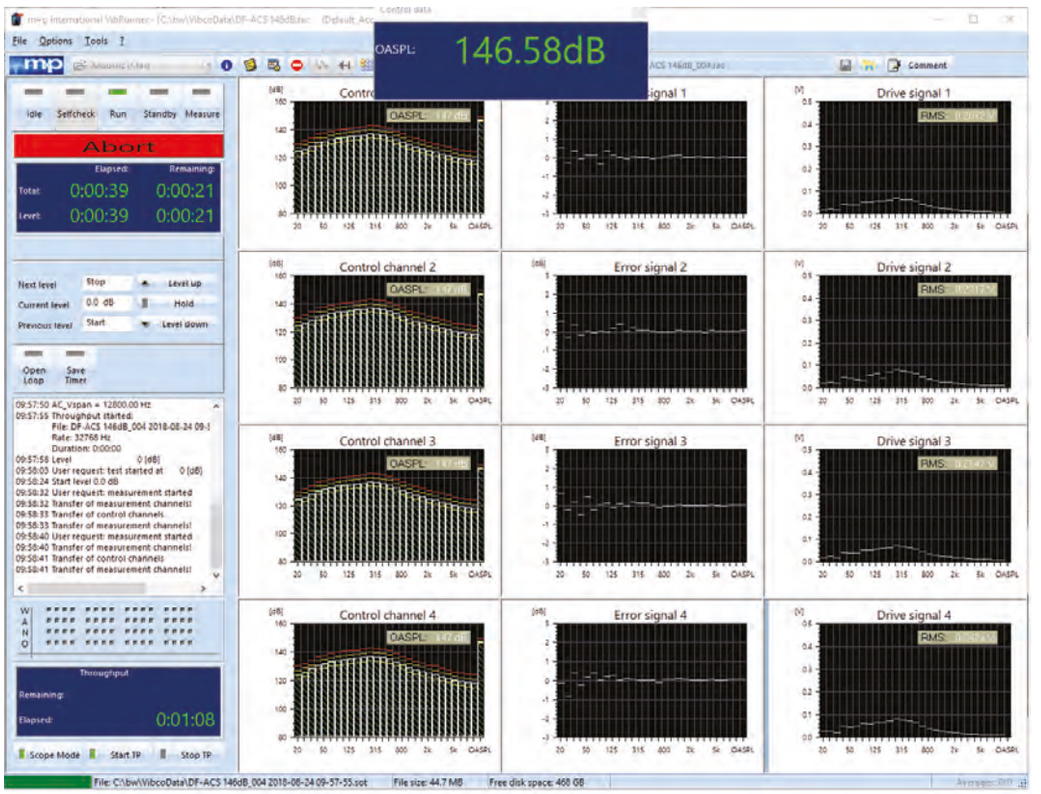
A number of incoherent closed loops are typical for this application: "The system is excited, measurements are taken, and the 1/3-octave bands are optimized while the overall level gradually increases," explains m+p international's team leader and senior development engineer, Raf Mangelschots.

"We need to make sure that all levels are correct – typically with a maximum deviation of 1dB per 1/3-octave band and 0.5dB for the overall sound pressure level."

The m+p VibRunner hardware is operated in combination with an updated version of the standard Acoustic Control System (ACS) software developed by m+p international. This software controls the complete test procedure and logs all steps of the process. Broadband random signals are used as excitation signals, with ANSI S1.11 certified octave or 1/3-octave time domain measurements used for control and analysis. This combination of m+p hardware and software, used with products supplied by d&b audiotechnik, is referred to as DF-ACS (Direct Field Acoustic Control System).

REVERBERANT CHAMBER VERSUS LOUDSPEAKER-BASED DIRECT FIELD

The installation of reverberant chambers specially designed for satellite testing is



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"AN INTELLIGENT TEST SETUP MAKES TESTING INDEPENDENT OF ROOM"

2 // m+p international's software controls the complete test procedure

very expensive and has high recurring operational costs. As a result, only a few such facilities are available on a global scale. Electro-pneumatic, high-intensity horns are typically used for sound generation, operated with either liquid nitrogen or compressed air.

The use of nitrogen is expensive and means personnel cannot enter the test chamber for a considerable time after the completion of the test. Also, the horns have a maximum output frequency of 400-500Hz. Higher frequencies are generated through harmonics – the characteristics of which can only be controlled by very complex strategies.

These dedicated test chambers are therefore following an approach different from the direct field concept promoted by d&b and m+p international. Working in reverberant chambers, the reverberant (diffuse) field dominates in almost any frequency range, as provided the distance to the limiting surfaces is sufficiently large, the impact of the direct field is no longer as crucial.

The homogeneity of the field is primarily achieved by means of diffuse sound. The reverberation times of 15 or more seconds are extremely long. Standing waves can also become a problem mainly because of the use of frequencies below the Schroeder frequency; a distinct modal behavior has in many cases been observed in chambers between low and medium frequencies.

In contrast to the above issue, the satellite under test is not in the reverberant (diffuse) field when using the d&b and m+p international approach. In contrast, the amount of direct sound produced clearly prevails here while reverberant sound is negligible.

"Given an intelligent test setup, we are rather independent of the individual room acoustics, provided that there is a sufficient distance to the walls," argues Rehders, who sees this as a major benefit of DF-ACS.

"We have managed to reliably generate a homogeneous sound field according to the required specifications, without using any narrowband measurements involving inevitable errors," adds Mangelschots.

NO MORE COSTLY SHIPPING

The satellite test scenario developed by d&b and m+p international does not require any specially prepared environment or test stand. Considering certain specifications, a multitude of different rooms will instead suffice to ensure significant results that are accepted by experts. Satellites no longer need to be shipped hundreds of miles, and the costs and risks involved with such transport (including not only the material itself, but also the engineers responsible) are no longer necessary. Also saved is the rental cost for such special facilities, which may even be operated by a direct competitor.

The d&b and m+p international teams have been cooperating successfully on this new satellite test approach for three years. The contact between these two German companies, each a market leader in its special field, was initially established via the m+p international office in Verona, New Jersey. For d&b audiotechnik, the global business unit, including Ralf Köhler, Tobias Wulf and Eva Argandoña, has been the driving force for this project.

Since the first joint tests were performed in Asheville, North Carolina, in October 2016, four test campaigns have been successfully completed in cooperation.

"By now we are fully aware of the loudspeaker configuration which is the most suitable for each project, and there are only a few minor issues that we are currently optimizing," Rehders concludes with some satisfaction.

"There has been a steep learning curve over the past three years, and we have been able to exhaustively answer all questions in our test campaigns."

Mangelschots also sounds an optimistic note: "We have already sent out the first quotations. Our system is available, consistent and provides reliable results faster, better and more cost efficiently than other solutions.

"The countdown has started. We are ready with our DF-ACS!" \\

Hans-Jürgen Borutta is chief development engineer for vibration control and signal analysis with m+p international Mess- und Rechnertechnik; Tobias Wulf is global account manager with d&b audiotechnik

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DIGITAL ADVANTAGE

A software solution for NDT radiography has been developed that improves quality and the efficiency of image interpretation

// BENOÎT RODRIGUES AND CÉDRIC BERTRAND

More digital radiography systems are emerging in the aerospace industry. These systems supply x-ray images in digital format, most often to the DICONDE/DICOM standard formats, which enables them to be reworked to improve the ease and efficiency of indication detection in aeronautical parts. Meanwhile, the emergence of technologies such as additive manufacturing (AM) requires an increase in the quantity and speed of manufacturing quality controls.

The increase in non-destructive testing (NDT) required for this confronts certified operators with the challenge of processing larger volumes of data.

To respond to this increase, TESTIA has developed a software dedicated to the analysis and processing of digital radiography images – NDTkit RT.

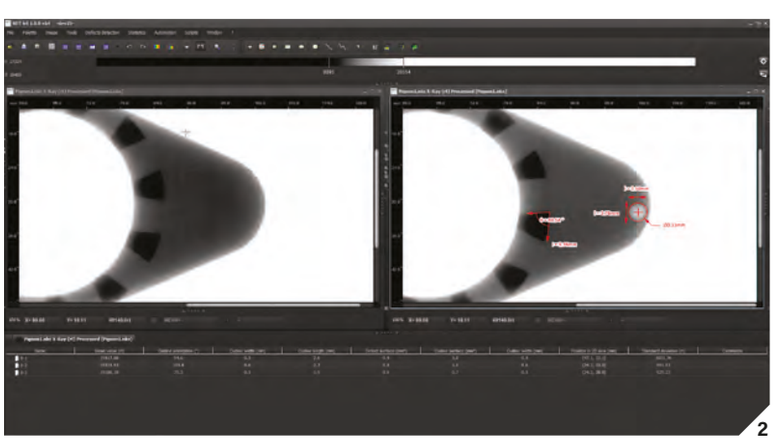
This software is a derivative from the Ultrasonic analysis software ULTIS. In 2019 the company plans to add more software to the system, which can analyze infrared thermography.

EASY COMPARISONS

NDTkit RT supports multiple image formats, including DICONDE and DICOM as well as TIFF, JPEG, BMP and PNG. The software features a set of classic tools to highlight indications with the mouse, such as image contrast and brightness variation, or optimize contrast in a region of interest.

1

To ease image comparison, the operator can display several images simultaneously and synchronize the mouse cursors as well as the zoom operation for both images. These functions make it possible to perform quick comparisons between a reference plate, and a part to be inspected, to detect any defects. Reference images can also be generated synthetically using a concatenation tool. This works by combining different pieces of the same part without defects, so an image of a perfect part without any flaws is formed.



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1 // Automation of spatial resolution check with a shot of an IQI

2 // Defect sizing and comparison with a reference image

This reference image can then be subtracted from another shot to be analyzed, to highlight potential flaws.

Defects can also be grouped according to rules defined by the user. For example, this function can be used to group porosity indications according to a set of geometric distance rules.

PROCESS AUTOMATION

To optimize production, repetitive tasks can be automated. This aims at relieving the operator from conducting redundant tasks and offers them optimal data for flaw research. Thanks to this automation tool, all the functionalities of NDTkit RT can be called sequentially and the analysis procedure can be launched without any intervention from the user.

Breakpoints can be added to let the operator validate a step. For instance, the automation can stop when a reference image is loaded and so that the user can perform a flaw revelation on the image to be analyzed. When the sequence ends, the software can automatically generate a report file containing all the results of the performed tasks, offering repeatability of analyses and standardizing output reports.

"THE SOFTWARE IS DEDICATED TO THE ANALYSIS OF DIGITAL RADIOGRAPHY IMAGES"

3 // DICOM database exploration

A typical sequence that NDTkit RT performs automatically is: opening, image scaling, loading a specific palette, adjusting brightness and contrast, loading a region of interest and automatic defect detection.

BENEFITS

NDTkit RT contains image processing algorithms capable of finding a resolution chart on an image as well as quickly qualifying the acquisition equipment. The software computes profile curves in the background to check the spatial resolution.

This algorithm is generic and is able to check many types of resolution charts, such as Duplex IQI.

Another benefit of the software and the use of the DICOM format is the ability to standardize a database architecture. This means that users can store their shots not in folders but in a database with a set of metadata. NDTkit RT is also able to interface with this type of database architecture. It offers the ability to search for more complex fields than the filename to recover images. For instance, a search can be performed to get all images with an ID beginning with a specific number.

CUSTOMIZATION

NDTkit RT works with plugins and is highly customizable. Users can add their own tools, algorithms and image filters to the software. An API is supplied with NDTkit RT that makes it easier to call its functions using Java or Jython source code. Using this functionality, users can create menus that will call their own tools, allowing them to benefit from the NDTkit RT environment and graphical interface while having to focus on the algorithmic part of their tools.

TESTIA also offers a development service, which can provide tailor-made tools or adapt the ergonomics of the software according to the needs of its users. The software is constantly improving and TESTIA aims at giving NDTkit RT more tools in the future, increasing its capabilities to automatically analyze digital radiography images and allow certified operators to focus on the diagnosis and final sanction. \\

Benoît Rodrigues is NDT engineer and Cédric Bertrand is NDTkit RT product manager at Testia

BEST IN TEST

Comprehensive and structured testing of electronically networked aircraft and cabin systems is necessary not just for economic reasons, but also increasingly in terms of meeting strict regulations

// ARNE BREHMER, HANS QUECKE AND NIROSHAN RAJADURAI

The software in avionics and ground-based systems is regulated by the standards DO-178C and DO-278, respectively. With failure being out of the question, significant analysis and effort is put into the verification and validation of these systems. In fact, industry-wide, in a typical project 50% of the development budget is used for testing software to FAA DO-178C Level A. The ability to automate and simulate these systems can greatly assist in reducing the overall effort, and hence implementation costs.

There are three major phases of verification and validation in avionics and ground-based software (Figure 2). They are unit testing, integration testing and system/functional testing. In each phase, test cases need to be derived from their appropriate level of requirements with full traceability between both.

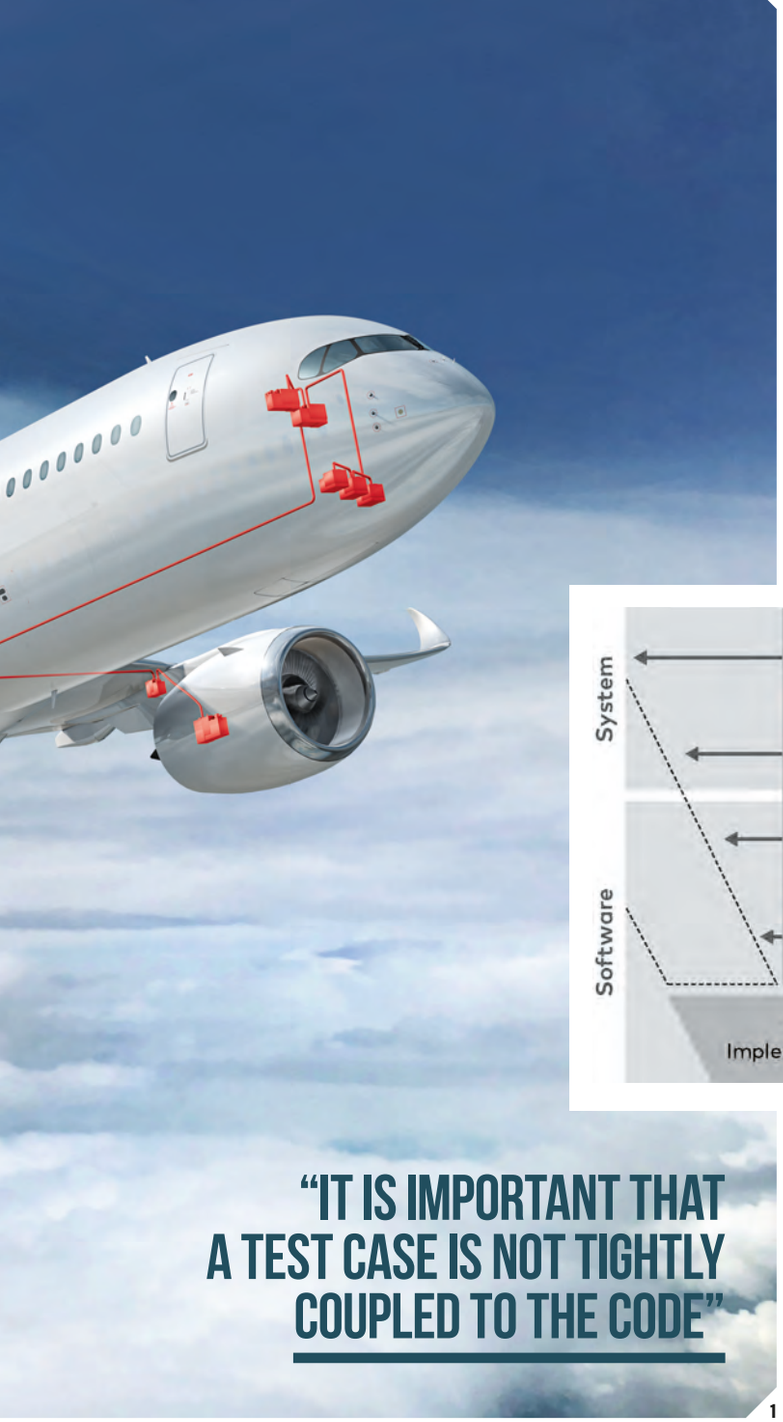
Low-level testing is used to test low-level requirements and is usually accomplished with a series of unit tests that allow the isolation of a single unit of source code. While the concepts and methodologies for this type of testing have been reasonably consistent over the years, the introduction of more networked systems based on the AFDX (Avionics Full-Duplex Switched Ethernet) protocol, and the drive for code reuse, demand innovations in the approach to testing software. Finding good solutions means looking at other industries that have successfully deployed complex networked systems, with rapid time to market demands and highly critical functionality. One such example is the automotive market, with its drive-by-wire systems, autonomous vehicle technology, 18- to 24-month development cycle and CAN/Ethernet networked platforms.

1 // Interlinked software running different parts of an aircraft must meet the DO-178C and DO-278 regulated standards

The similarities in these systems make it possible to transfer proven concepts and processes from the automotive industry into the avionics domain. The approaches can be considered at three levels, as described in Section 6.4.3 of DO-178C: low level testing, software integration testing and hardware/software integration testing. Finally, it is worth considering how these can be coupled into a process that provides greater agility and introduces shift-left strategies into the development process, which broadly means to test earlier.

LOW-LEVEL TESTING

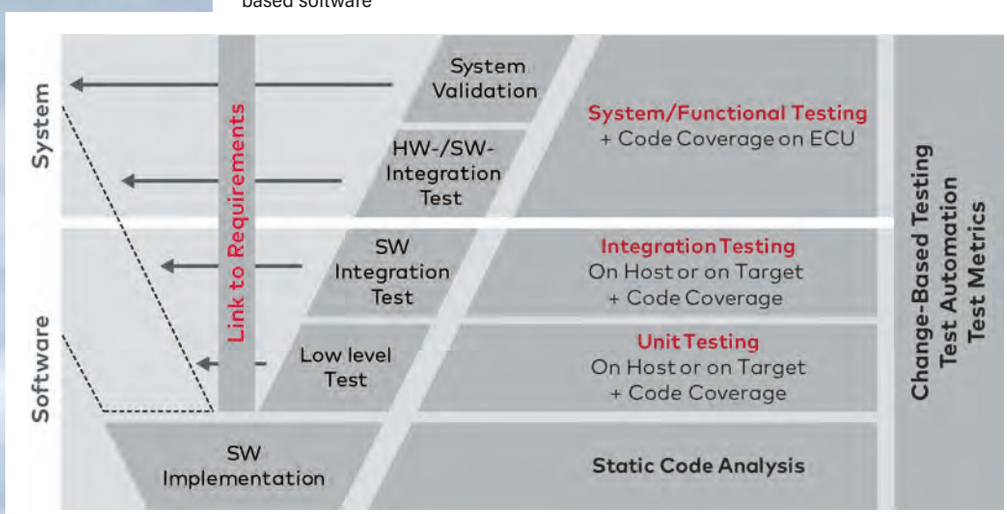
To test a single unit in isolation, a huge amount of framework code such as test drivers and stubs for dependencies (Figure 3) must be generated. Ideally this should be done automatically with a tool that offers an intuitive and simple approach for



“IT IS IMPORTANT THAT A TEST CASE IS NOT TIGHTLY COUPLED TO THE CODE”

1

2 // The major phases of verification and validation in avionics and ground-based software



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defining test scenarios. This meets the main requirements of Section 6.4.2, Requirements-based Test Selection, and the subsections Normal Range Test Cases and Robustness Test Cases of DO-178C. With the growing need for code reuse, it is very likely that a certain section of source code will be used in several configurations. Therefore it is important that the definition of a test case is not tightly coupled to the code and provides flexibility in how the code can be maintained as the software evolves. Typically the use of a data-driven interface for the definition of test cases is more maintainable over time than a source code definition.

This approach also means that when the source code and associated test cases are deployed in a continuous delivery workflow, as changes are made to the code the testing framework can quickly be regenerated and the test cases appropriately remapped. Where significant changes have been made, they can be flagged for further review without breaking the rest of the workflow.

A good example of this is the Unit Test Automation tool VectorCAST. The tool fully supports testing on targets or using the target simulator normally provided by the compiler vendor. Structural coverage from testing isolated components can be combined with the coverage gathered during full integration testing to present an aggregated view of coverage metrics.

VectorCAST test cases are maintained independently of the source code for a data-driven test approach. This technique allows tests to be run on host, simulator or directly on the embedded target in a completely automated fashion.

SOFTWARE INTEGRATION TESTING

This concept verifies the interrelationship of components and is also known as software-in-the-loop (SIL) testing. The aim is to bring the software components together and test them without any of the complexities of the underlying hardware. A critical aspect of testing software during this phase is the ability to simulate dependencies and interfaces in the integrated unit under test.

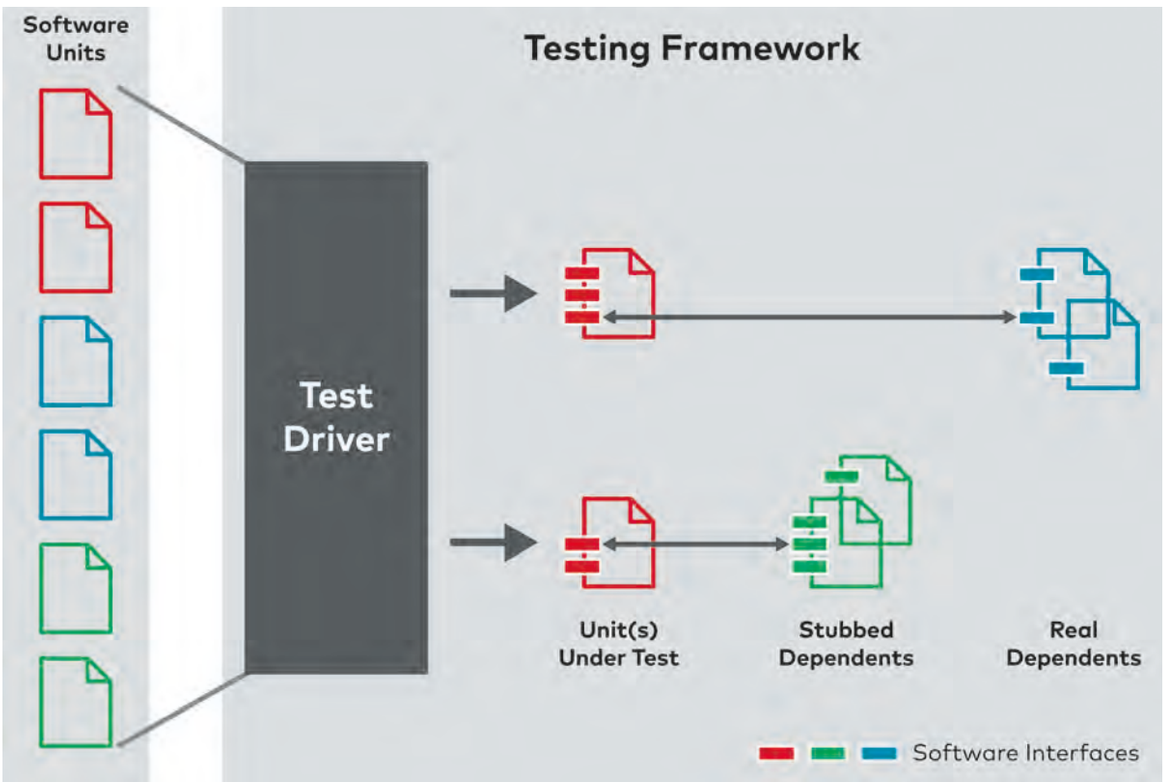
To simulate this software conveniently, it is common to use a host-based compiler like Visual Studio, GCC or MinGW to run the code, and once a level of confidence has been achieved the cross-compiler can be used. Depending on the certification level for DO-178C (Level A, B or C), certification credit for the activity may only be permissible when done using the cross-compiler and running on the target.

In the low-level testing framework, the software units can still only be tested via programming API calls. In this case a test automation framework like VectorCAST is ideal, as it will automatically build the required drivers and stub any units that are outside the units of interest. There could also be an opportunity to reuse some of the test cases from low-level testing for units that are higher in the call tree.

Alternatively the software components to be tested may be closely reliant on the underlying hardware, and a more robust simulation of the hardware is required to correctly verify the software functionality.

HARDWARE/SOFTWARE INTEGRATION TESTING

This is performed on the target hardware using the complete executable image to satisfy high-level requirements. The challenge when testing at this level is to



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3 // Low-level testing framework to test a single software unit in isolation – using framework code such as test drivers and stubs for dependencies

"A CRITICAL ASPECT OF TESTING SOFTWARE DURING THIS PHASE IS THE ABILITY TO SIMULATE DEPENDENCIES"

provide enough external stimulation to the line replaceable unit (LRU), so that it functions correctly. The external simulation comes in various forms – logical pins, avionics data network and modeling tools. Additionally, because of the complex nature of the networks, it should also be possible to easily extend or customize the simulation interfaces quickly and easily.

An example system to validate an LRU at this level can be set up using the VT System and CANoe tools from Vector (Figure 4). The software and hardware combination offers a test system that can be scaled from simple test equipment at the developer's workstation to a highly automated hardware-in-the-loop (HIL) environment. The core idea of the VT System is to combine all the hardware functions required for LRU testing in a modular system seamlessly integrated into CANoe. The test hardware covers the inputs and outputs, including the power supply and network connections of a control unit or subsystem. At each pin, changing the function according to stimulation, measurement, load simulation, fault connection and switching between simulation and original sensors and actuators is possible. These functions are universally designed to such a degree that, once constructed, a test system can be used for different LRUs.

In CANoe, in addition to the network environment, the physical environment can also be simulated using appropriate MATLAB/Simulink models. A closed HIL simulation is just as possible as a simple, manual stimulation without elaborate models. CANoe offers the same flexibility in test automation, while vTESTstudio provides a modern authoring tool. Tests can be defined in different programming languages like Vector's own CAPL and .NET/C#. Furthermore, test procedures can be described in tabular form or graphically noted test models. It is used to define test procedures and enables the developer to flexibly combine the different input methods. The finished test sequences are stored as test units and then executed in CANoe.

CANoe executes the test cases and at the end of each test run the system creates a detailed test report. Finally, all threads, from test and execution planning to execution documentation, converge in test data management. This ensures the traceability of tested requirements.

ENABLING A LEAN CONTINUOUS INTEGRATION PIPELINE

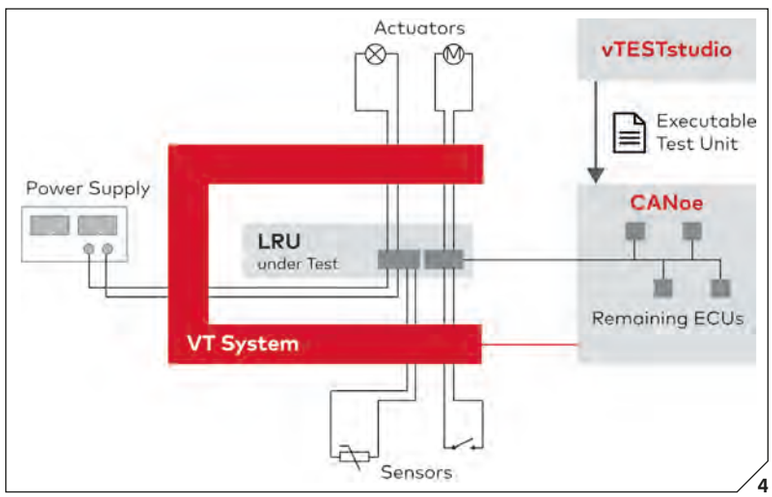
One of the biggest challenges with software development is the unintended propagation of defects or issues through the development cycle of a system. These issues can often be identified very early but are sometimes missed because the software is merged without the adequate

verification and validation. To address this quality issue, there are various discussions on the topic of shift left. However, in general it can be very time consuming to rerun all low-level software integration and hardware/software integration tests. In some cases a complete end-to-end run of all test cases can take two months. This timeframe does not suit the rapid progress necessary to provide developers with early feedback on issues that they might have introduced when writing the software.

Change-based testing (CBT) can help address this. This method helps organizations test faster and smarter by analyzing each code change against all existing test cases and choosing the subset of tests that are affected by the change (Figure 5). By running only this subset of tests, execution times are greatly reduced and developers get immediate feedback on the impact of their changes. This allows bugs to be fixed as soon as they are introduced, rather than weeks later during full testing.

By using a test automation platform like VectorCAST, structural code coverage is collected from all levels of testing, including low level, software integration and hardware/software integration. The ability to merge code coverage reporting with software integration and hardware/software integration tools such as CANoe and VT System provides a single perspective of the system's aggregated code coverage, and how a specific test contributed to the overall code coverage.

Thus, when a change is made to the underlying software, the VectorCAST decision engine quickly computes the impacted tests at all levels and dispatches them appropriately – even when the test is to be run through CANoe or VT System. Running a subset of tests represents a substantial saving in execution time and shortens to a matter of hours, and with a high level of confidence, the time taken to determine the impact of a change.



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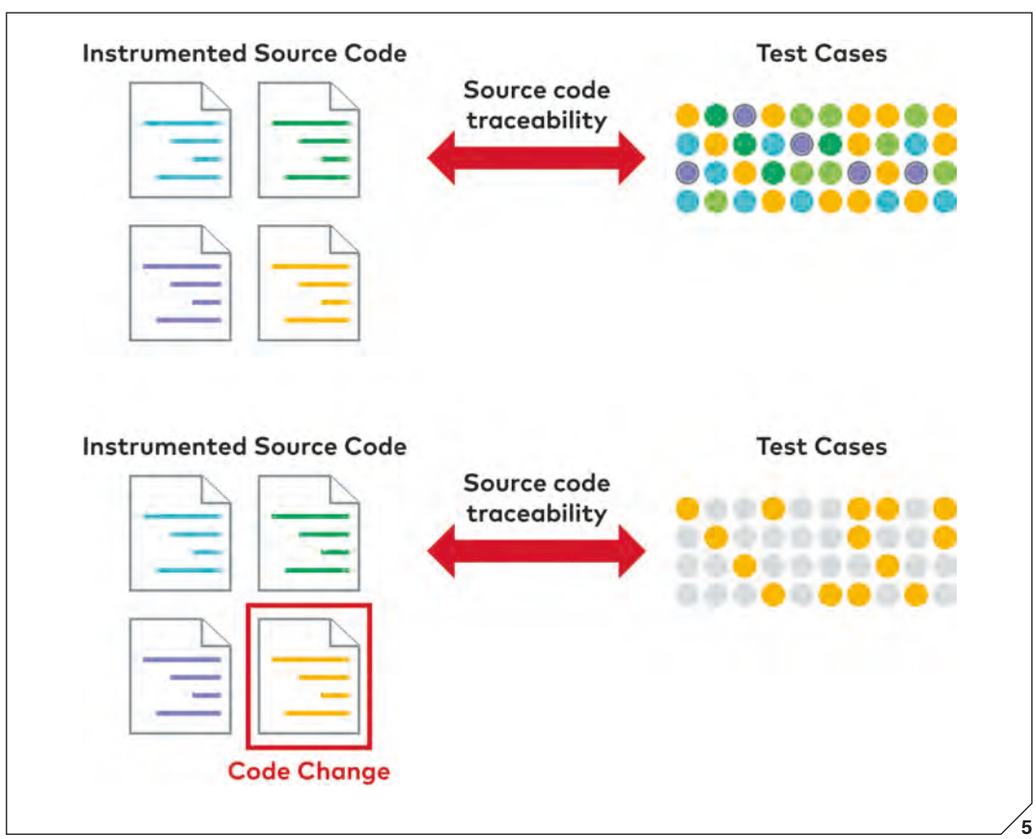

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TACKLING TEST COMPLEXITY USING VECTOR TOOLS IN ALL TEST PHASES

As the complexities of avionics and ground-based systems continue to evolve, the need to provide more sophisticated strategies and tooling to address the compliance required for verification and validation for DO-178C and DO-278 will continue to grow. The networked aircraft will require the ability not only to ensure that a single LRU functions correctly, but also that they all function correctly when the entire system is brought together.

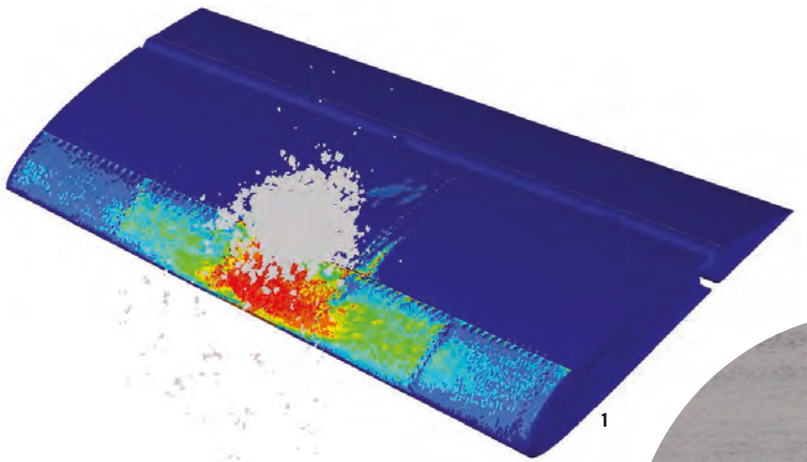
This means that the ability to isolate components at a software unit level, as well as an LRU level while simulating the remaining interfaces, will be critical to achieving the quality requirements of the avionics industry.

Furthermore, the artifacts from verification and validation can be introduced into a continuous integration process to introduce modern shift-left concepts into the development of safety critical systems while ensuring compliance with the standards. \\

Dr Arne Brehmer is head of the aerospace business area; Hans Quecke is team leader and product manager for networking and communication design and production; and Niroshan Rajadurai is EMEA director at Vector Informatik

4 // Example setup to simulate the environment around an LRU

5 // Change-based testing greatly reduces testing time while ensuring completeness



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VIRTUAL TESTING OF BIRD STRIKES

Studies show that improved simulations of this relatively common hazard can save aircraft manufacturers time and money

// DARIO MENDOLICCHIO AND JEAN-MICHEL TERRIER

Around 13,000 bird strikes were reported across 662 airports in the USA in 2016. After the engine, the wing is the next most common area to be damaged. The fuselage belly fairing can be damaged by bird strikes as well as from debris kicked up from runways.

Impact damage from bird strikes ranges in seriousness, through scratches, dents, deformed surfaces that affect aerodynamics and handling, punctures in wing skins that allow environmental ingress, to compromised structural integrity. Bird strikes cannot be prevented, which means that the damage-tolerance and fatigue of an aerostructure after a bird strike must be investigated by engineers, and is part of the certification process.

COMPOSITE AEROSTRUCTURES

The aerospace industry has long recognized the potential for lightweighting with composites. However, composite behavior under impact is complex and often occurs subsurface. Impact damage is not easy to detect visually and its progression is difficult to measure.

Market pressures on manufacturers also mean that physical testing and iterations between designs need to be reduced to a minimum. Bird strike testing, known colloquially as the chicken gun, is key to demonstrating damage tolerance. It is an expensive test suitable only for completed structures. Reliable simulation for highly complex impact events, like bird strike and ditching, can play an important role in reducing the number of chicken gun tests and shortening the product design cycle.

SIMULATION TOOLS

Multiscale technology aims to increase accuracy and simulate the heterogeneous materials that are used in finite-element solvers to simulate impact, mechanical, structural, fluid and fluid-structure interaction phenomena. Within the Altair HyperWorks CAE technology platform, Multiscale Designer develops multiscale material models by capturing linear elastic, inelastic and ultimate failure material behavior at the constituent level, to produce consistent material properties that can be used in analyses at the ply level.

Altair has conducted two studies recently to improve the understanding of how bird strikes affect composite aerostructures and can provide efficiency improvements during aircraft testing.

1 // Multiscale damage prediction model at 6.2 seconds after impact

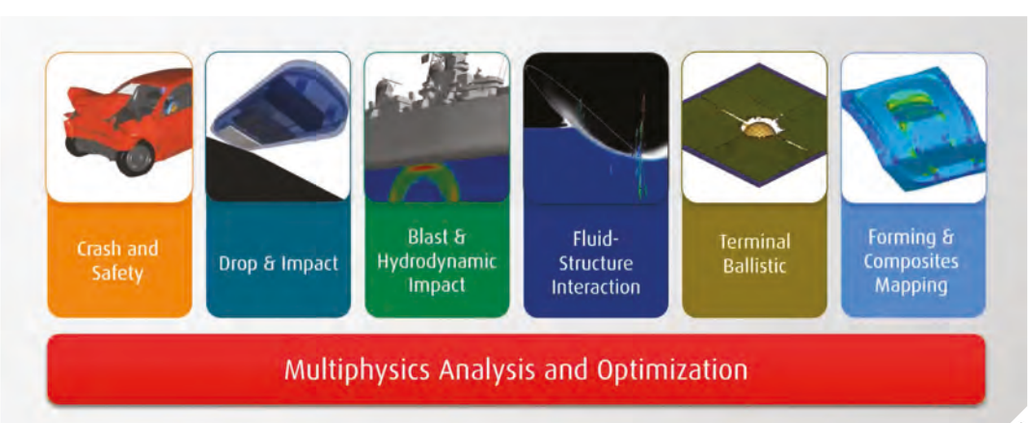
2 // Flight US Air 1549, which ditched in the Hudson river in January 2009 after a bird strike

3 // Applications of multiphysics simulation software

AIRCRAFT UNDERBELLY FAIRING

To understand how damage from a bird strike on a composite underbelly fairing affects the composite structure, multiscale technology was used in Altair Radioss.

The simulation used the Altair Radioss Smooth Particle Hydrodynamics (SPH) bird model, which has been validated against test data. Using an SPH approach avoided numerical problems associated with the



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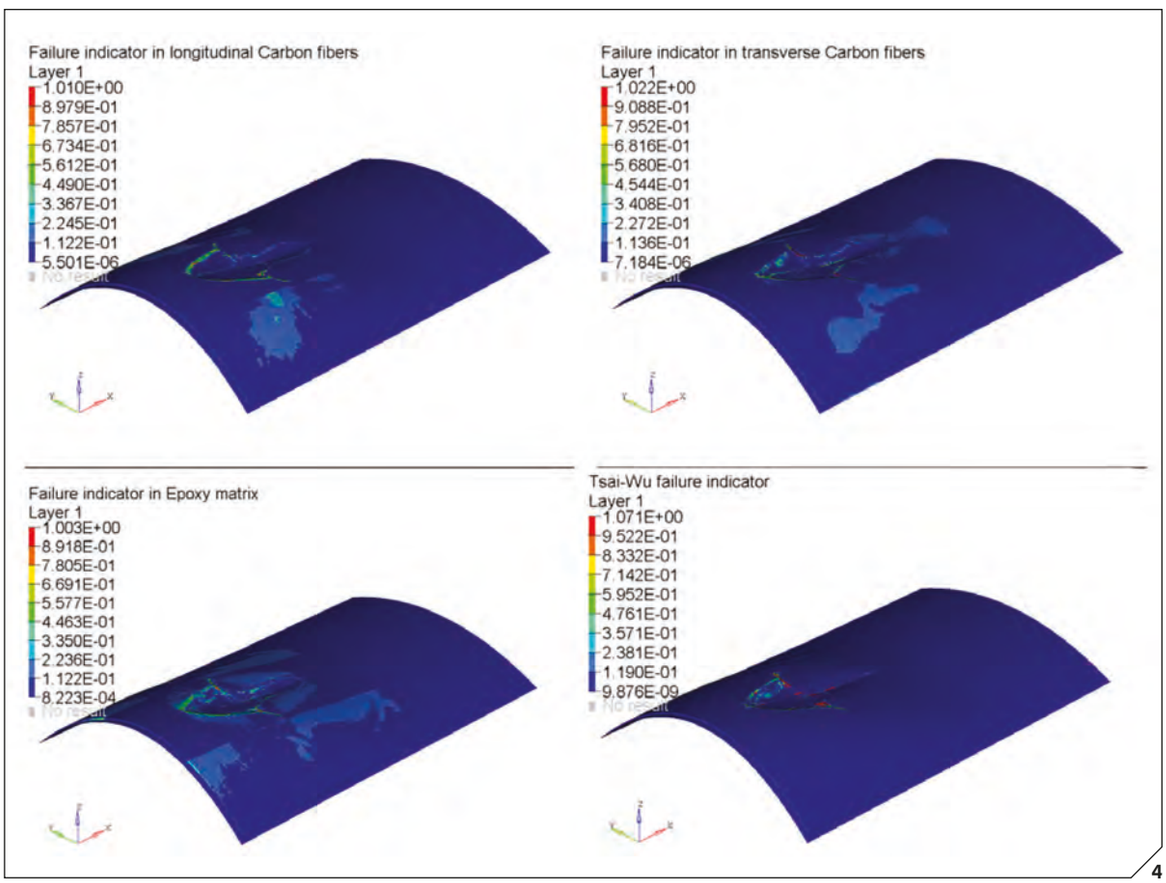

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4 // Simulation of a bird strike six seconds after impact using Altair Radioss, comparing the multiscale damage prediction and a macroscopic Tsai-Wu model. A value of less than 1 means the layer has failed and is shown in red

extensive deformation of mesh elements. The simulation was of a bird with a velocity of 180m/s and a 30° angle of attack impinging the fairing surface.

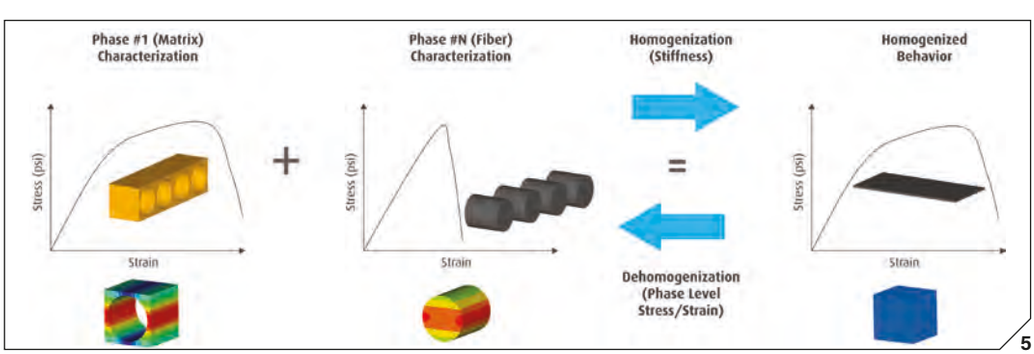
The simulation (Figure 4) showed damage at the micromechanical level, so it was important to resolve the results into fiber and matrix stresses and strains. When introducing failure criteria, the mechanism of microscopic failure could be modeled. Different failure indicators were introduced for the epoxy matrix and the carbon fibers. A better understanding of the failure mechanism was achieved as the failure indicators were reached.

A bird strike analysis on an aircraft wing was also done using Altair HyperWorks, as part of the Altair Aerospace Technology Demonstrator. The demonstration showed the interaction between the various solvers available to simulate and understand highly non-linear and dynamic loadings. Both examples demonstrate the importance of an accurate material model to attain good impact results. Being able to predict damage at the micromechanical level will lead to more accurate damage predictions, which should result in lighter structures. Also, being able to predict fiber versus matrix failure will lead to better insights into how to design robust yet lightweight structures.

Once validated, simulation tools can be used to virtually analyze a range of load cases, service conditions and scenarios. Validation is high-priority in aerospace programs, to meet the need for structural designs made from new materials of which engineers have little prior experience, and can be used during virtual structural development for quicker identification and right first time validation. Virtual testing is a route to faster, trouble-free design, and enables mature aircraft to enter service, reducing in-service bulletins or upgrades. An ambitious target is a new certification philosophy, based on virtual testing. \\

Dario Mendolicchio is business development manager and Jean-Michel Terrier is vice president global business development for Altair Radioss

"MULTISCALE TECHNOLOGY AIMS TO INCREASE MODELING ACCURACY"



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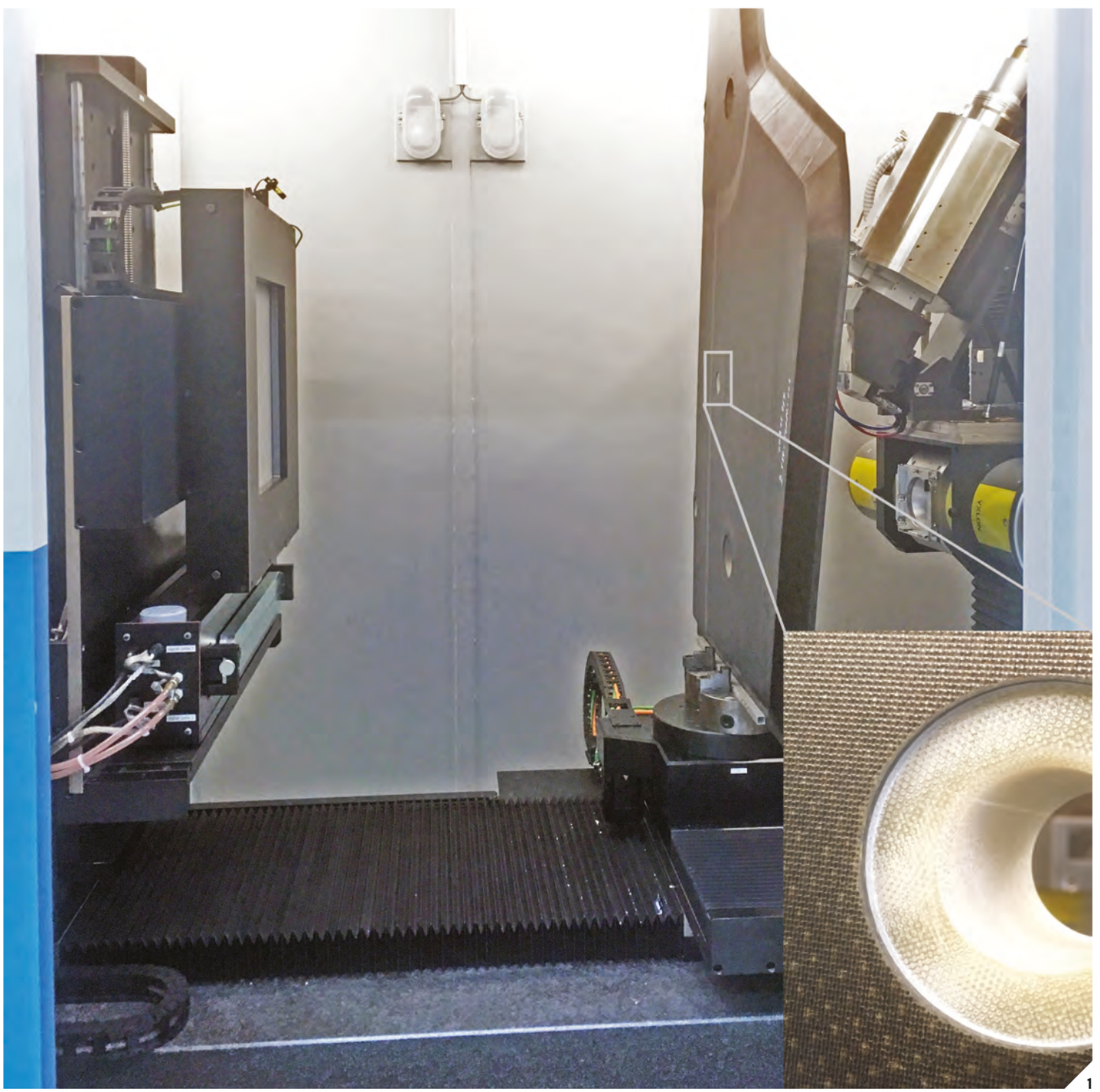
5 // Altair Multiscale Designer develops material models by capturing linear elastic, inelastic and failure material behavior at the constituent level

HIGH-RESOLUTION TESTING OF FLAT COMPONENTS

When testing large flat components, the use of digital laminography provides sharper images with less superimposition than digital radiography can

// ALEXANDER LESSMANN



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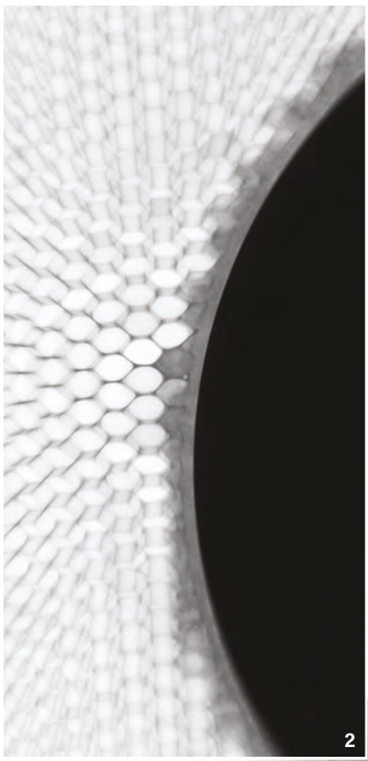


1 // The Yxlon CT system Y.CT Modular features a microfocus tube

2 // The details of the bonding are blurred in the digital radiography image

3 // The digital laminography image can identify where adhesive is missing

"USING DIGITAL LAMINOGRAPHY, THERE IS A MUCH SHARPER IMAGE"

When conducting digital radiography with digital flat-panel detectors, x-ray images are captured and displayed in real time on a monitor or stored digitally. However, the various irradiated layers of the test object are all superimposed in the transmission direction, which makes the interpretation of x-ray images rather difficult.

Computed tomography (CT) gets around this issue by rotating the test object and providing several hundred x-ray images from various angles. In the subsequent reconstruction process, a three-dimensional image of the test object is calculated by the computer.

The software used to visualize such a tomogram makes it possible to view virtually any cross-section at any position. The individual layers of the test object are displayed without overlay, similar to optical microsections.

But even CT reaches its limits when it is applied to flat test objects, which are commonly encountered in the aerospace and electronics industries. Either the test room is not large enough or the need for a higher image sharpness requires a microfocus x-ray tube and strong geometric magnification, which makes it necessary for the engineer to work close to the tube.

Both of these scenarios prevent the complete rotation of the component during the inspection process. One of several possible solutions is to rotate the test object at only a small angular interval, also known as limited-angle CT or swing laminography. An even better solution is to perform a complete laminography.

ROTATION OF THE TEST SUBJECT

When using digital laminography for the non-destructive testing of flat objects, there is no need to move the sample at all after the test room is set up. Instead, the x-ray tube and the digital flat-panel detector move in a circle around a pivot point which is located in the center of the test area.

The example illustrated in Figure 1 shows a 1.1 x 1.6m (3.6 x 5.2ft) aircraft component made of a honeycomb composite material with the test area lying at the edge of a circular opening.

The inspection system used for this test was the Yxlon CT system Y.CT Modular, with its microfocus tube. The 4.8x geometric magnification prevents the need to rotate the large component, which would otherwise collide with the x-ray tube. By performing a circular motion as described above, the microfocus tube and detector take tens of projection images and subsequently reconstructs each layer. This leads to a test result that is only slightly superimposed with a few other layers, but is still highly resolved laterally.

SHARPER IMAGES

The honeycomb structure is clearly visible in the digital radiography image (Figure 2). However, the finer details of the bonding along the transmission direction are blurred. Due to the oblique irradiation, the honeycombs are also only irradiated parallel in a small area and the surrounding area is distorted.

In contrast, with digital laminography (Figure 3) there is a distinctly sharper image and less layer superimposition. The information about the bonding edges and the porosity within the adhesive is considerably more recognizable.

The laminography presented here as a supplement to computed tomography is produced using expanded control and reconstruction software. If the test engineer decides it is necessary, a modular setup, like the Yxlon Y.CT Modular, also enables subsequent expansion of an existing CT system. During operation the user is then able to seamlessly switch between CT and digital laminography as needed. Yxlon thus not only provides a well-engineered solution for high-resolution testing of large and flat components, but also offers the user maximum flexibility for a wide variety of applications. \\

Dr Alexander Lessmann is senior application specialist, CT and Level III radiography at Yxlon International

1

MULTI-CAMERA APPLICATIONS FOR HIGH-SPEED IMAGING

The rigorous and exacting nature of aerospace testing requires the best high-speed imaging capabilities

// KENYA EBERSOLE

Cost effectiveness is a key factor in any testing scenario and having the proper tool for the job is critical to ensuring exceptional results. Aerospace testing situations are often one-shot events, with high dollar tags and lots of preparation. When high-speed imaging is included in a test it is important to make sure the camera will deliver the data needed. Vision Research's Phantom cameras range from the extremely small to the extremely high speed. They are easy to use, can synchronize, and can provide consistent data processing and analysis. Applications such as combustion analysis, engine analysis, non-contact vibration analysis and destructive testing all benefit from the broadest range of cameras available on the high-speed market.

COMBUSTION TESTING

Combustion happens very quickly and creates extremely bright light. Cameras with frame rates as high as 150,000fps and higher are often required to view the important details of combustion.

The best cameras for this situation are ones with 1MP sensors that can achieve high frame rates at lower resolutions. However, high frame rates produce large quantities of data, so it is important for testers to think about data management and workflow.

If the combustion testing is repeated many times in one testing session, researchers should consider a camera with large amounts of memory that can be partitioned. Data safety must be considered if there is a chance of power loss during recording. In these situations, nonvolatile memory is most suitable, because it not only protects the data but also allows the operator to conduct experiments in rapid succession. Data can be downloaded later when convenient.

1 // The Vision Research Phantom v1840 high speed camera offers high image quality at 18Gpx/sec

Combustion events are difficult to image properly because they typically have a bright white part in the image while the surrounding image may be dark. The extreme light differences that occur require cameras with a high dynamic range to help discern the details near the brightest parts of the image. Dynamic range is the camera's ability to register the various shades between black and white. The higher the dynamic range, the more shades a camera can register close to complete white or black, allowing important detail in the combustion event to be identified.

Additionally EDR (extreme dynamic range) is a common feature that stops pixels from oversaturating by resetting the exposure for individual pixels that are becoming exposed too quickly. EDR is useful in combustion events because it helps stop overexposure and a loss of detail

in the parts of the image that have the bright combustion, while maintaining exposure and detail in the darker regions of the image. Finally, a very low minimum exposure can reduce the bright light of a combustion event on an image. Many high-speed cameras have standard minimum exposures of 1µs, while some models can have a minimum exposure of just a few hundred nanoseconds.

The Phantom v2512 meets all of the common requirements found in combustion testing. Starting at 25,700fps at full resolution of 1280 x 800 up to 153,000fps at 256 x 352 and reaching up to 1,000,000fps at 256 x 32 with its fast option enabled. The camera also achieves a minimum exposure of 265ns.

ENGINE FUNCTIONALITY

Engine analysis, especially in the aerospace field, has its own special set of high-speed imaging considerations.

As with combustion, high frame rates can be necessary, but the working space can often be restricted by the size of the engine compartment. Compact and powerful 1MP cameras are ideal in this situation, where frame rates can reach sufficient speeds in tight spaces. The Phantom VEO 710 measures a small 5 x 5in (13 x 13cm) and is capable of reaching speeds of up to 200,000fps.

Light is a concern when analyzing engine functionality, especially when the study takes place inside engine compartments. Extremely high-speed applications require high levels of light. When adding light is not possible, other factors, such as pixel size and ISO rating, can be used to compensate. The ISO rating is a measurement used to classify camera light sensitivity. However, sensor performance characteristics are a trade-off between sensitivity, frame rate and image quality. Additionally camera manufacturers tend to measure their camera sensitivity differently. Put together this means that not all ISO ratings are considered equal.

One proxy for ISO measurements is the pixel size of a camera's sensor, because typically the larger a pixel, the more light sensitive it is. The best way to identify a camera with sufficient light sensitivity is to request demonstrations and compare images under identical situations.

The Phantom v2512 has the largest pixels available at 28µm, which makes it extremely light sensitive and a good choice for situations that are light restricted but not space restricted.

"AEROSPACE TESTING SITUATIONS ARE OFTEN-ONE SHOT EVENTS"

DIGITAL IMAGE CORRELATION

Non-contact vibration analysis is another type of aerospace testing that benefits from high-speed cameras. Researching vibration and deformation of rapidly spinning helicopter blades is difficult when traditional contact methods are being used.

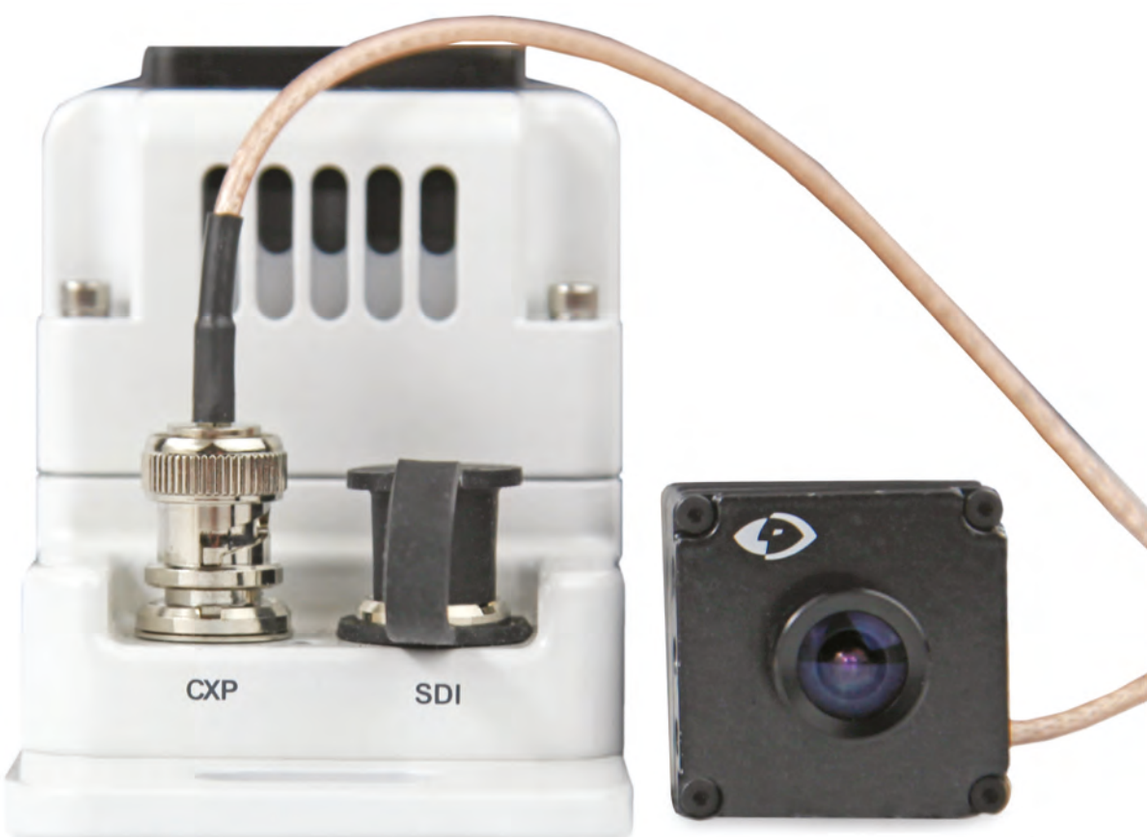
Sliprings are electrically noisy, the sensors provide only a single point of information, and they add weight that can affect measurements. High-speed cameras eliminate these concerns by incorporating an optical measurement technique called digital image correlation (DIC). DIC enables full-field analysis of a material's or structure's deformation, displacement and strain. To measure vibration in a rotating blade, for example, it uses a random pattern of speckles painted onto the blades.

High-speed cameras then track the changing position of the speckles as the blades rotate so that measurements can be taken without interference. When using multiple high-speed cameras at once, a 3D image can be created to enhance the analysis of contours and displacements.

"As high-speed camera technology continues to develop, it is not only allowing DIC techniques to be used in a wider array of applications, but also providing quality quantitative data that rivals or surpasses data provided by traditional methods," explains Nick Long, field applications engineer for Vision Research.

DIC provides very satisfactory results when multi-megapixel cameras such as 2MP or 4MP are used. A camera setup such as a pair of Miro 341 or VEO 640 cameras will provide high-resolution images at up to 1,400fps.

Phantom cameras use internal electronic global shutters, which is critical when studying the quickly spinning blades of a



2 // Vision Research's tiny Miro N camera has 128GB of flash memory and is suitable for use in destructive testing

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"WE HAVE SEEN A GOOD DEAL OF INTEREST IN AEROSPACE TESTING APPLICATIONS FOR CAMERAS THAT WE ORIGINALLY DESIGNED TO SERVE THE AUTOMOTIVE TEST INDUSTRY"

3 // Miro cameras were originally designed for automotive crash testing and meet the stringent requirements of aerospace applications

4 // Vision Research's high-speed cameras are used by the US military in demanding environments

helicopter. A global shutter exposes all the pixels at once. This means motion blur and bending of spinning objects does not occur, unlike when a rolling shutter is used. The Phantom v1840 and v2460 UHS series cameras are suitable for DIC because they can provide maximum image quality with higher speeds and a global shutter.

RUGGEDNESS

The final scenario in high-speed aerospace testing is when high-speed imaging must take place in situations that can be considered destructive or environmentally rugged. Such situations require cameras that are capable of withstanding tough testing and can protect sensitive data.

Cameras that are traditionally used in automotive crash testing can be applied to aerospace testing. There are a variety of features available on Phantom cameras that make them capable of functioning in situations where they are required to be mounted on or very near the equipment being analyzed.

While there are commercial options available and they may be cheaper than custom items, they are less than ideal solutions as they are not built to be durable and do not put data security high on the priority list.

"We have seen a good deal of interest in aerospace testing applications for cameras that we originally designed to serve the automotive test industry. Their size, environmental specifications, and data protection design provide real benefits to aerospace testing," says Doreen Clark, Vision Research product manager.

The Phantom Miro C Series is an example of a camera designed for automotive crash testing, with features that are beneficial to many environmentally demanding aerospace testing applications. The cameras are only 3in cubes, originally designed to fit into cars, but can also fit into pods or other tight spaces on aircraft. They are capable of withstanding extreme conditions: up to 170*g* shocks, 24G_{rms}, and temperatures from 0-50°C (32-122°F), while being extremely compact and providing 1,800fps at 1280 x 1024 resolution and up to more th 67,000fps at smaller resolutions.

Additionally, the camera is specifically designed to protect data and is equipped with an internal battery and 128GB of internal nonvolatile memory. All these measurements make the camera perfect for intense aerospace testing.

The Phantom N Series is another camera that was originally designed for even smaller spaces and destructive applications in the automotive crash test industry, and whose features are very beneficial to aerospace testing applications. The Phantom N Series camera is a 1in (2.5cm) cube that is built to excel in destructive environments. The key to this camera is that the head, where the sensor is held, is separate from the portion that stores captured data. Connected by 10ft (3m) or more of CXP cable, the head can be placed next to a destructive event while the data storage base is safely placed behind a wall or under a protective case.

When the destruction occurs, the Phantom Miro N5 will transfer everything up to the very moment of destruction to the secure base. The head of the camera is easy to replace and can be done so quickly in the field for minimal downtime between shots. Combining the use of the C and N series cameras enables close and distant imaging that can deliver a variety of information about an event.

High-speed cameras bring invaluable information to all phases of aerospace testing applications. Understanding and matching camera capabilities to specific application needs will maximize the benefits the technology offers. \\

Kenya Ebersole is marketing communications specialist with Vision Research

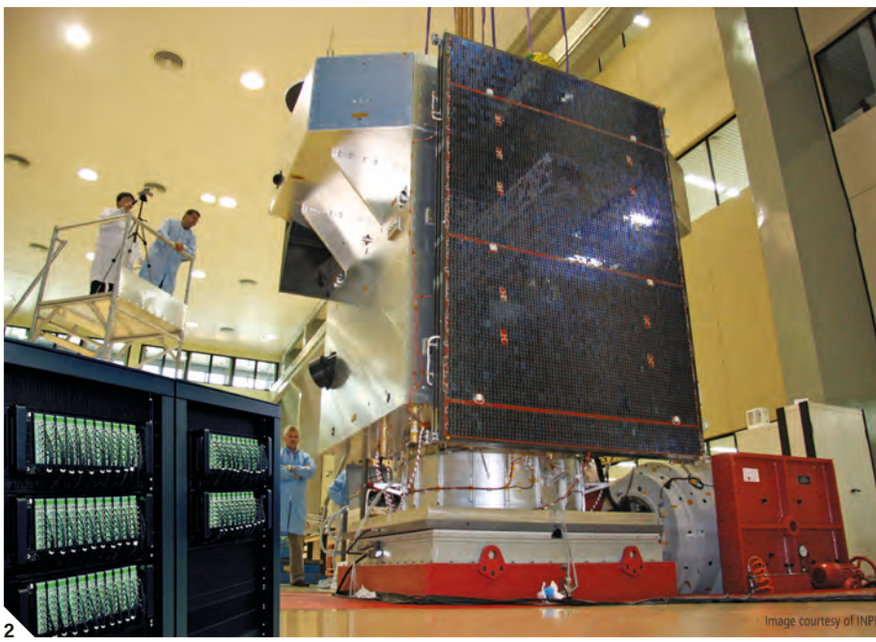
BRIDGING THE DIGITAL DIVIDE

Søren Holst, president of Brüel & Kjær, explains how the merger between his company and Hottinger Baldwin Messtechnik will help engineers meet the demands of a digital future

// BEN SAMPSON

1 //

"THE MERGER IS AN ASPIRATION FOR THE FUTURE"



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Sound and vibration instrumentation supplier Brüel & Kjær (B&K) announced in April 2018 that it was to merge with fellow Spectris Group company and strain and load gauge and instrumentation supplier Hottinger Baldwin Messtechnik (HBM). Søren Holst, who joined B&K in 2015, has headed up the transition management team for the merger, and will become the first president of the new company, which will be called HBK – Hottinger, Brüel & Kjær – in January 2019.

In this exclusive interview, he discusses his own background, what the merger means for the two leading companies' product ranges and what customers can expect from HBK in the future.

WHAT WAS YOUR FIRST JOB IN TEST AND MEASUREMENT?

It was for a medical technology company that made blood analyzers – it was precise and highly integrated technology. The manufacturing process involved craftsmen blowing glass electrodes and integrating them with mechanical and electronic components. After that, I worked for companies related to test and measurement in human hearing. Half of the world's hearing aids are made in what is called Acoustic Valley in Copenhagen. There are a lot of world-leading experts for acoustics in our region.

WHAT ARE YOUR RESPONSIBILITIES AS PRESIDENT OF B&K?

At the moment, it's about driving the changes that are going on with the company. I have to work with the employees, customers and suppliers, communicating strategy so they know the direction of the company.

My career background has given me the understanding of engineering needed to run a global technology company. This is a niche industry that is by its nature global. We have to be able to service customers 24/7 and listen to their feedback.

WHY IS THE MERGER WITH HBM HAPPENING?

Both companies do the same thing – just from slightly different angles. Our colleagues at HBM make instruments and sensors to measure physical force, strain and torque, whereas we specialize in sound and vibration. Both of our companies' products are used to measure and validate the physical parameters of a product throughout the product's lifespan.

One of the simplest reasons for the merger is for our customers, who increasingly want to consolidate to a single platform to measure the different physical parameters of a product.

Underlying this is the digital transition the world is going through. Engineers are developing more products at a faster pace and these products have more digital features. The amount of data involved in product development is exploding. Our customers need to validate designs more frequently. They want to use simulation tools more, so that they can be more effective at product development.

But there is a gap between physical test and measurement, and simulation. By combining forces, HBM and B&K can take a leap into the digital world and bridge that gap. The company will strive to become a global leader and will excel at providing insight and confidence through its digital products.

WILL B&K BE BACKING OUT OF THE SOUND AND VIBRATION MARKET?

No, on the contrary. Our technical center of excellence for sound and vibration is in Copenhagen and will remain there, where our employees and Acoustic Valley are.

The merger is an aspiration for the future. B&K and HBM have very strong foundations in sound and vibration measurement, and in torque and strain measurement. We want to strengthen the solution aspect through partnership. We are developing data acquisition software and hardware that will make data easier to handle and more open. Our customers will benefit from the improved transparency and structure of the data, which will fit into their work processes better. We believe that's where there are efficiency gains to be made.

HOW WILL THE MERGER AFFECT YOUR CUSTOMERS?

It's business as usual in 2019. The products and the branding are remaining the same, but over time will become more consolidated. Our aerospace customers will gradually see a more coherent product offering that will help them gain efficiency. The new company will have a very strong

1 // Søren Holst, president of Brüel & Kjær

2 // Satellite undergoing vibration testing with a Brüel & Kjær LDS shaker and LAN-XI data acquisition modules *(Photo: INPE)*

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3 // Noise source identification using BK Connect Acoustic Camera

4 // A simple pass-fail engine vibration system for helicopters using a Type 2250 handheld analyzer

5 // High-frequency head and torso simulator covers the full audible frequency range, up to 20kHz

portfolio of solutions that are relevant to aerospace companies, from sensors to analytical software.

We have been diligent in planning the merger. It's a big thing for our employees and customers. This is a growth strategy – there are no staff reductions planned. We are joining forces to develop a joint platform, which is where we can provide benefits for our customers.

DO YOU THINK THE TWO COMPANIES' CULTURES ARE COMPATIBLE?

We are merging two companies that have more than 60 years of history each, and we are finding that there are many similarities between us culturally. We are both technology-driven companies with roots in northern Europe with lots of experience built up over decades, founded by strong individuals in each case. We have the strongest collection of sound and vibration experts of any single company in the world; HBM has the same collection in its field.

WHAT FEATURES WILL BE IN NEXT YEAR'S PRODUCTS?

What we like about aerospace is that they are the most demanding customers.

"CUSTOMERS WANT TO CONSOLIDATE TO A SINGLE PLATFORM TO MEASURE THE DIFFERENT PHYSICAL PARAMETERS OF A PRODUCT"

Aircraft and satellites are expensive and have extremely high safety standards. They are very demanding in terms of technology and require demanding testing solutions. They require high-speed measurements that produce terabytes of data under difficult conditions. Our engineers like a challenge and this is a driver for innovation for us now and in the future.

For example, we are investing in a new platform that is based on years of working with our aerospace and defense customers. It has evolved from dedicated projects with large customers. We've taken the learnings and codified them into a software platform.

HOW IS SENSOR HARDWARE DEVELOPING?

The R&D for hardware never stops. In the future, data processing will move closer to the sensor. The technologies for sensing will evolve over time. We have just launched one of the most advanced sensors with a high frequency range, expanding it from 6kHz to 20kHz to mimic the human ear. It looks like a mannequin, but inside it sit two accurate replicas of the human ear, made by laser scanning many people's ears. A microphone that mimics the tympanic membrane sits inside each ear.

HAVE ENGINEERS ADOPTED DIGITAL WORKFLOWS EFFECTIVELY?

Our aim is to develop an open software platform and data formats that make things more efficient and effective for our customers. We have statements from large aerospace customers who say that more than half of their teams' working time is spent on data archaeology and IT issues. These are highly trained experts, scrambling around to find data that will match their processes. We are in a strong position to solve this problem, because within HBK we will have access to a company called HBM Prenscia that is a pure data analytics company. It will provide the expertise in this field that can be combined with the test and measurement competencies.

WHAT TRENDS DO YOU THINK WILL CHANGE TESTING IN THE FUTURE?

In my view, air traffic will continue to grow, and the environmental footprint of air travel will become more crucial to the industry. The airline industry will need to become more efficient. Also, air taxis are starting to happen. These aircraft will operate mostly in urban areas. I can see a lot of noise-related issues with that.

Our overall aspiration is to enable engineers to do great work. All engineers will be living and working in a digital world. We want to enable them to thrive and prosper in that digital world by giving them the tools they need to navigate and work in it effectively.

Today there are efficiency gains in test and measurement that are not being fully realized, because we are yet to fully embrace the digital tools and workflows of the future. The merger and our collaborative work are great steps toward realizing those efficiency gains. \\

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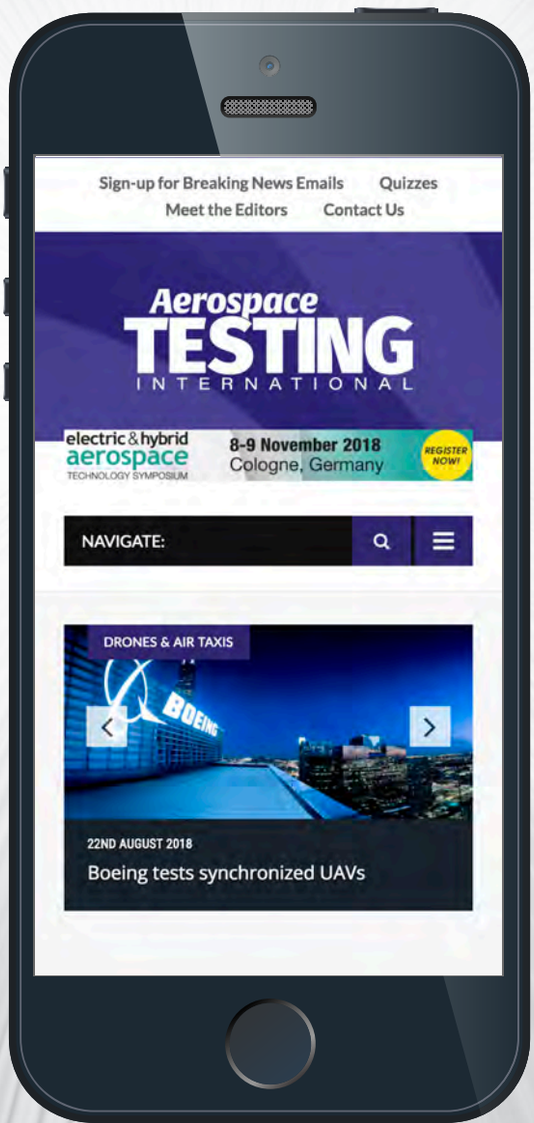

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SMOOTH OPERATOR

Jitter characterization during reaction wheel operation can help minimize the impact of vibration on satellites

// BILL ZWOLINSKI AND CHRISTOF SONDEREGGER

Reaction wheels are used for attitude control of satellites without the need to use thrusters and propellant, which is in limited supply. The operation of a reaction wheel uses an electrical motor to rotate a flywheel at various rotational speeds, causing the satellite to counter-rotate proportionately due to the conservation of angular momentum. This operation rotates the satellite around its center of mass but does not reposition the satellite, as can be done with a thruster.

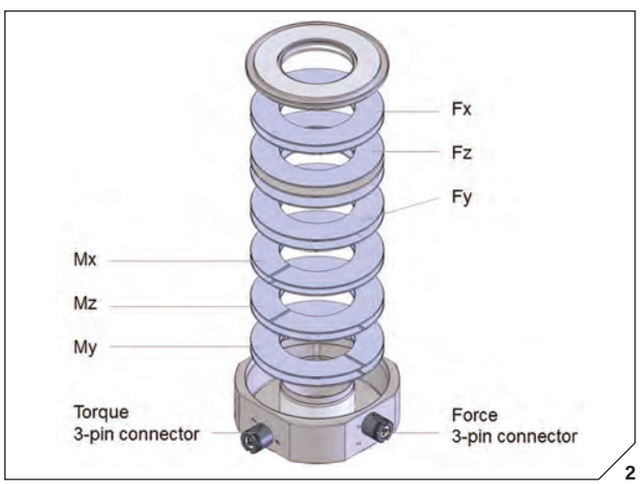
As the flywheels rotate there are small fluctuations, called jitter, that are directly coupled into the satellite and can affect mission operation. For example, if a satellite is imaging and pointing at a specific location, jitter can blur or distort the image.

A reaction wheel can also be operated as a momentum wheel, using near-constant rotational speed to influence a satellite's attitude by creating angular motion to stabilize the satellite's axis to point in a nearly fixed direction.

Characterizing the unwanted vibration or jitter during reaction wheel operation supports balancing operations to optimize unwanted disturbances. Balancing applies masses on parts of the wheel, which is essential to reduce residual forces and moments during operation. It is becoming increasingly common for satellite manufacturers to request jitter characterization.

Satellites with low mass and size, usually under 500kg are becoming more common because they are cheaper. Using many small satellites could be more useful than fewer larger ones in certain applications, such as scientific data collection and university research. Smaller sizes and a diversity of missions require a variety of reaction wheel sizes and performance. For small satellites, resolution of forces and moments lower than 5mN and 0.5mNm can be significant to the mission. Various rotational speeds can be used, resulting in the need to measure a range of vibrational orders and resonances.

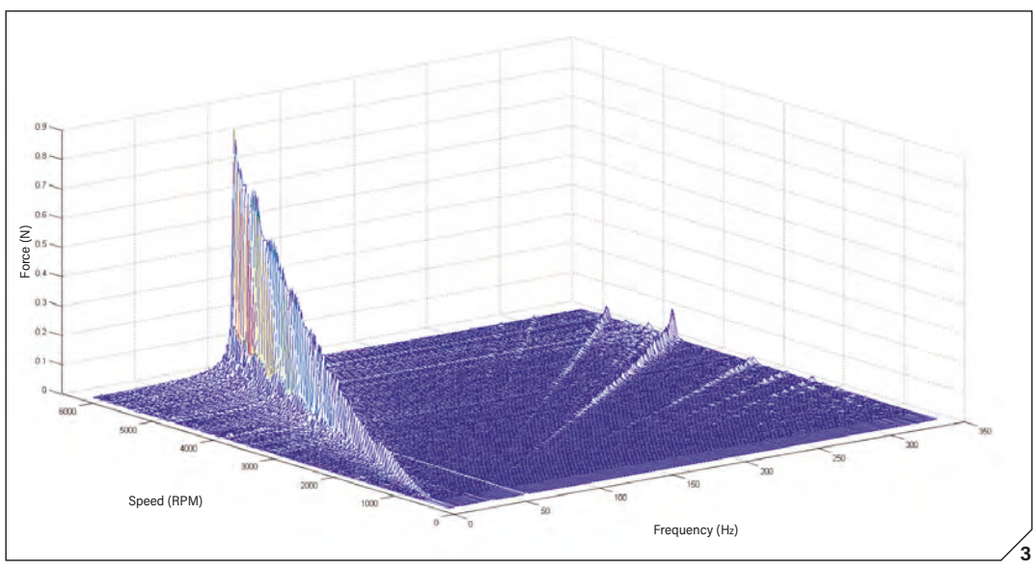
Recent years have seen advances in terrestrial observation accompanied by an increase in the need to measure Earth's surface and atmosphere with greater precision. For example, cameras on the latest Earth observation satellites feature resolution on the order of 0.5m. We can quickly get a perspective of commercial



1 // Small satellite reaction wheel jitter investigations using the 9306A six-component force sensor on a vibration isolation table

2 // Internal design of a piezoelectric six-component force sensor

"JITTER CHARACTERIZATION IS BEING REQUESTED BY MANUFACTURERS"



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3 // Waterfall plot showing the radial force output from a candidate reaction wheel plotted against speed versus frequency

image quality with Google Earth. The reduction of reaction wheel jitter contributes to the improvement in image quality.

PIEZOELECTRIC TECHNOLOGY

A six-component piezoelectric sensor, such as the Kistler 9306A, is ideally suited for jitter characterization of small reaction wheels. Such a solution provides very high measurement resolution as well as direct measurement forces and moments. This makes it possible to measure dynamic force changes greater 0.5mN, and moments changes greater than 0.02mNm, depending on the signal bandwidth and assuming optimal measuring configurations with optimal charge amplifier (type 5080A recommended). A static weight can be 'eliminated' by resetting the charge amplifier (similar to a tare function). This allows the measurement range to be based on the magnitude of the dynamic signals of interest while increasing the signal-to-noise ratio. Piezoelectric sensors deliver a rigid measurement platform, achieving very high natural frequencies of 6.9kHz in force and 6.3kHz once mounted.

The design uses six pairs of quartz discs cut in different orientations to measure the six components of interest. The resulting charge sensitivity is up to 7.3pC/N and moment sensitivity up to 255pC/Nm. The sensor output uses a laboratory grade, low-noise, quasi-static charge amplifier to deliver the high resolution previously mentioned.

The measuring chain for performing reaction wheel jitter investigations starts at the six-component sensor output. This is converted to a low-noise voltage by the charge amplifier. The voltage output is input to a six-channel DAQ with a noise level at least as good as the charge amplifier, to allow for the lowest possible measured signal.

Time domain, FFT and waterfall representations are usually of interest for such investigations and are correlated to the rotational speed of the wheel.

COMPONENT CALIBRATION

With mechanism testing and jitter characterization, it is of great importance to calibrate the measurement instrument accurately. The application demands the ability to resolve low-level measurements, where the effects of such jitter on the mechanism design and spacecraft system and subsystems makes it a critical success factor. The smaller the satellite, the smaller the jitter level under investigation, so accurate calibration is even more critical.

A hexapod six-component calibration system has been developed by Kistler (Figure 4). The advantage of this system is that it can automatically calibrate the 9306A for full-scale operational range in positive and negative directions. Parameters evaluated included sensitivity, linearity and cross-talk of the multicomponent sensor. As microvibration uses only a fraction of the measuring range, an additional partial range calibration for low full-scale forces and moments is performed on request, using a conventional hydraulic press with reference standards and fixtures.

LOW BACKGROUND NOISE

To measure low-level, high-resolution forces and moments, the test environment should be constructed to minimize environmental noise from sources such as airflow and seismic inputs. Typical considerations include a vibration isolation table with resonances outside the frequency of interest, such as is shown in Figures 1 and 5.

This will isolate the force sensor from external vibration from sources such as compressors, machinery, people walking and road traffic. In an area with high environmental induced vibration, testing should preferably be performed very early in the morning or at night when activity is low. Even airflow from an air-conditioning system can create unwanted input to the sensor and may require the use of a box over the test article. In short, an evaluation of the environment when taking low-level measurements will ensure that external influences are minimized to optimize measurement of the jitter. Electrical noise from the signal-conditioning system can sometimes be improved by using battery power instead of AC mains power. Some signal conditioners offer DC and AC input.

HIGH-FREQUENCY RESPONSE

A piezoelectric sensor can be modeled as a lightly damped second-order system. As

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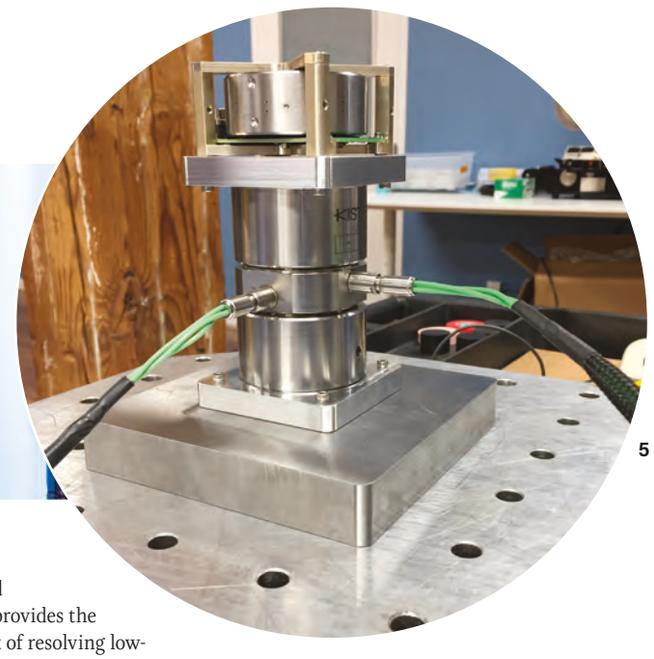

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4 // Automatic calibration on hydraulic hexapod at Kistler

5 // The reaction wheel jitter investigations used a 9306A force sensor with vibration isolation table and an airflow insulation box

such, the natural frequency (fn) can be used to estimate the amplitude response tolerance using different frequencies.

Most piezoelectric sensors follow the high-frequency response rule. For example, a 5% amplitude response means that over a frequency range, the amplitude can vary ±5%, which is a tight tolerance. The test engineer should decide on the amplitude response tolerance of interest and the frequency range of interest based on the lightly damped second-order approximation. For a natural frequency of 6.9kHz, the 5% amplitude response is up to 6.9kHz/5, or 1.4kHz. The 10% amplitude response has a frequency within a range of up to 6.9kHz/3, or 2.3kHz. For higher frequency measurements, the trade-off is amplitude response tolerance.

As mass acting on the sensor affects natural frequency, a very basic tap test using a small impact hammer can be used to determine the frequency response and related natural frequency. Once the natural frequency estimate is known, the user can establish an upper frequency limit as a factor, based on the desired amplitude response tolerance as previously discussed.

RANGEABILITY AND RESOLUTION CONSIDERATIONS

Piezoelectric measurement chains permit adjustment of the full-scale measurement range using a amplifier. By using a lower full-scale range, the broadband noise is improved and rangeability provides the added benefit of resolving low-level signals. The maximum noise of the DAQ used for the investigation should also be in the same range or even lower to allow for the best resolution possible.

THE IMPORTANCE OF SIGNAL SYNCHRONIZATION

It is crucial that measurement signals are synchronized, or results may be interpreted completely incorrectly. Synchronization can be performed in two ways. The classic solution is to have a separate line, where a system clock is routed to each device to ensure that the measured values are recorded at the same time. The other option is to equip each device with a precise clock and periodically adjust it as is used in the precision time protocol (PTP).

PTP, as described in IEEE 1588-2008, is a procedure whereby the clocks of local network components can be adjusted to achieve accuracy in the sub-microsecond range – without extra cables.

Kistler LabAmp 5165A and 5167A devices have two network connections and integrated PTP switch functionality. They synchronize themselves via the normal network cables. Depending on the required data rate and number of channels, several devices can be connected in series without the need for an external PTP switch.

PTP recognizes two clock types – master and slave. A slave synchronizes itself to its corresponding master. The most precise clock in a network is determined by the automatic 'best master clock' algorithm. Once this 'grand master' is selected, the synchronization of the next slave takes place, which may in turn act as master for the next iteration. After a successful initialization, synchronicity is checked at regular intervals and the clocks are adjusted if necessary

TYPICAL MEASUREMENT RESULTS

Figure 3 is a waterfall plot showing the radial force output from a candidate reaction wheel and how the force output from the wheel varies with speed versus frequency. The primary ridge on the graph is created from the static imbalance of the rotor, where the force shown is equal to $F = m^*r^* \times w^2$ and the m*r term in that equation is the rotor's static imbalance.

The smaller ridges showing in the higher frequencies tend to be running harmonics of the bearing/rotor system. Spacecraft designers use this information to create mathematical models of the disturbance output from the reaction wheels to evaluate the effects of jitter on their instruments.

The six-component piezoelectric measurement chain provides robust measurement capability to accommodate various reaction wheels. The result is the measurement of low-level jitter with high precision to enable the balancing and characterization of the reaction wheel.

Other benefits of the jitter measurement system includes six-component calibrated operation, a high-sensitivity sensor, rangeable operation, high-frequency operation and synchronized digital six-component data. \\

Bill Zwolinski is business development manager of test and measurement and Christof Sonderegger is product manager of special force with Kistler

"REDUCTION OF THE REACTION WHEEL JITTER ON BOARD SATELLITES CONTRIBUTES TO THE IMAGE QUALITY ADVANCE"

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A Environmental Test Solution from Chongqing China

Chongqing, a historic city going back over 3,000 years, is a pivotal point of the Chinese economy in the southwest of the country, with strong research and development presence of automobile, motorcycle, vehicle parts, applied electronics, nuclear and defence industries. It is also the largest production base in China for environmental test equipment, always ready to provide Chongqing, the whole of China and even the world's manufacturing industry with various environmental testing solutions.

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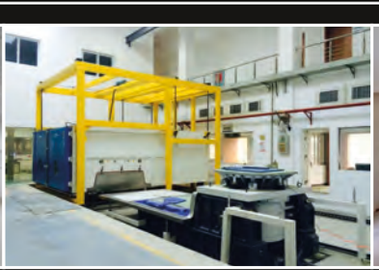
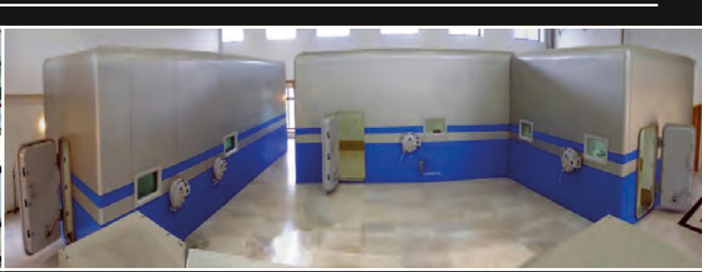
In response to 'Intelligently Made in China' – the next step of 'Made in China', in 2016 **Hardy** built a brand-new, international standard-conforming factory in Chongqing Huanghuayuan Industrial Zone, thus maintaining a good reputation in the home market, at the same time taking a solid step forward toward making **Hardy** environmental test solutions available to the world.





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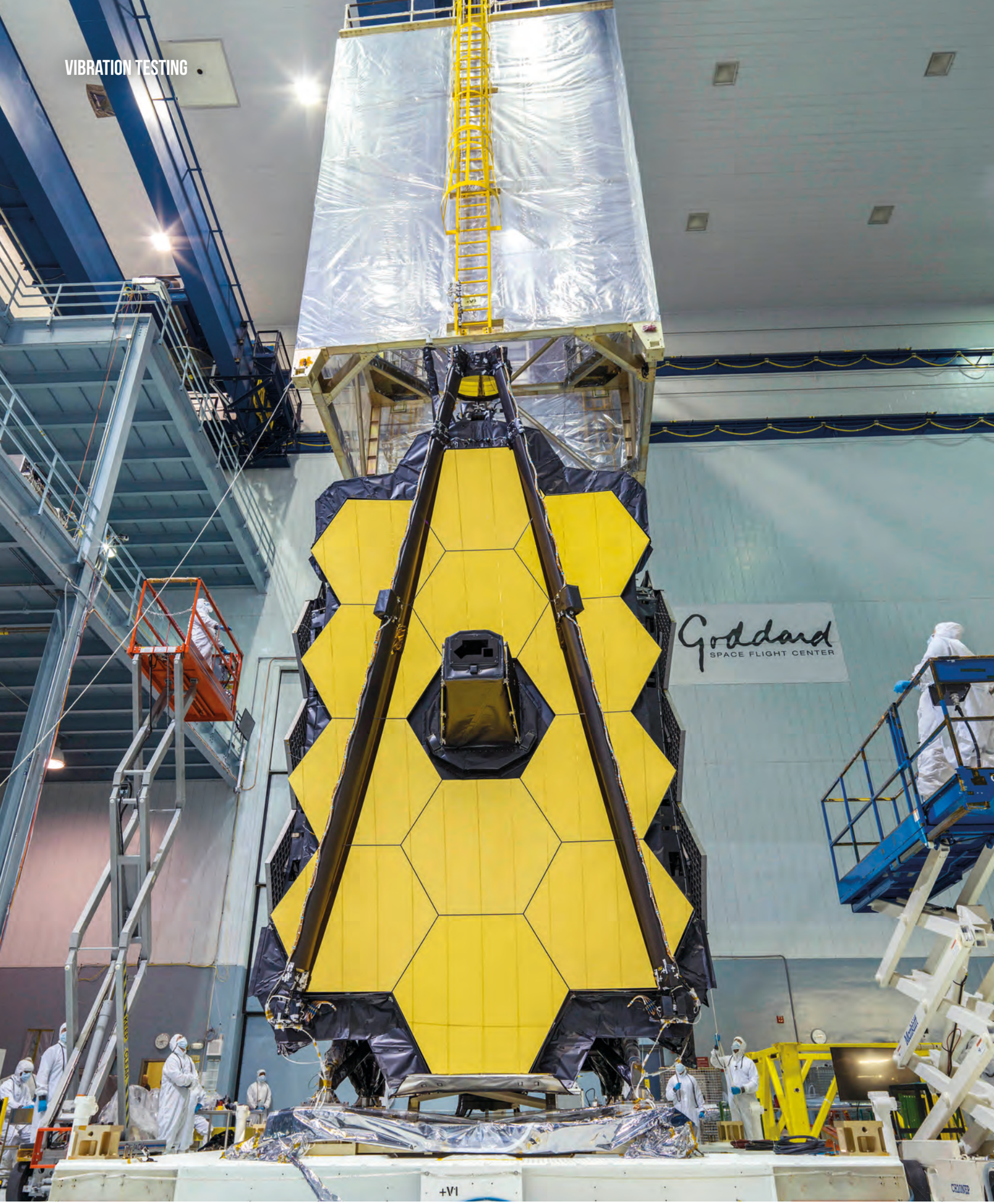

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SAFETY FIRST FOR SATELLITE AND SPACECRAFT TESTS

A solution that provides the smooth ramp-down of vibration testing has helped to safely test the world's most advanced space telescope

// THOMAS REILLY

The primary objective of satellite and spacecraft vibration testing is to ensure a high level of confidence in the survivability of flight hardware during launch. Unfortunately vibration testing is risky and the industry is full of examples where satellites and spacecraft were damaged during test.

Data Physics and Team Corporation combined resources to integrate advanced safety features into vibration test systems. These features detect and potentially eliminate anomalies that might otherwise cause damage to flight hardware during test. While it is standard practice to monitor for over-test conditions on the test article, the solution also monitors the entire test system environment, including the vibration test system itself and facility resources such as supplied power. This approach tightly links the health of the entire test environment to automatic and safe shutdown of the test. If a shutdown event is detected, the vibration test controller will deploy a user-configurable controlled ramp-down to prevent damage to the satellite or spacecraft – after the trip.

SWEPT SINE VIBRATION TESTING

Vibration qualification of satellites and spacecraft requires swept sine vibration testing of actual flight hardware. Swept sine qualification tests consist of subjecting the test article to sine vibration, typically in the range of 5-100 Hz. This is normally done at very high sweep rates to minimize the number of cycles at resonant frequencies. Test levels are selected to keep exposure of the test article within acceptable levels. Force and acceleration limiting prevent over-test. Notching, or reducing the vibration amplitude over specific frequency ranges, also prevents excessive loading of the satellite or spacecraft structure.

Testing starts with a low-level sweep and is repeated at increasing levels until the full-level sweep is completed. Between each sweep, data is analyzed, and changes can be made to control and limit profile levels to ensure maximum allowable levels are not exceeded. After the full-level sweep is completed, the low-level sweep is repeated and compared with the previous one to ensure there are no changes in the dynamic response of the test article. This sweep test sequence is performed for the three orthogonal axes.

SHAKING A SPACE TELESCOPE

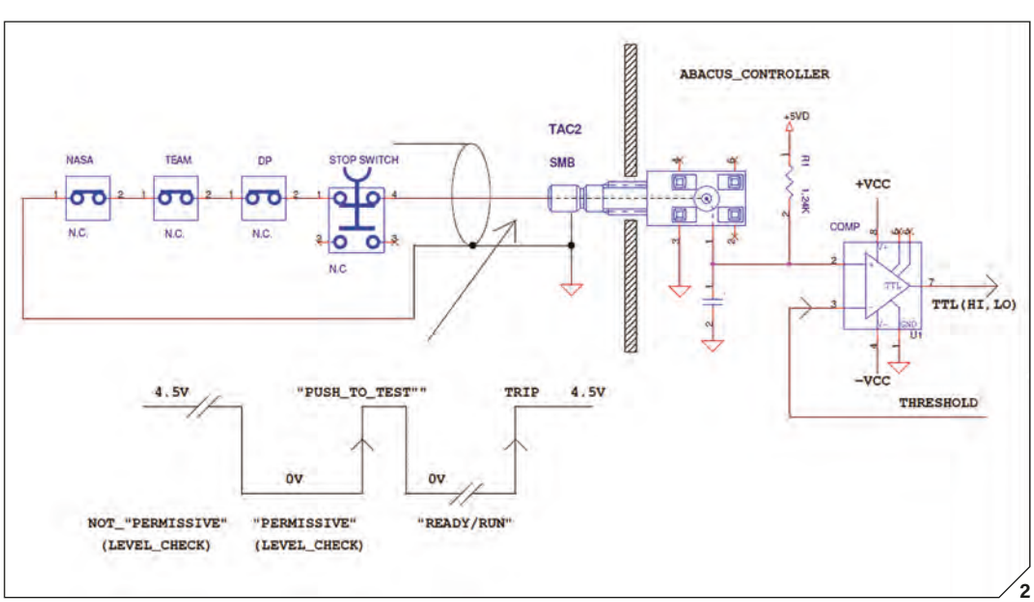
NASA Goddard Space Flight Center recently completed vibration testing of the Optical Telescope Element/Integrated Science Instrument Module for the James Webb Space Telescope (JWST). The JWST test article weighed around 15,000 lb (6,800kg), with a high center of gravity that generated significant overturning moments when subjected to excitation during test. These complex dynamics, in addition to the extremely high value of the test article, further elevated the need for a vibration testing solution that integrated advanced safety features with sophisticated vibration test control.

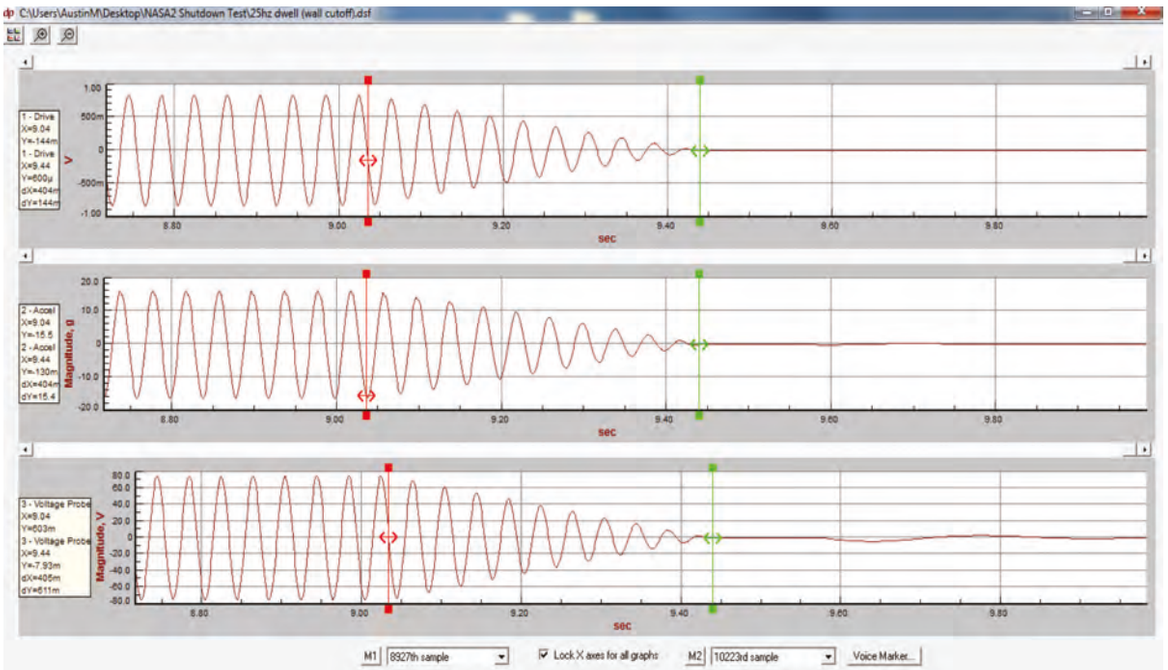
The Data Physics and Team Corporation vibration test system used for the JWST testing consists of a 50,000 lbf (220,000N) electrodynamic shaker with a large slip table for the horizontal plane, and a guided head expander configurable for one or two 50,000 lbf shakers in the vertical plane. The shakers are controlled with the Data Physics Matrix Vibration Controller.

There are several critical systems which ensure the safe operation of the test. The slip table and guided head expander include linear variable differential transformer (LVDT) sensors to detect over-travel of the tables. The hydraulic power supply provides monitoring of hydraulic pressure and can provide a signal to shut down the test if the pressure is not within acceptable levels. The shakers also have an LVDT to detect armature overtravel and can provide a signal to shut down the test. The amplifier has settings for maximum

1 // Preparing the James Webb Space Telescope for testing at NASA Goddard (Photo: NASA/Chris Gunn)

2 // Shutdown relay schematic





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3 // Shaker drive voltage shutdown profile after complete loss of facility power

voltage and current. All these measurements are linked to the control system. Exceeding any of these levels will shut down the test.

As further backup protection, an independent measurement system monitors vibration at locations not measured by the vibration control system. This measurement system can assign abort profiles to any measurement channel. If levels exceed limits defined in these profiles, the independent measurement system can send a signal to the vibration controller to shut down the test.

"SOPHISTICATED MONITORING AND CONTROL PROTECTED THE SPACE TELESCOPE FROM POTENTIAL DAMAGE"

SAFE SHUTDOWN SYSTEM

The safety systems described above detect an over-test condition and trigger an immediate hard shutdown. While this quickly stops vibration from the shakers, the instantaneous stopping of excitation can create transients – rapid deceleration up to hundreds of *g*. This can be more harmful to the flight hardware being tested than the over-test condition that caused the shutdown.

Data Physics and Team Corporation have created a comprehensive system for managing all the safety systems and ensuring a smooth, safe, soft shutdown of the shaker system given a shutdown event and trip. The safe shutdown system used at NASA for testing of the JWST had several major components – the Table Health Control System, an advanced vibration control system, as well as a specially designed amplifier.

TABLE HEALTH CONTROL SYSTEM

This is a computer and sensor system that protected the JWST from potential damage due to unexpected vibrations, should failure of the vibration test system have occurred during testing. JWST tests required that no unexpected vibrations should be introduced during sine testing, such as from the failure of a bearing that supports the vibration table.

The Table Health Control System monitors various subsystems including overall hydraulic supply pressure, hydrostatic supply pressure locally at each bearing, and pneumatic pressure and position of the air isolation system. It also provides communication between the interlocks and the vibration controller. It must provide a 'permissive' signal, indicating that all systems and the table are working and in the proper state, for the vibration controller to start a test. Upon detection of a fault condition, the Table Health Control System will stop the vibration test at a user-definable ramp-down rate. It also controls the startup operations for the shaker systems, bringing the vibration test system from park to the operate state in a controlled manner. At the end of testing, the Table Health Control System turns off the hydrostatic bearing and air isolator.

VIBRATION CONTROL SYSTEM

The vibration controller has modifications to the sine signal generation code to ensure that all shutdowns from the controller include a 400ms ramp-down. The sine signal generation code runs in the digital signal processor hardware on the controller front-end and receives instructions from the control loop processing code. A watchdog feature looks for instructions from the control loop. If the control loop does not issue a command to the drive generation within the expected time, a soft shutdown is initiated. This mitigates risk of over-test due to controller malfunction.

All interlocks are connected to the tachometer input channel of the controller hardware front-end. The tachometer channel is continuously monitored to detect a trip of one of the interlocks. Trip of an interlock will initiate a soft shutdown within a few milliseconds.

An uninterruptible power supply (UPS) provides the ability to continue operation of the vibration controller instrumentation after loss of power. Should power loss occur, the UPS signals the controller to initiate a soft shutdown.

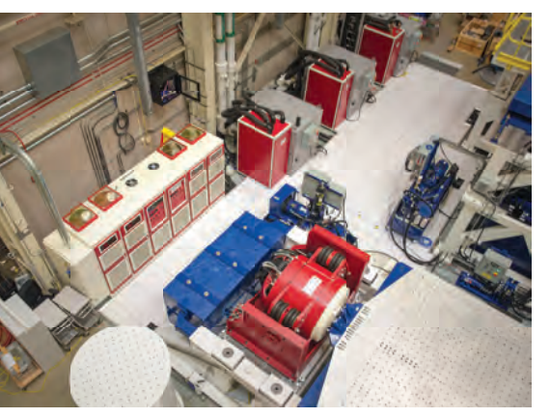
MODIFIED AMPLIFIERS

The amplifiers that deliver power to the electrodynamic shakers are designed to support a soft shutdown after complete loss of power.

Modifications to the amplifier include larger capacitors and a UPS that supplies power to IO modulators. Given a power loss event, these features enable continued operation long enough for the controller to smoothly shut down the test. \\

Thomas Reilly is general manager – instruments with Data Physics

TAKING VIBRATION TESTING TO NEW HEIGHTS



Once safely in orbit around the Sun, NASA's Webb telescope will enable us to observe things never before seen. Preparing this one of a kind instrument for launch conditions demanded a vibration testing solution just as unique—pairing incredible shaker force magnitude with an ultra-precise "smart" shaker control system for safe testing. Whether you're developing new products or making history, we can help take your program to the next level with confidence.

dp Data Physics

dataphysics.com
sales@dataphysics.com

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A PERFECT VIEW

Selecting the best camera for a test requires the consideration of several factors to ensure accurate and useful results

// TIM CALLENBACH AND WENDY TELFORD

High-speed imaging provides aerospace engineers with the video data necessary to perform detailed analysis of combustion processes, turbine efficiency, material durability, fluid flows, aerodynamic stability, and many other important aspects of aerospace technology. There are a number of companies that manufacture high-speed cameras, so how do you decide which company to buy from and which model of camera to purchase? As discussed below, there are many factors to consider when procuring a high-speed camera.

FRAME RATE

The first and most obvious consideration in the purchase of a high-speed camera is frame rate. How many frames per second are required to capture sufficient video detail to enable the analysis of a high-speed event? A low-end, high-speed camera can capture 1,000fps at 1MP resolution, while a high-end camera can run at 20,000fps or more at 1MP resolution. Most high-speed cameras provide the ability to run at increasingly higher frame rates as the pixel resolution is reduced.

VARIED RESOLUTIONS

High-speed cameras are available in a variety of resolutions between 1MP and 4MP. Higher resolutions are important when the field-of-view of the camera is large, or when a very small spatial resolution is required because there are fine details in the high-speed event that need to be studied. The higher the resolution of the camera, the lower the maximum frame rate will be. With a 4MP camera there are four times more pixels to process than with a 1MP camera. Therefore, it is not possible for the user to achieve the same maximum frame rate with a higher-resolution camera as with a lower-resolution camera. Furthermore, higher-resolution cameras are typically less sensitive because their sensors have smaller pixels.

1 // Drop test of fuselage at Wichita State University

2 // 3D PIV laser illumination in wind tunnel

LIGHT SENSITIVITY

In certain applications, light sensitivity is the single most critical consideration when purchasing a high-speed camera because it affects so many things. Light sensitivity impacts the ability to use a short exposure time to effectively eliminate motion blur when capturing a very high-speed event. It impacts the quality of the video because without sufficient light sensitivity the images will be dark and hard to analyze. And it impacts the ability to focus, especially when using telescope or microscope lenses.

There is a huge variation in light sensitivity among high-speed cameras. Light sensitivity is typically presented as an ISO value. The higher the ISO value, the more sensitive a camera should be.

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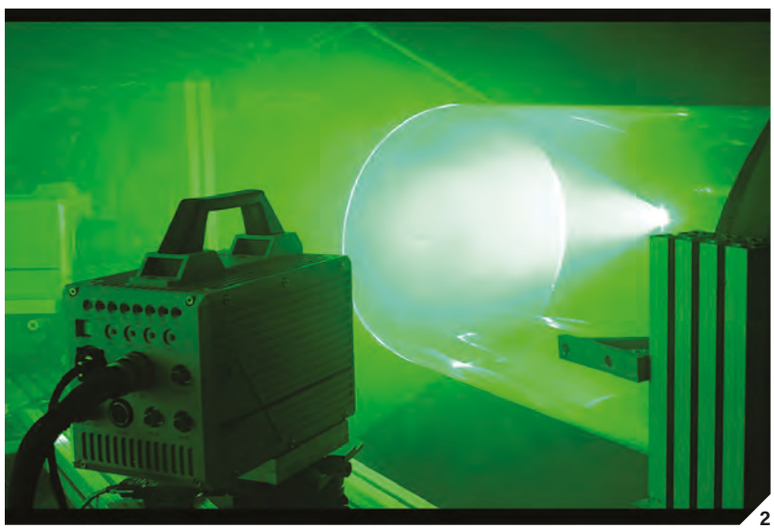
However, when you look at a datasheet or brochure, you should take the information regarding light sensitivity with a degree of skepticism. There are standards – such as ISO 12232 Ssat – that define how to measure light sensitivity, but some high-speed camera vendors do not adhere to the standards when measuring the ISO values of their cameras. Other vendors publish ISO values for their cameras, but do not specify exactly which ISO standard the values conform to. Without this, the ISO values are meaningless.

BIT DEPTH

Bit depth is an important consideration as it impacts image quality and the ability to apply image processing to the recorded images to enhance their usability. Most high-speed cameras capture image data that is either 8bit, 10bit or 12bit. Images with larger bit depths contain more information, enabling the viewer to see greater details within the images. They also provide flexibility for image processing functions that can be used to enhance poorly illuminated areas, meaning those areas can be brightened for easier analysis. The 12bit images are larger than 8bit or 10bit images, and therefore require more memory within the camera and will shorten the camera's record time.

"THE FIRST CONSIDERATION WHEN BUYING ANY CAMERA IS FRAME RATE"



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MINIMUM EXPOSURE TIME

A camera's minimum exposure time is often a critical factor in choosing a high-speed camera. Certain very fast high-speed events require extremely short exposure times – sometimes less than 1µs– to stop the motion of those high-speed events. A camera's ability to achieve a sub-microsecond exposure is dependent on two things. First, the camera's sensor must be capable of performing such a short exposure. Second, the camera's sensor must be sensitive enough that when it does use a sub-microsecond exposure, it can capture enough photons of light during the exposure to generate images that are of sufficient quality for analysis.

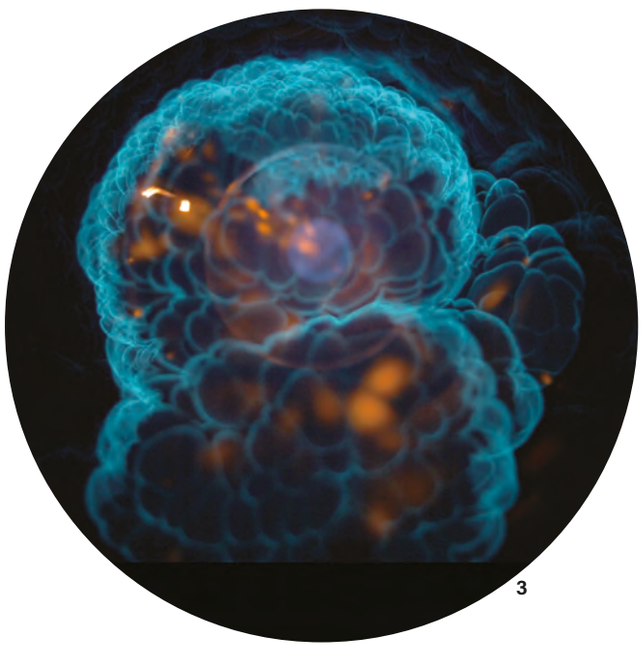
INTERNAL MEMORY

The amount of internal memory is an important issue for consideration when purchasing a high-speed camera, as a high-end, high-speed camera can generate a huge amount of data in a very short time. For instance, a camera can generate 128GB of 12bit image data in just under 4.5 seconds when run at 20,000fps at 1MP resolution. No streaming mechanism exists to enable this amount of data to be transferred to a PC or external storage device in real time, so high-speed cameras have internal memory to which the data is initially captured. After the recording is completed, the image data can then be offloaded to a more permanent location.

DATA OFFLOAD PERFORMANCE

Most camera suppliers have chosen to implement Gigabit Ethernet to enable the transfer of image data from the internal memory of a high-speed camera. However, not all Gigabit Ethernet implementations are the same. For instance, using TCP/IP protocol tends to be inefficient for downloading large video sequences because there is a lot of overhead involved with that protocol. Gigabit Ethernet using UDP protocol, on the other hand, is quite efficient and can result in image data transfer speeds of up to 5GB per minute. Not all camera manufacturers implement UDP protocol. Furthermore, some camera manufacturers provide two Gigabit Ethernet interfaces (instead of one) so that data transfer speeds can be doubled.

As an alternative, some cameras can transfer images to removable non-volatile memory such as SD cards and CFast cards, or to integrated SSD drives. Such download methods can be very useful, but when you calculate the overall transfer time required to get your image data from the internal camera memory to a PC, you will need to consider both the time required to transfer



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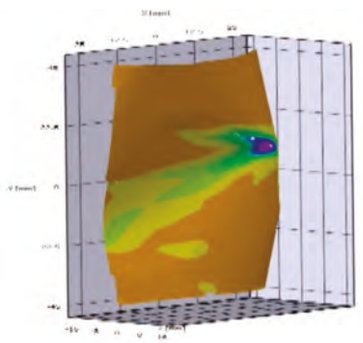

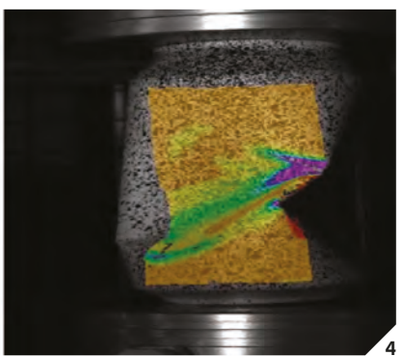

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> "UNLESS COLOR CHANGES ARE CRITICAL TO THE ANALYSIS, A MONOCHROME CAMERA IS THE BETTER CHOICE"

3 // Combustion photo *(Mark Johnson – Slowmo.co.uk)*

4 // Digital image correlation showing stress and strain

images from the camera to the non-volatile memory and the time required to transfer images from the memory to the PC.

COLOR VERSUS MONOCHROME

When you purchase a high-speed camera, you will have to decide between a color and a monochrome camera. Often when a camera purchase is being considered, the marketing department wants a color camera because color video is more impressive to the viewer. However, it is important to understand that because of the way high-speed sensors are made, a monochrome camera will be two to three times more sensitive than the equivalent color camera. Unless color changes within a high-speed event are critical to the analysis of the event, a monochrome camera is typically the better choice.

CAMERA SIZE

The physical size of a high-speed camera is an important consideration if your application provides only a limited space in which to fit the camera. There are some important trade-offs involved in purchasing a smaller size camera. Small cameras are often less sensitive than larger cameras due to the implementation of small sensors with small pixels (for use with small lenses). In general, they also have lower frame rate performance and less memory because they contain less internal room for the electronics that impact these performance parameters.

NIAR CASE STUDY

Laboratory director Gerardo Olivares has four Photron SA-Z cameras – two color and two monochrome – in The Virtual Engineering Laboratory at Wichita State University's National Institute for Aviation Research (NIAR). Olivares says the high frame rate, excellent sensitivity and high overall image quality make the Fastcam SA-Z an ideal high-speed camera for his testing processes.

Photron cameras were used recently during a drop test of an airplane fuselage. The test was done as research for the FAA, to examine the behavior of composite materials when used for main aircraft structures. In this case, the materials were a honeycomb structure covered by a carbon fiber laminate.

A 10ft (3m) section of composite fuselage was brought into the lab and filled with appropriate ballast to simulate the 1,500 lb (680kg) weight of an operational fuselage. Extensive accelerometers and strain gauges were attached, with two SA-Z high-speed cameras placed on each side of the test area. Two monochrome cameras were set up to record the entire width of the fuselage and two color cameras were placed on the other side, focusing primarily on the emergency exit door area. The test represented a pure vertical crash at 30ft (9m) per second.

A laser beam was used to trigger the cameras and instrumentation so that image collection began when the fuselage was about a foot away (0.3m) from impact. Set to record at 20,000fps and using the Photron camera's Pre-and Post-Triggering feature, 25% of the images were captured prior to impact and the remaining 75% were recorded during and after impact. Using Digital Image Correlation (DIC) software for analysis of the images, researchers were able to determine the extent of the deformation and stress in the composite materials of the fuselage.

The FAA is studying the results of the test to support future regulations on the use of composite materials versus metallic materials in 14 CFR PART 25 commercial aircraft. Composite materials are lighter and manufacturers design and build their products based on FAA certification requirements showing safety levels equivalent or better to metallic materials.

EXPERIENCE COUNTS

Frame rate, resolution and light sensitivity are typically the most important factors to think about when purchasing high-speed cameras for aerospace testing applications, but as discussed above there are other things to consider as well. To guarantee the successful implementation of high-speed cameras within such environments it is important to select an experienced supplier who can provide a range of highly-reliable cameras, along with exceptional customer support. \\

Tim Callenbach is sales manager and Wendy Telford is a freelance contributor at Photron

HIGH-SPEED CAMERAS FOR SLOW MOTION ANALYSIS

Photron provides a wide range of high-speed cameras with exceptional light sensitivity for slow motion analysis. Our FASTCAM series offers cameras with megapixel resolution and performance to 21,000 frames per second (fps), as well as 4-megapixel cameras that produce true HD resolution images at frame rates to 2,000fps.

KEY APPLICATIONS:

Combustion analysis
Turbine testing
Engine burn studies
Fluid dynamics and PIV
Materials testing and DIC
Aerodynamics assessment

NEW PRODUCT
nova
FASTCAM series by Photron

PHOTRON OFFERS A WIDE RANGE OF CAMERAS WITH POWERFUL FEATURES:

Megapixel resolution to 21,000fps
Reduced resolution to 2.1Mfps
Unparalleled light sensitivity
Minimum exposure to 159ns
128GB of internal memory
Fast download to PC or SSD
Extremely rugged design
Standard 2-year warranty

Photron

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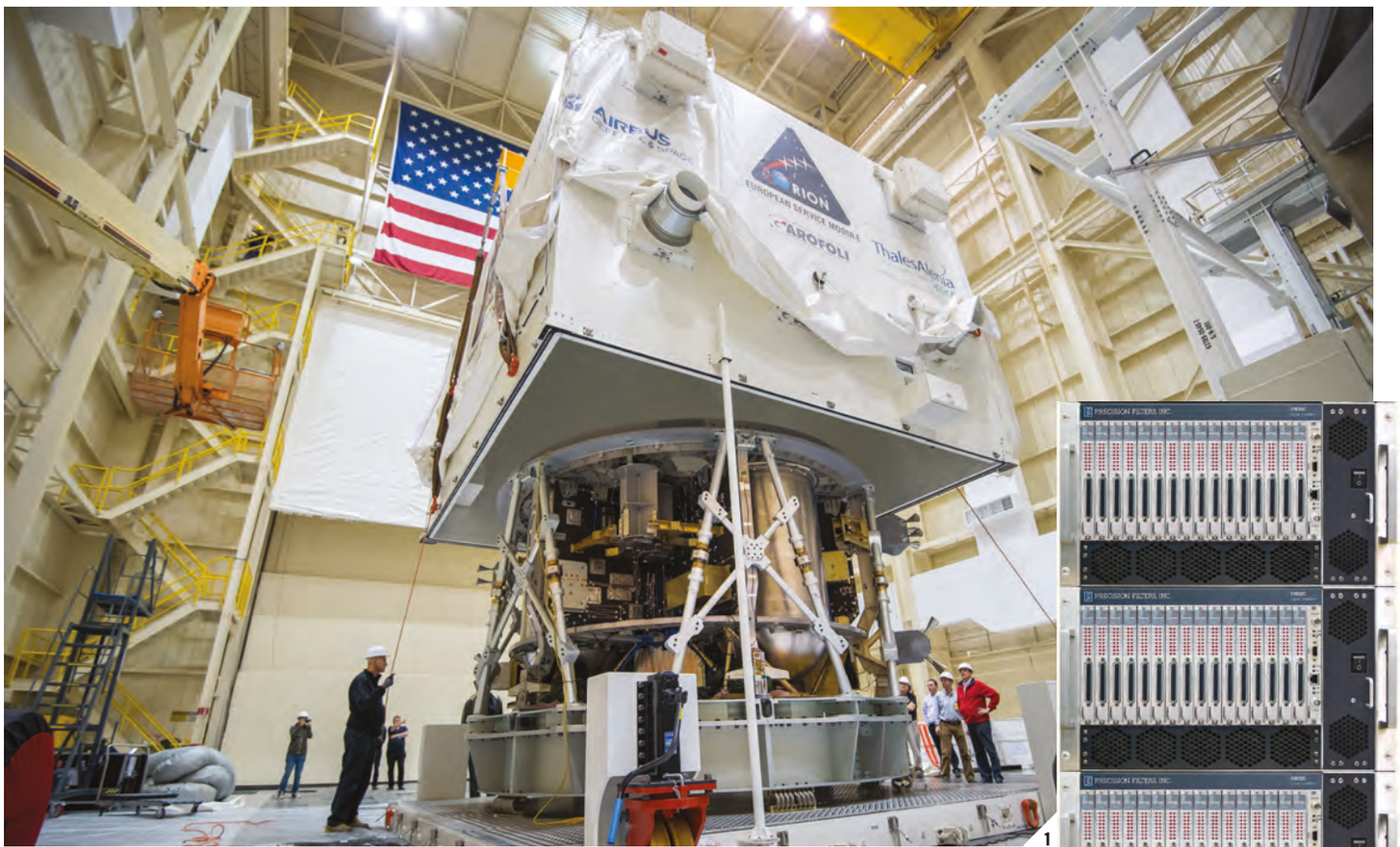

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SIGNAL CONDITIONING FOR VIBRO-ACOUSTIC TESTS

NASA is using Precision Filters' latest signal conditioning systems in the testing of its new spacecraft

// DOUG FIRTH

As humans push farther into our solar system, they need spacecraft proven to withstand the extreme conditions encountered in space. The NASA Plum Brook Station Space Power Facility (SPF) in Sandusky, Ohio, is home to the world's largest and most powerful space environmental simulation test cells.

At 100ft (30m) in diameter and 122ft (37m) high, the SPF's Space Simulation Vacuum Chamber is the world's largest space environment thermal vacuum chamber and an ideal site for testing space hardware. The SPF also houses the Reverberant Acoustic Testing Facility, a 101,500ft^3 (2,800m^3) chamber that blasts test articles with acoustic sound pressure of up to 163dB, making it the most powerful spacecraft acoustic test chamber in the world. The three-axis vibration system of the Mechanical Vibration Test Facility shakes test subjects of up to 75,000 pounds to simulate the vibration that occurs during launch and ascent. In addition, NASA has developed the capability to perform electromagnetic interference/compatibility (EMI/EMC) testing on full-scale spacecraft.

Such rigorous, large-scale testing means accurate measurements are essential. To support the large number of sensor measurements taken at the SPF, NASA needed a new system to interface to spacecraft and facility sensors to condition, digitize, display, analyze, store, and archive the critically important test data.

The installation required a total of 1,024 channels of sensor conditioning. Due to the wide range of test protocols and the tests' high cost and crucial importance, the data system had to be flexible, reliable and traceable to National Institute of Standards and Technology (NIST) standards. Above all, test data had to be highly accurate and fully defensible. Together, the signal conditioning front-end and the data acquisition system comprise the Plum Brook Station Facility Data Acquisition System (FDAS).

1 // The European Space Agency's service module for the Orion spacecraft is moved into position at the Plum Brook Space Power Facility (*Photo: NASA)*

2 // Precision Filters' 28316C plug-in signal conditioning cards in a rack

NASA chose Precision Filters' 28000 signal conditioning system for the data system front-end to interface to the spacecraft and facility sensors and to provide amplified filtered sensor signals to the downstream data acquisition system. The 28000, a mix-and-match transducer conditioning system, has over a dozen plug-in signal conditioning cards to meet almost any sensor conditioning requirements required.

The Precision 28316C 16-channel isolated IEPE conditioner card was selected for the vibration measurement requirements. The high density card provides the required 768 channels. NASA chose the 28144 quad-channel wide-band transducer conditioner for the 184 full-bridge sensors, and the 28304 quad-channel charge/IEPE amplifier for the 40 channels of IEPE/ charge sensors. Seven 6U 28000 chassis house the entire system.

The 28316C card supports programmable filtering, gain and IEPE supply current. The balanced push-pull IEPE supply and isolated input of the 28316C break the ground loops that traditional IEPE conditioners cannot address. To monitor transducer health, sensor open, short and bias levels are checked and reported. To facilitate the logistics of setup and gain scaling to the calibrated sensitivity of 768 sensors, the 28316C is compatible with the latest Transducer Electronic Data Sheet (TEDS) equipped accelerometers.

For piezoelectric pressure and accelerometers, the 28304 provides charge mode conditioning. The card supports voltage substitution, shunt calibration and T-insertion for system, sensor and cable health checks.

When the test regimen requires Wheatstone bridge conditioning, the 28144 is compatible with ¼, ½ or full bridges for static measurements using constant voltage excitation and dynamic measurements using PFI's proprietary balanced constant current excitation. The voltage excitation supply uses balanced voltage excitation to improve rejection of high-frequency common-mode signals. The 28144 includes a four-pole programmable filter with selectable flat amplitude response characteristics with sharp roll-off for spectral analysis, or pulse Bessel type characteristics for time domain uses including transient and waveform analysis.

Whether the sensor type is voltage, IEPE, bridge, or charge, each channel of the 28000 is fully programmable to provide sensor scaled, amplified and filtered data-acquisition-ready signals to the FDAS's downstream A/D converters.

NASA needed automated in situ calibration, as the expected test schedule does not tolerate a month of downtime each year for equipment calibrations. Precision Filters' built-in test hardware and software lets Plum Brook engineers perform NIST traceable calibration tests on site, without removing the system from the equipment rack.\\

Doug Firth is president of Precision Filters

"THE INSTALLATION REQUIRED A TOTAL OF 1,024 CHANNELS OF SENSOR CONDITIONING"

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ETHERNET IP CAMERA FOR AIRBORNE APPLICATIONS

Ethernet IP cameras used as flight test instrumentation should be ruggedized and use the latest compression technology and network equipment to provide excellent results

2

// BY RUSSELL MOORE

Ethernet-based networks having become the dominant choice for flight test instrumentation (FTI) applications, requirements for integrating Ethernet-based (IP) cameras with FTI data acquisition (DAQ) equipment, network recorders and telemetry devices have increased. As cameras move to HD formats, transmitting raw video adds complexity and limits the number of video frames that can be transmitted and stored. Synchronizing this data with other flight test parameters can also pose a challenge.

Dedicated compression cards can solve some of these issues, but they have negative implications for size, weight and power (SWaP). Ethernet cameras with integrated compression can address these issues, providing multiple output streams to support recorder and telemetry applications. An Ethernet switch can also manage video streams and synchronize FTI and video data.

The extreme environmental conditions typical of FTI applications require highly ruggedized and reliable HD Ethernet cameras. For new flight test applications, video data needs to be coherently synchronized for telemetry and available for storage. Ideally, data in the telemetry stream will be highly compressed to minimize downlink bandwidth. Recorded data, on the other hand, can be lightly compressed to provide maximum quality for post-flight analysis.

Various image-processing functions are essential for delivering the appropriate image quality during test flights. Rolling shutter cameras can be used in airborne cabin and over-the-shoulder cockpit applications. Global shutters use simultaneous acquisition to capture the entire frame in a single instant of time and can be used where the subject is rotating, or moving with high velocity, to eliminate motion-induced distortion.

ENVIRONMENTAL FACTORS

During flight test, the aircraft and its systems must be pushed to their limits to prove the validity of the design assumptions and to record the safe operational limits. FTI cameras must be designed to meet stringent and harsh environmental requirements in order to withstand extreme vibration, shock, humidity and temperature. For example, an FTI camera may need to operate on a runway at 50°C (122°F), and shortly afterward at -30°C (-22°F). Such thermal differences can change electronic component impedances as a result of temperature or moisture condensation.

CAMERAS IN FTI APPLICATIONS

Full HD video at 60fps can take up to 3Gbps of bandwidth per channel. Several HD cameras recording uncompressed video can overload the data acquisition system. Also, transmission bit rates affect video quality. Lowering the bit rate will reduce the video quality unless the frame rate is decreased. To maintain video quality, changing the frame rate has a linear effect on the suggested bit rate. Compressing HD

1 // Curtiss-Wright's HDC-430-1 Full HD GbE streaming IP camera

2 // Video frames contain similarities which codecs exploit to compress data

"HIGHER-QUALITY VIDEO WILL REVEAL DETAIL SD CAMERAS CAN'T PROVIDE"

video with an industry standard algorithm can reduce bandwidth to a more reasonable amount without significantly affecting image quality.

COMPRESSION STANDARDS

Modern video compression algorithms, also known as codecs, exploit the similarities between and within video frames such as in Figure 2. Codecs used for FTI include MPEG2, H.264, JPEG 2000 and H.265 high-efficiency video coding (HEVC) compression. Codecs can compress an HD video stream down to less than 10Mbps, reducing the bandwidth and recording capacity needed without a loss in quality.

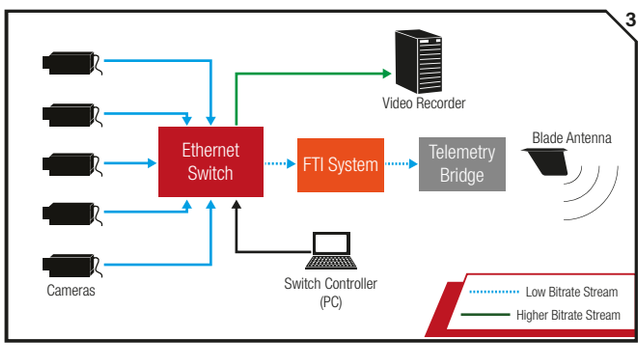
A camera that supports onboard compression and Ethernet packet-based transmission can handle multiple compression streams, which can be particularly useful for FTI. For example, two compression rates can be defined for the same video channel over the same Ethernet connection, enabling the user to set one data rate for the recorder and a second data rate for PCM transmission.

AN IP CAMERA ECOSYSTEM

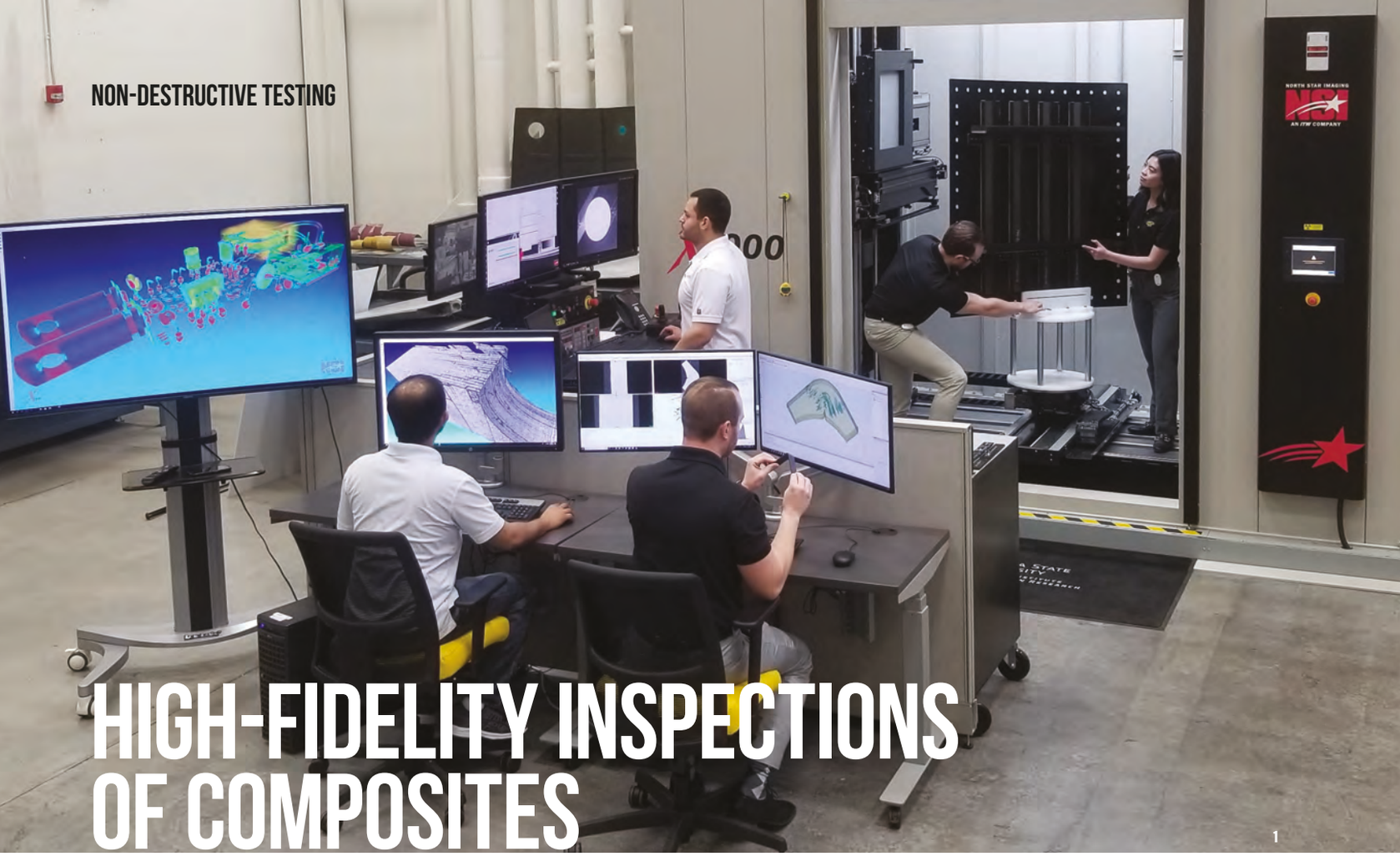
Curtiss-Wright provides FTI system solutions that integrate with data acquisition and recording systems. These rugged HD IP cameras (1080p; 30fps max.) include the rolling-shutter HDC-430-1 and the global-shutter HDC-450-1. They support image/video streams from under 1Mbps to 20Mbps compressed with a next-generation H.265 HEVC codec. They also support NTP time synchronization and time-stamping.

Properly optimized, this approach delivers excellent video quality for telemetry. A second, higher quality video copy, with a bit rate of around 20Mbps, recorded on board the aircraft, will reveal details that traditional SD cameras can't provide. An Ethernet camera that supports onboard compression enables video compression to be removed from the DAQ system, or eliminates a dedicated unit. The camera can be connected via an Ethernet switch directly into the system, like any other DAQ unit. Even better, because there is no need for dedicated hardware compression, SWaP is minimized and installation wiring greatly simplified. \\

Russell Moore is director of business development, Advanced Imaging Systems, at Curtiss-Wright Defense Solutions



3 // Multiple compression of FTI cameras



HIGH-FIDELITY INSPECTIONS OF COMPOSITES

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Researchers have developed an ultrasonic inspection tool for assessing damage in advanced composite materials and structures

// WARUNA SENEVIRATNE

Researchers from the National Institute for Aviation Research (NIAR) at Wichita State University, Kansas, are developing an ultrasonic tool for detecting and characterizing damage in composites. The Acousto-Ultrasonic Defect Indicator (AUDI), which is at the prototype stage of development, assesses mechanical property variation in composite materials to provide information that can be used for local stress analysis or for determining safety margins and repair needs.

CHALLENGING COMPOSITES

Due to its anisotropic and heterogeneous nature, the damage growth characteristics of composites are complex. Typically, a mixture of several failure modes is involved, such as matrix cracks, fiber breaks and delamination. Most of these failure mechanisms are not visible to the naked eye or to typical field inspection techniques.

X-ray computed tomography (XCT) is one of the high-fidelity inspection techniques used to observe damage growth in composites. However, x-ray technology has limited applicability in the field due to the lack of access to both sides of the part and the need for protective enclosures to prevent radiation leaks.

Similar to pulse thermography and Mobile Autonomous Ultrasonic Scanners (MAUS), AUDI couples two ultrasonic probes, a sender and a receiver, to the object's surface. AUDI requires only single-sided access and provides wide area assessment, because the probes are placed apart from each other (Figure 5). The acousto-ultrasonic technique uses externally generated stress waves for determining stress wave factors based on spectral moments, obtained from windowing frequency components of the power spectral density that represent the received ultrasonic waveform.

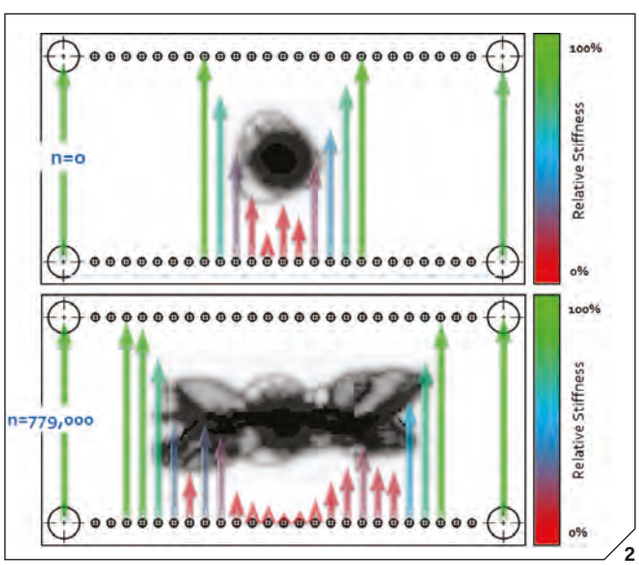
The technology combines aspects of acoustic emission and ultrasonics by simulating stress waves that resemble acoustic emission waves without disrupting surrounding materials, in order to assess the defect state.

The ability to quantify relative strength compared with a pristine case enables the calculation of a margin of safety to determine repair needs. Therefore AUDI can be used for non-destructive inspection. The unit can detect material anomalies that may not be readily detected, such as cure variations and poor adhesion between composite plies, but cause significant variations in mechanical properties. In addition, more research is being done that will demonstrate the AUDI's ability to detect weak bonds and kissing bonds.

The prototype unit is also being used by researchers to monitor the fatigue damage growth behavior of composite panels with impact damage, in order to demonstrate the capability of the technique for assessing local stiffness loss as the damage progresses. When inspected, several specimens with various damage levels are mechanically tested to compare the acousto-ultrasonic NDI readings against

1 // The x-ray CT system in use at NIAR, Wichita State University

2 // Demonstration of acousto-ultrasonic prototype scanner for detecting relative stiffness loss (height of color-coded arrows) as damage progresses



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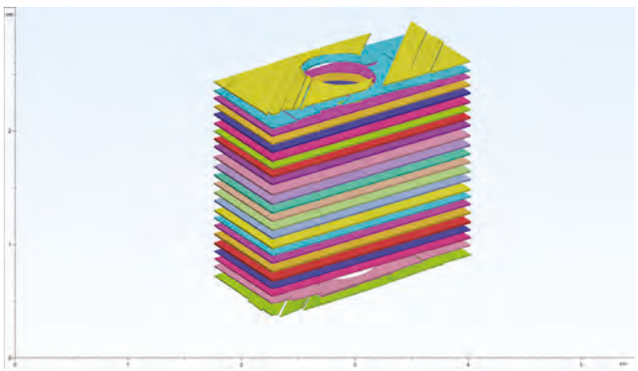

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3 // High-fidelity ply-by-ply x-ray CT scan of a 24-ply composite laminate

localized stiffness loss. Full-field strain measurement obtained from digital image correlation during mechanical testing is used for correlating analysis models developed based on localized stiffness loss calculation obtained using acousto-ultrasonic scans.

HIGH-FIDELITY VALIDATION

Due to complex damage growth characteristics and a lack of reliable analysis techniques, overly conservative assumptions are often made by engineers when assessing the fatigue life of composites. A greater understanding of the fundamentals of fatigue damage initiation and growth characteristics of composites is also needed to develop more efficient composite structures. Under a US Air Force Research Laboratory sponsored program for Advanced Material Characterization and Structural Certification, NIAR researchers are developing a database of fatigue damage growth data using XCT that includes fatigue damage growth data under constant amplitude fatigue, as well as realistic fatigue spectra representing fighter, transport and bomber operations.

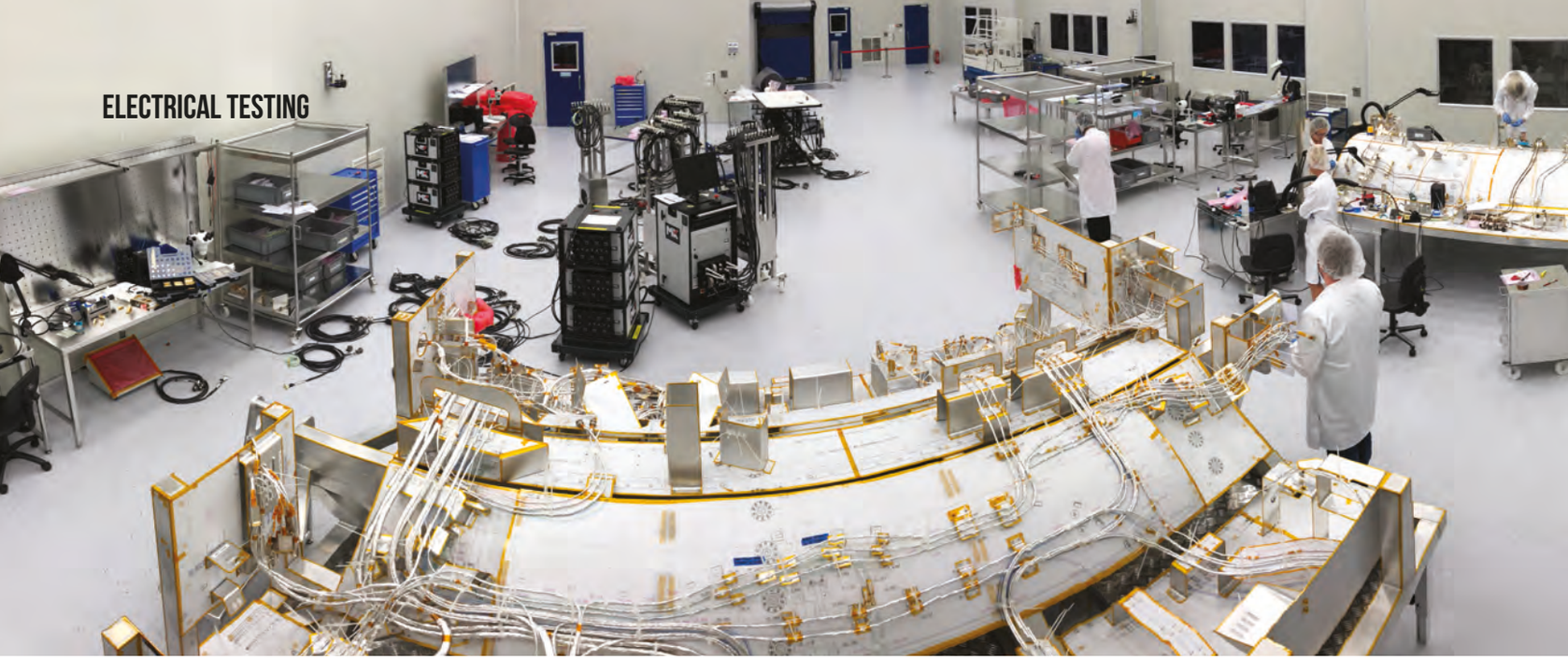
This high-fidelity damage growth data will then be used to validate analysis methods that can capture the complex damage evolution of composites.

One example of a finite element analysis method used on composites is the US Air Force developed mesh-independent b-spline analysis method (BSAM). This analysis technique is capable of modeling matrix cracks, delamination and fiber breaks. Only high-fidelity inspections such as XCT can be used to validate such high-fidelity analysis models. A technique known as 4D XCT, a collection of three-dimensional XCT data over time, is being used so that the damage evolution under cyclic loading can be captured with ply-by-ply detailed information for validating high-fidelity analysis predictions (Figure 2).

Once the high-fidelity damage models are validated through experiments and XCT damage growth data, AUDI's capability for detecting localized stiffness loss due to fatigue damage growth will also be independently compared with analysis predictions. \\

Dr Waruna Seneviratne is technical director and senior research scientist at NIAR

"AUDI REQUIRES ONLY SINGLE-SIDED ACCESS AND PROVIDES WIDE AREA ASSESSMENT"



INTELLIGENT OPTMIZATION

An electrical harness shop in Poland has optimized its testing processes using the latest measurement tools and data analytics

// **JASON EVANS**

Harness shops, airframe equipping lines and aircraft final assembly lines are all aiming to reduce testing. Across the board, testing is viewed as a bottleneck. But the vast majority of large assembly or final assembly line tests find failures, so the focus changes to how to best optimize testing.

This was the challenge posed by the engineers of PZL Warszawa-Okęcie, a subsidiary of Airbus Defence and Space, when it selected MK Test Systems to design and provide automatic electrical test systems for its expanding harness shop and space assembly operations in Warsaw.

Jakub Łukasiewicz, electrical harnesses production department manager and space programs production manager, leads the team of engineers that posed the ΣTOP (Electrical Test Optimization Project) challenge. He says, "The Sigma was selected because it hints at our commitment to improve performance and streamline manufacturing through the elimination of waste and early adoption of best practice, combined with new technology and ideas."

The teams managed by Łukasiewicz manufacture electrical harnesses and equipped assemblies for a range of aircraft and space programs including the C-295, A320 Neo, A330, A400M, MetOp and the Jupiter Icy Moons Explorer spacecraft.

MK's solution was to provide a set of five test control stations and 15 mobile satellite switching modules, with any number of switching modules able to be controlled by any of the control stations. At any time, any main console can be testing in any location, with up to 15,000 test points available for any project.

Each stage of the testing process was optimized to achieve the overall target.

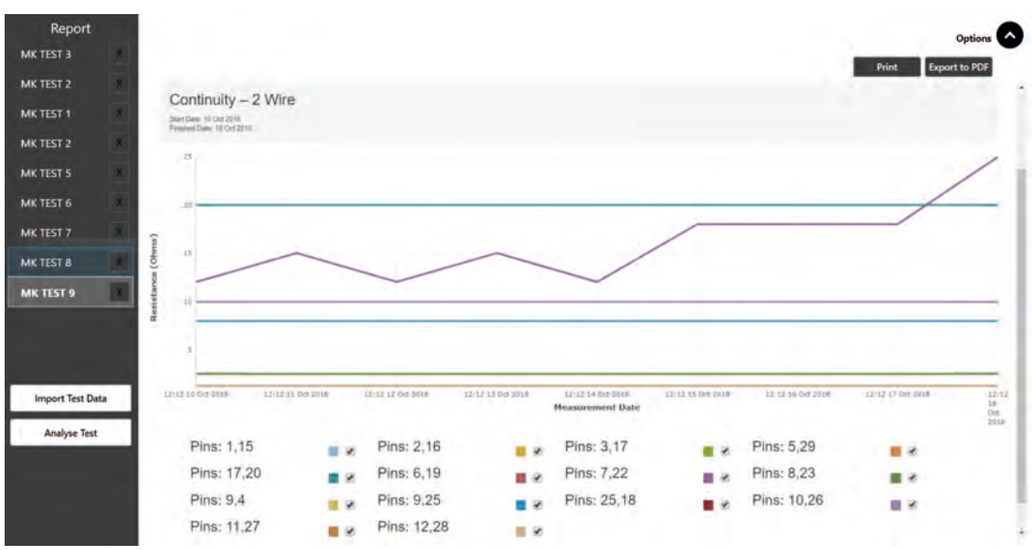
When creating test programs, engineers at PZL make use of source design data in production and planning. MK Test's third-generation APG (Automatic Program Generation) software toolset allows the use of this data in the fully automatic creation of test sequences and programs. Programs are created in real time, allowing all design changes to be accommodated during test. MK Test's APG mapping tool allows PZL users to map specific source data formats, enabling the APG tool to be used across all projects. Optimization means eliminating manual programming where possible to do so.

PZL also possessed a number of interface cables from a previous test solution. To enable reuse of these cables and rapid and error-free hook up of the test system to the product, MK and PZL implemented an intelligent cable ID system. The unique Active XRef system is double-ended, allowing random hook up of the product and intermediate connections. The test system recognizes the location and sequence of hook up and adjusts the test program to suit. The optimization facilitates rapid, error-free hook up.

The test systems are able to measure continuity resistance, short circuit location

1 // PZL Warszawa-Okęcie makes electrical harnesses for aircraft and satellites

2 // Data from the measurement system is used to optimize testing



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"OPTIMIZATION MEANS USING DATA TO LOOK INTO THE FUTURE AND ELIMINATE REPEAT FAILURES"

and resistance, capacitance, high voltage insulation resistance and HiPot. Fault diagnosis is most important to the operators. MK Test's solution makes measurements and records each value, indicating pass or fail status against the test parameter and then uses those measurements to diagnose and report the nature or location of any failure.

The system is a wiring fault analyzer. Common faults such as inversions or crossed wires are reported as such. Distance to open circuits and short circuits can be indicated. High-voltage insulation failures automatically trigger an HV scan that creates group analysis tests to detect the true location of the insulation breakdown. Images can be associated with each connection or component to guide the operator to the physical location of a fault. All this is intended to speed up the detection of faults.

In addition to the test-time results report, MK's reporting and data toolset has been developed to support the industry's move to digitization and the use of data mining. Every measurement is logged and held in a database that can be interrogated using a range of custom analysis tools. Paperless test processes and the ability to use data to improve the testing process efficiency produce dramatic optimizations.

Test result data provides a business with in-depth understanding of the types and regularity of specific failures, and therefore an opportunity to design out the cause of failure. Patterns of failure can indicate material batch issues, changes in supply chain quality, specific training requirements and design change, all of which can be addressed to improve production output. In time, measurements that never fail can be identified, so the user can analyze whether a test is stringent enough or if it is relevant or required.

Hugo Aniksztejn of MK Test Systems says, "The ΣTOP challenge allowed us to demonstrate many of the latest developments in our third-generation test-management software. Digitization and big data are a reality, and working with the team at PZL we are demonstrating the benefits of joined-up data and processes."

Electrical test optimization means total testing efficiency, maximum automation and the use of results data to look into the future and eliminate repeat failures. \\

Jason Evans is sales director at MK Test Systems

HOW TO CHOOSE THE RIGHT ACCREDITATION

The scope of materials testing programs should ultimately be determined by the requirements of the material's industrial use

// MATTHEW BRADY

Many times, when setting up or selecting a material testing facility, the question arises: what should the testing be certified to? The answer will vary depending on factors such as the industry, the material and the end use. The two most common certifications are ISO/IEC 17025 and Nadcap. There are key aspects of each certification's procedures that can be used to confidently select the most suitable for a material testing program.

ICO/IEC 17025 CERTIFICATION

The first certification is governed by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) and specifies the general requirements for the competence to carry out tests and/or calibrations, including sampling. That means the certification only applies to testing and calibration facilities. In an ISO/IEC 17025 certification, things such as the quality system, calibration intervals of measurement equipment, internal procedures and recording of the laboratory's environmental conditions are evaluated.

When certifying a testing laboratory, the ISO and the IEC audit the lab for each specific test it wants to perform. This means that the test laboratory cannot be certified for a general test such as 'tensile', but rather would be certified for a specific tensile test such as ASTM D3039. Audits are conducted on-site and mostly consist of reviewing work instructions and internal procedures, and a verbal walk through by

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the person who will be performing the test. The goal of an ISO/IEC 17025 audit is to confirm that the measurements made are accurate and repeatable to the specified test standard.

NADCAP

Nadcap (originally an acronym for the National Aerospace and Defense Contractors Accreditation Program) is a certification program for the aerospace and defense industry that covers everything from sales to quality. This accreditation is governed by the Performance Review Institute (PRI), which maintains certification and performs on-site audits. One of the main differences between ISO/IEC 17025 and Nadcap for the testing facility is that Nadcap certification falls under specific types of tests. For example, when you become accredited to tensile testing per ASTM D3039 you are automatically accredited to all similar tensile testing, such as ISO 527 and ASTM D638.

1 // An Intertek technician performs tensile testing according to ASTM D3039 as per Nadcap requirements

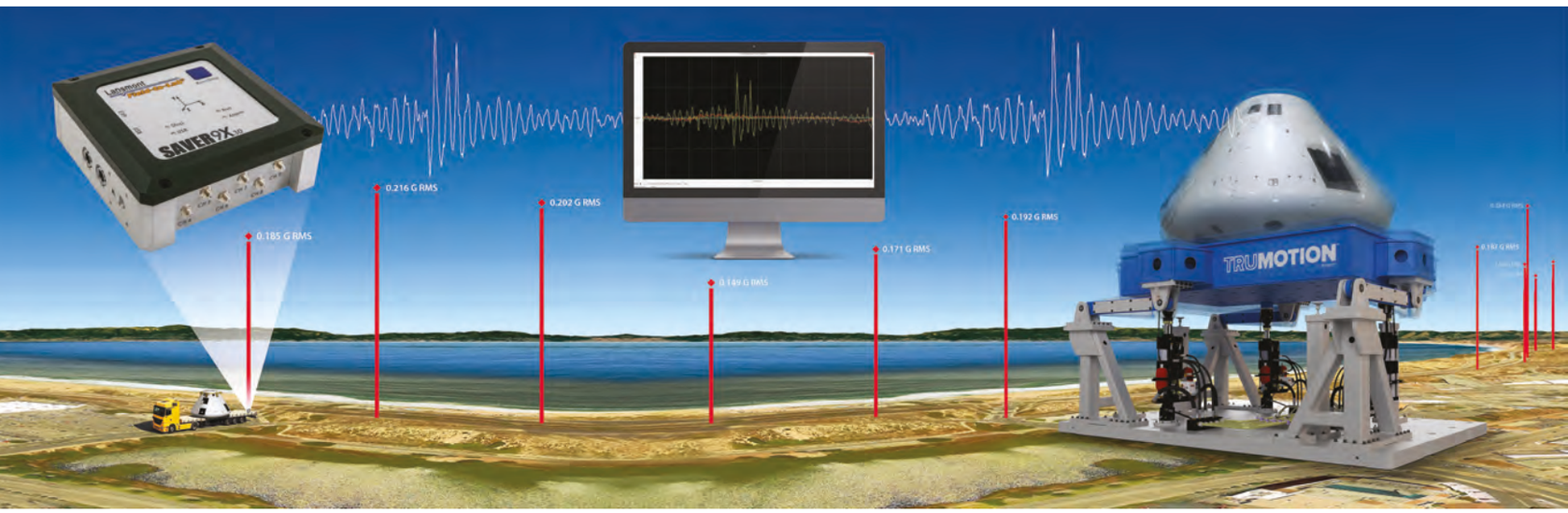
Another key difference is that a Nadcap audit requires live tests. When an on-site audit is conducted, 75% of the tests that are on the certification scope are selected and witnessed.

Nadcap accreditation also covers additional procedural requirements outside what is stated in a test method. One such procedural requirement is the traceability of test specimens. When a test panel is made and is about to be machined into test specimens, it has to be marked and photographed in such a way that the panel can be reconstructed once testing is complete. Non-ambient testing also requires the use of two thermocouples, one attached to the test specimen, gauge length permitting, and the other near the specimen and the temperature gradient being monitored. Additional requirements for tensile and compression testing are also stated in the Nadcap procedure and must be demonstrated during the audit.

So the question still remains: what certification should I pursue?

Both certifications ensure that a testing facility is up-to-date with its calibrations and performing testing accurately. They both check that procedures are following the applicable test method or internal work instructions. However, even though both certifications are perfectly acceptable, one will be more appropriate for you than the other and that is dictated by the industry. If you are planning on pursuing the aerospace or defense industry, then Nadcap is your obvious choice. Other industries, such as automotive or medical, will be more interested in ISO/IEC 17025 certification. \\

Matthew Brady is a former engineer at Intertek



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TESTING FOR TRANSPORTATION

Guaranteeing the integrity of an aerospace product after delivery has become easier with the latest sensors and analysis software

// **DAVE HUNTLEY**

Aerospace products are designed and tested to thrive in harsh environments. However, transportation hazards are difficult to avoid while moving assets. In many cases, inputs that occur when moving over roads will differ dramatically from those experienced during flight. Something as simple as the orientation of a product in a vehicle can cause issues. Input dynamics and load paths will differ and can result in unique or unexpected strains and stresses. Establishing a clear and detailed understanding of dynamic transportation conditions can help ensure that products arrive in good working order.

A transportation environment is dynamic and will differ according to geography, season, vehicle type, vehicle load and many other factors. Fortunately it is possible to record and characterize environmental transportation modes and routes accurately. This enables the development of more representative pre-shipment tests and simulation procedures. Confidence evolves from tests, and the best tests evolve from the best data.

DYNAMIC HAZARD MEASUREMENT

Lansmont's Field-to-Lab methodology measures the dynamic hazards present in the field, then uses those measurements to drive laboratory testing and simulation to generate results that are close to reality. The company's Shock And Vibration Environmental Recorders (SAVERs) are used to continuously measure and record a transportation route. The SAVERs record when the dynamic conditions exceed a user-defined threshold and wake up at periodic time intervals to sample ambient dynamic conditions.

SAVERs can record thousands of time-domain waveform events, with pre-trigger, temperature, relative humidity, atmospheric pressure and GPS coordinates that can establish statistically significant real-world baseline conditions. An engineer can observe an actual product during its distribution, pilot a pre-distribution run, validate a product, or evaluate a protective solution using the measurements.

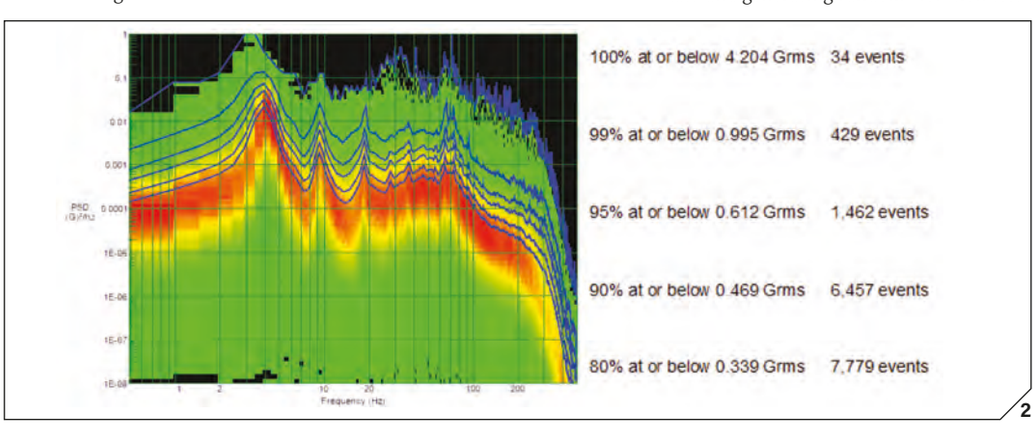
1 // The SAVER continuously measures the dynamic hazards in the transport environment. The resulting data can be directly used to drive laboratory simulation

2 // Example graph of Constructed Probability Spectra Analysis generated from transportation data of an aerospace product

Lansmont's SaverXware software facilitates the Field-to-Lab process by quickly filtering data to important events. A simple health-reporting feature provides in-the-field data analysis, so the user can quickly document and define the shock, drop/impact, vibration, temperature, humidity and atmospheric pressure experienced on a transportation route. These reports take minutes to generate and are currently used by several large aerospace contractors to facilitate the hand-off from one organization to another.

ADVANCED ANALYSIS

Constructed Probability Spectra Analysis is a new technique for analyzing vibration data and generating random vibration test



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"CONFIDENCE EVOLVES FROM TESTS, AND THE BEST TESTS EVOLVE FROM THE BEST DATA"

profiles from field data. The analysis allows detailed understanding of the distribution of intensities, as well as the amount of time experienced within the range of intensities. Measured data possessing the signature of vehicle motion is selected for the summary analysis. Each summary event is processed into an individual power spectral density (PSD) and with the summary event population accurately defined, vibration intensity information is aggregated across that entire data set.

A single frequency analysis line from within the targeted measurement bandwidth is selected and the user looks across all the selected events and notes each PSD level. This enables a summary of the PSD levels into a distribution, which depicts how many times each PSD level was encountered at this frequency.

Each of these distributions represents what happened in terms of a PSD level at a given frequency. Once the probability map has been created across all the frequency bins, each frequency is examined and a PSD level estimated to encompass a given percentile of the data. That information is used to construct a profile. Color is used to represent the number of times a PSD level was observed at each frequency. The colors correspond to the event range of occurrence (Figure 2) – from green for a few events, to red for lots of events, with black indicating no observation.

Overlay traces indicate the constructed probability profiles at 80%, 90%, 95%, 99% and 100% at or below PSD levels. These profiles represent the probability that an encountered PSD level will be at or below the profile in the event population.

Constructed probability analysis reporting provides a powerful new tool that brings clarity to the interpretation of vibration data originating from distribution environment measurements. Constructed probability reports create actionable summaries that can help describe a given environment and drive laboratory testing.

Aerospace products originate from complex designs and their response to dynamic inputs are correspondingly complex. It's critical to understand not only how those designs will respond to controlled engineering test inputs, but also how they will respond to the complex inputs they will encounter during transportation.

The final step, once protective transportation solutions have been developed and validated, is to monitor the actual transportation of assets to ensure established design limits are not exceeded. This becomes an ongoing business process with the benefit of simple health reports to provide a go/no-go report that helps automate shipment acceptance and provides documented environmental exposure summary for every shipment. That simple summary provides confidence for mission-critical functionality. \\

Dave Huntley is president of the Lansmont Corporation

1

TESTING ON DEMAND

A range of EMC, temperature and climatic testing chambers that take up the minimum space possible provide engineers with the assurance they require

// RALPH THEISS

Whether they are satellites, commercial airliners or helicopters, modern air and space vehicles are exposed to extreme stress during use. German company Weiss Technik has the knowledge and experience to ensure that aerospace companies can be confident that their products will meet the requirements of their operating environments.

The company's environmental test chambers are a key part of the development, quality assurance and production of both proven and new technologies, materials, the components themselves and the entire system. This is perhaps the most important aspect of the aerospace sector.

ENVIRONMENTAL TEST

Weiss Technik's test systems for environmental simulation can accurately recreate environmental influences from around the world. Components can be tested under real load for functionality, quality, reliability, material resistance and service life. The LabEvent laboratory test chambers can test the functionality of a product when exposed to specific temperature and humidity conditions from -70°C to +180°C (-94°F to 356°F).

There are several advantages to testing components in an environmental chamber in this way. For example, malfunctions can be detected and handled at an early stage, enabling cost and time savings during development. Limited laboratory space and the need to test smaller samples in the workplace often call for compact and quiet instruments. LabEvent test chambers are available in nine sizes, ranging from 20-500 liters. Most are available as benchtop chambers. All 40 device variants in the range meet the latest directives for fluorinated greenhouse gases by using the eco-friendly refrigerant R449A.

OPERATION BY SMARTPHONE

The test chambers can be remotely operated by tablet or smartphone via the innovative WEBSeason user interface. It provides the capability to control and monitor tests at any time, anywhere.

1 // Weiss Technik's LabEvent chambers can test parts under realistic temperature conditions

2 // The LabEvent chambers have a small footprint of less than 1m² (11ft²) and capacities of up to 500 liters

Language and units can be set to suit the user and the settings can be saved. The WEBSeason user interface provides flexibility and is easy to use.

As an option, the test chambers can be equipped with the SIMPATI programming and logging software to provide optimal operation of environmental simulation tests. Up to 99 systems can be connected and programs can be created to automate processes. The SIMPATI software also enables the storage of measurement data and the archiving of documentation.

STRESS SCREENING

The latest features to be introduced to the test chamber portfolio include

"THE TEST CHAMBERS CAN BE OPERATED BY TABLET OR SMARTPHONE"

2

environmental stress screening (ESS), where the temperature within the chamber is changed at a rapid rate of up to 10K/min.

High product reliability is a basic requirement in today's competitive marketplace and is often the only difference between manufacturers. The reliability of electronic products can be substantially improved through the use of ESS techniques. They can help minimize the risk of errors and the failures of components, avoiding electrostatic discharge and ensuring their electromagnetic compatibility while simultaneously improving the reputation of an organization.

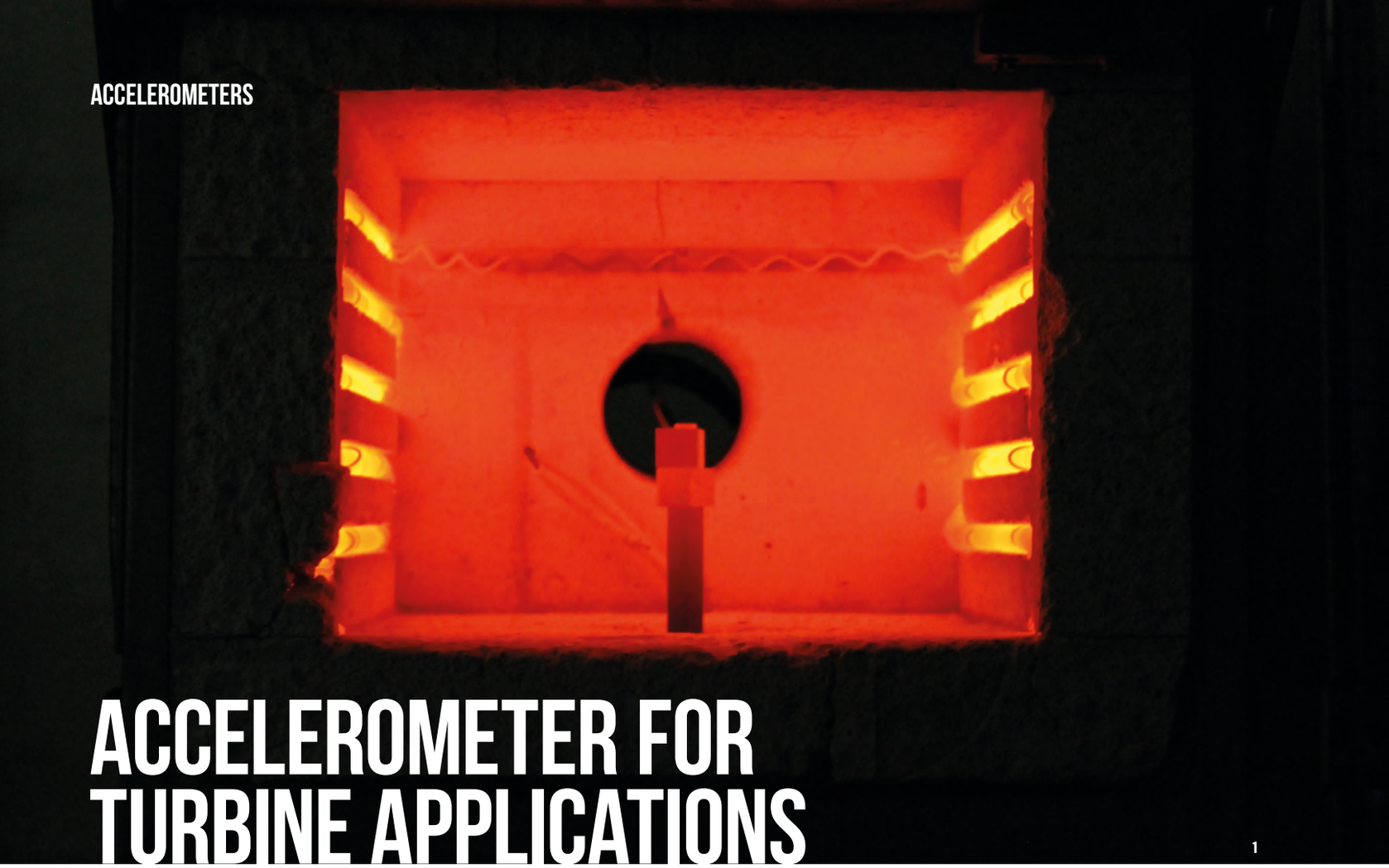
Weiss Technik has also recently introduced a cost-effective 150 liter climate test chamber to its range.

All the test chambers in Weiss Technik's LabEvent range are in compliance with test standards including DIN-, ISO-, MIL-, IEC- and ETSI. Weiss Technik's engineers continue to develop the range to ensure this remains the case.

Complemented by the latest technologies and enhanced by innovative software, Weiss Technik's LabEvent range of test chambers provides a solution for reproducing testing conditions in R&D, while meeting the operational and regulatory requirements of one of the most demanding industries.

The Weiss Technik companies are part of the Schunk Group. With 22 companies in 15 countries, Weiss Technik can provide support to customers around the world. The products under the weisstechnik brand also include environmental simulation and air conditioning as well as containment solutions.\\

Ralph Theiss is product manager for small volume chambers with Weiss Technik



ACCELEROMETER FOR TURBINE APPLICATIONS

1

The Model 3262C is a versatile, robust and innovative ultra-high-temperature accelerometer

// **PABLO FERREIRO**

Dytran Instruments recently introduced its Model 3262C, an ultra-high-temperature accelerometer suitable for turbine testing in aircraft and stationary installations.

The Model 3262C differential output accelerometer can operate in environments of up to 1,200°F (649°C) and can be used in the extreme and harsh conditions found in the hottest section of turbines on aircraft. The sensor has been specifically designed to reduce inputs from random non-vibrational stimuli, such as temperature transients, base strain, magnetic or electromagnetic interference, and acoustic noise, making it well suited for aerospace and industrial testing.

This accelerometer incorporates Dytran's most innovative advances in high temperature technology, including the proprietary treatment of Lithium Niobate, patented Silver Window™ technology to prevent oxidation issues, and the differential mode design.

Material selection was critical in achieving an ultra-high temperature design. Lithium Niobate is one of the few piezoelectric materials that can work at 1,200°F (650°C) continuously and up to 1,400°F (760°C) in excursions. It has the greatest piezoelectric sensitivity compared with other high-temperature crystals of around 80 pC/Newton. Our proprietary treatment eliminates the crystals' sensitivity to the pyroelectric behavior inherent to the crystallographic group of materials, enabling them to perform well at temperatures of up to 1,400°F (760°C).

1 // The Model 3262C accelerometer can survive the ultra-high temperatures found in HALT HASS chambers

2 // Graph showing the frequency response for the 3262C accelerometer

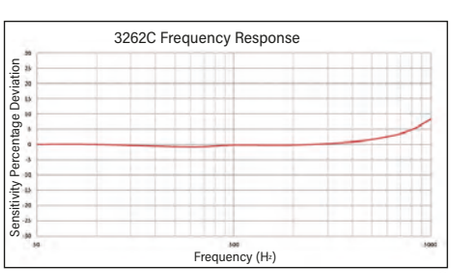
3 // Graph showing the insulation resistance for the 3262C accelerometer, which is improved by the patented Silver Window treatment

4 // Graph showing the high-temperature response of the 3262C accelerometer

This material is designed to work in shear mode which results in a larger piezoelectric output. With proper crystal orientation, the material becomes less susceptible to strain from the mounting surfaces.

Another important aspect of the high-temperature piezoelectric material for both single crystal and piezoceramic, is a loss of oxygen when the temperature goes above 700°F (371°C). The oxygen loss puts the piezoelectric material in a condition that reduces its insulation resistance properties and makes it more electrically conductive. The reduction of insulation resistance can reach values in which standard commercial charge amplifiers cannot work properly.

The best way to counter the reduction of the insulation resistance of piezoelectric materials at high temperatures is to allow oxygen back into the piezoelectric crystals. Dytran developed Silver Window technology to produce a constant supply of oxygen to the interior of the sensor housing that is activated only when



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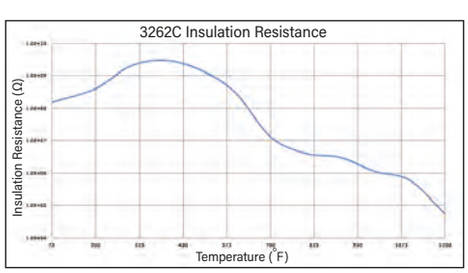

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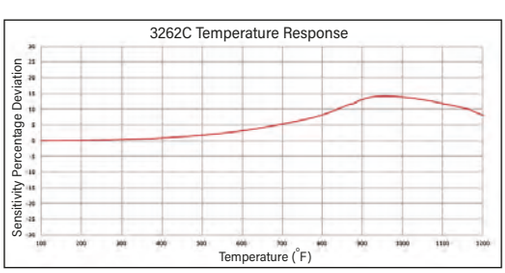

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5 // The Model 3262 accelerometer has several innovative features, including a rugged hardline cable

"THERE ARE FEW PIEZOELECTRIC MATERIALS THAT CAN WORK AT 1,200°F"

operating at high temperatures. The technology incorporates a patented metallic Silver Window, that allows diffusion of oxygen from the exterior of the housing and supplies it to an Oxygen depleted sensor. A sensor made with Silver Window technology is still hermetically sealed, as the silver metal allows diffusion only through the metal matrix and the sealing of the sensor is hermetic in nature.

Another innovative feature of Model 3262C is its capability to operate in differential mode, keeping the metal housing of the sensor electrically isolated from the internal structure. This helps to reduce the noise level, when coupled to a differential charge amplifier, while giving more resolution to the measurement, and keeps ground loops from entering and distorting the vibration signal.

Model 3262C features an integral hardline cable that has a silicon dioxide mineral insulator. Silicon dioxide is non-hygroscopic, and the hardline cable is laser welded to create a robust bonding. A strain relief is incorporated into the hardline cable to avoid excessive bending of the cable close to the weld, near the sensor housing. The whole sensor is robust and features laser welds and super-alloy metal components designed to last through a multitude of harsh testing environments.

The 3262C can be used in a variety of applications where durable, ultra-high-temperature accelerometers are needed, such as engine test cells, turbines and large diesel engines. Its mounting base is designed for these kinds of structures, with a robust tri-bolt ARINC mounting base and outstanding resistance to thermal shocks during temperature excursions.

The Model 3262C is also suitable for vibration health monitoring on helicopters and other aircraft. The determination of the condition indicators for proper maintenance requires the installation of sensors in harsh environments within the aircraft's systems. The 3262C is suitable for these extreme heat environments, having been designed for long-term high-temperature testing. \\

Pablo Ferreiro, is a R&D engineer with Dytran

AIRBUS INAUGURATES ÄLVDALEN FIRING RANGE WITH H145M

1

2

The Swedish Defence Materiel Administration's Test and Evaluation Division has recently opened up the Älvdalen firing and exercise range for users other than the Swedish Armed Forces

// JONAS LINDE

The first international customer for the new Älvdalen firing and exercise range was Airbus Helicopters. The company wanted to perform its first firing trials with 70mm FZ275 laser-guided rockets (LGR), which were developed by FZ Thales Belgium, from an H145M helicopter. The H145M was equipped with the Airbus HForce system.

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

The main issue for the PtF was that the test aircraft was an EASA-certified design. EASA generally does not manage weapon installations and permits to fire. However, this issue was solved through good cooperation between FMV FTC, Airbus's airworthiness expertise, the Swedish military flight safety directorate (FLYGI), the Swedish CAA (Transportstyrelsen) and the German office for Civil Aviation (LBA). The permissions were issued in two steps. The first only concerned the ferry flight from Donauwörth in Germany to Älvdalen in Sweden. Permission for the use of the weapon system – including live firing and the use of the laser – was gained at the very start of the campaign.

There are always challenges when live firing weapon systems. For the Airbus LGR, the weapon danger areas fitted well within the perimeters of the Älvdalen range. Setting a laser danger area is generally more difficult, but the remote location of Älvdalen helped and the hilly terrain also contributed to establishing the laser danger area.

The campaign was performed late in 2017 and under rather harsh weather conditions. To accommodate the needs of Airbus Helicopters, FMV FTC arranged for a large tent hangar and a purpose-built target to be constructed.

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

1 // An Airbus H145M helicopter over Älvdalen, Sweden

2 // The hardened target area at Älvdalen

THE ÄLVDALEN FIRING AND EXERCISE RANGE

The 540km² (200 square miles) Älvdalen range is large enough to allow live firing with almost any weaponry that can be fitted to a helicopter – laser-guided rockets such as Hellfires and Stingers, for example. The remote location also permits the use of lasers and the possibility to perform live navigation and communications jamming. During the winter, Älvdalen is an excellent range for night-vision goggles and cold climate trials and exercises.

The range also has a specially prepared hardened target area, which is an ideal place to set up static targets or for different kinds of moving targets. The size of the range allows performance of realistic test or training scenarios.

FMV FLIGHT TEST CENTRE

The FMV FTC is the DT&E (Design Test and Evaluation) branch of the Swedish Defence Materiel Administration's Test and Evaluation division. FMV FTC is

"THE RANGE IS LARGE ENOUGH FOR THE LIVE FIRINGS OF ALMOST ANY WEAPONRY SUITABLE FOR A HELICOPTER"

responsible for performing DT&E and T&E of all aerial systems procured by the Swedish Air Force.

During more than 80 years of service, FMV FTC has gained experience in almost every aspect of T&E, from component and subsystem verification and validation to top-level system-of-system interoperable capability T&E.

FMV FTC performs a variety of T&E projects, from acceptance testing of new fighters and helicopters to advanced weapons and electronic warfare (EW) integration and capability trials.

ELECTRONIC WARFARE

Experience from recent conflicts and especially operations at Donbas in Eastern Ukraine has underlined the importance of mastering all aspects of EW. FMV FTC has extensive experience in T&E of EW systems and is also hosting the SALT (Surface-to-Air Launch Trial) live-fire trial series at the Vidsel test range, where target seekers and countermeasures are being tested head-to-head.

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3 // A purpose-designed target for FZ275 rockets at the Älvdalen range, Sweden

Another area that has grown in importance recently is jamming, including navigation, communications, radars and other sensors. FMV FTC operates a number of ground-based and airborne jamming systems and at the available test ranges can stage test and training scenarios under jammed conditions.

Another important issue is the radar and IR signature from the aircraft itself and from dispensed chaffs and flares. FMV FTC has the capability and knowledge to measure and verify such characteristics.

FUTURE

The coming years will bring several interesting projects for FMV FTC, with the Echo version of the JAS39 Gripen as the largest challenge. FMV FTC is also in discussion with the international fixed- and rotary-wing community about upcoming opportunities. Plenty of interesting projects are in the pipeline.

Jonas Linde is director of marketing & Sales, senior flight test Engineer, with FMV T&E, Swedish Defence Materiel Administration

AUTOMATED X-RAY INSPECTION

Aerospace parts are often complex and demand highest inspection quality using digital radiography

// LENNART SCHULENBURG

Many manufacturers and service-providers are still using analog film, which is expensive, time-consuming and requires the use of poisonous chemicals, to inspect aerospace parts.

In the past there was no alternative to film for x-ray inspection of complex aerospace parts while fulfilling demanding quality requirements, but the latest advances in digital detector technology have changed this fundamentally. Modern detectors are not only reliable but deliver crisp images at very high resolution. In a migration from film to digital, the time, labor, consumables and storage space savings justify the investment. It also allows the use of CNC-capable systems or even robots to automate the process.

Low volume and high variation between parts is the second challenge when automating x-ray inspection process. Off-the-shelf systems are not able to cover all the required test positions most of the time. Customized solutions that use advanced manipulation systems such as overhead gantries or robots are required. Such systems are tailored toward a specific application and are often designed for just one customer. Nowadays automation is mandatory to stay competitive and mitigate a significant lack of skilled inspection personnel.

Digital detector technology has improved a lot recently and led to broad use in non-destructive testing (NDT) applications. Modern detectors are compliant with aerospace standards such as ASTM E 2737 and E 2597 and have a long lifetime. This durability and radiation hardness makes the return on investment much faster. All major aerospace OEMs have developed their own digital x-ray requirements, which enables suppliers to qualify their processes accordingly. The transition from film to digital is easier than ever, but having an experienced partner makes it easier still. VisiConsult can deliver the system and takes care of the whole process from inquiry all the way to final approval. NDT managers benefit from more than 20 years of experience and precertified systems.

"AUTOMATION IS MANDATORY TODAY TO STAY COMPETITIVE"

1 // The XRHGantry is a roof mounted nine-axis inspection system

2 // To deal with high volume, inspection systems can be equipped for robotic loading

3 // An operator inspecting a turbine blade in the VisiConsult XRH222

ONE-STOP SHOP FOR X-RAY

As well as complex customized solutions, VisiConsult offers high-end (micro) computed tomography (CT) systems, portable solutions and standard inspection cabinets, which share a common user interface and operating system.

Operators need only one training session to use all the equipment types. VisiConsult offers more than 60 digital

3

detectors to meet the needs of a wide range of applications. Following a new customer inquiry, application engineers at VisiConsult perform a detailed analysis to distinguish the right combination of subcomponents based on the resolution, form factor and cost requirements.

QUALIFICATION AND RELIABILITY

Particularly in the aerospace industry, qualification processes are not easy to master. Leading programs such as NADCAP require compliance with an 80-page checklist and all major OEMs have developed their own specifications.

VisiConsult has extensive experience with these requirements and makes sure all its solutions are pre-approved.

Customers benefit from this vast experience as VisiConsult shares this knowledge and experience while working on a project. The job is not finished when a system is installed, but when it is qualified.

In a globalized world, service is more important than ever. VisiConsult has employees in Germany, France, the USA, Denmark, India and Brazil to support customers in different time zones. They are complemented by a global network of partners, trained in sales and service. This allows local language first-level support worldwide, while VisiConsult's service team is always in the background to support customers with remote support.

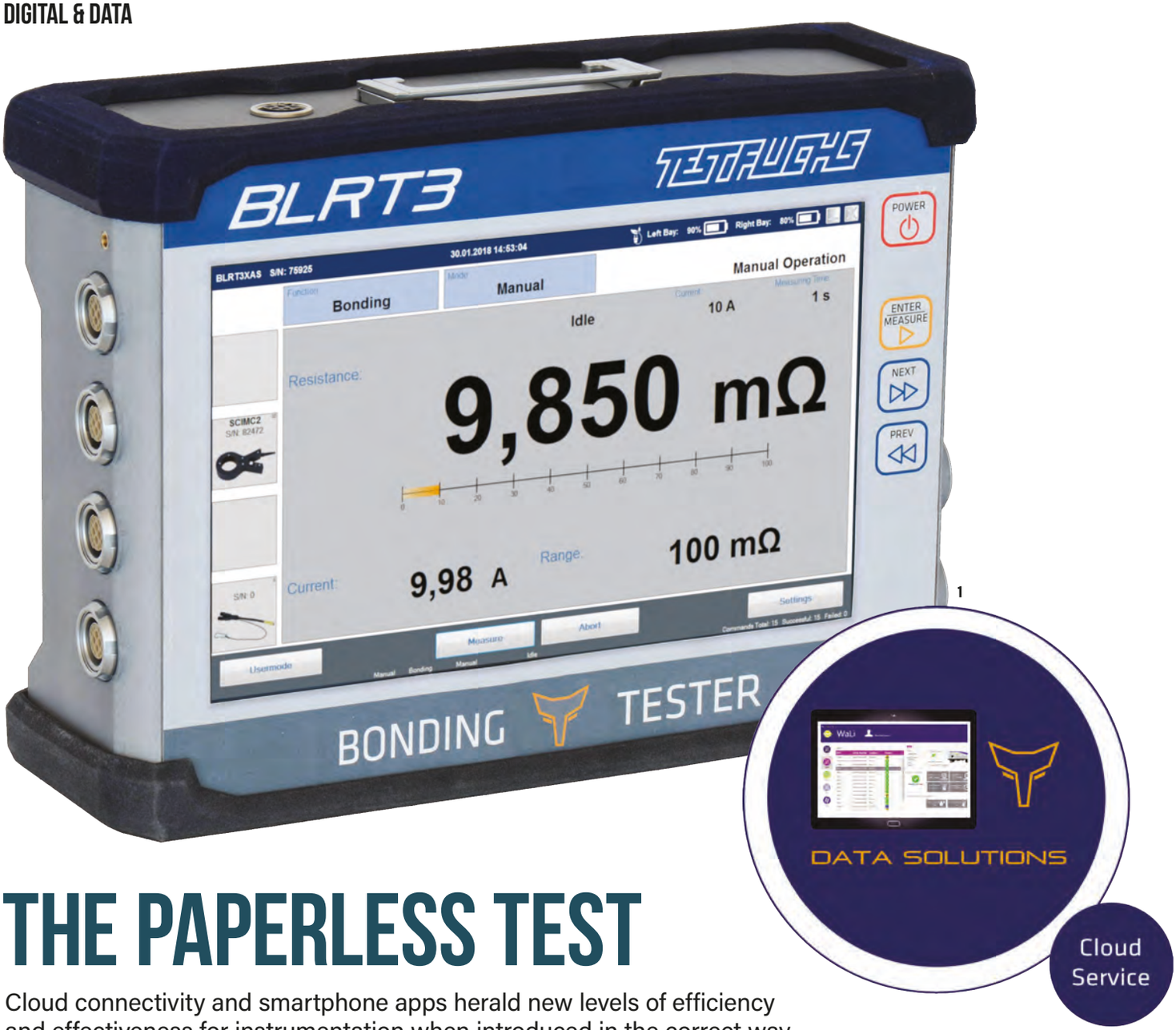
SUCCESS STORY: MRO

Aerospace manufacturers already deal with part complexity. Even more challenging is the maintenance, repair and overhaul (MRO) environment, as a wide variety of parts can be supplied.

VisiConsult has developed a solution with flexibility and the highest degree of automation for a German MRO company. The roof-mounted XRHGantry has nine independent axes and is located in a spacious x-ray protection room. The system is programmed using joysticks or handheld remote. All programs can be saved and replayed using the system's CNC-capable and encoded drives. Thanks to this, inspection time for a fan case can be reduced from more than 10 hours to less than an hour without compromising quality. The system passed Rolls-Royce and Airbus audits without any problems and has completely replaced the use of film.

A second system is planned to be installed later this year. To complement the setup, the maintenance provider also has an XRH222 standard cabinet for smaller parts such as nozzles and turbine blades. \\

Lennart Schulenburg is sales and marketing director at VisiConsult



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THE PAPERLESS TEST

Cloud connectivity and smartphone apps herald new levels of efficiency and effectiveness for instrumentation when introduced in the correct way

// URSULA RABI

The Internet of Things has been a buzzword for years and we still laugh about the tweeting washing machine or the self-ordering fridge. Nevertheless, these first appliances have enabled further research and development, while more and more useful applications for the industry have evolved.

In an ideal world, analog devices could simply be transformed to digital devices by the use of micro-controllers. But this would just mean we have a different type of what was used before, when there are many more gains that can be made by transitioning to digital.

Test-Fuchs works intensively with partners to optimize processes for gaining economical and time advantages. In the field of resistance testing, the company finds a lot of things that could be improved. Much has been learnt about how lightning can affect airplanes. As a result protection techniques have improved, but the testing method has stayed the same. Engineers often still use analog instruments, which are difficult to handle and are heavy. They write their results on printed forms with a pen – a slow and inconvenient procedure.

INTUITIVE AND ACCURATE

With the new Bonding and Loop Resistance Tester (BLRT3), Test-Fuchs aims to accelerate the testing possibilities for bonding or loop resistance. The customizable interface provides users with the necessary test information from the manual, which is uploaded from laptop or server. Single test results are stored on the device, with no pen or paper required, and transferred back to the original place. The BLRT3's simple and intuitive design and usage without paper reduces the risk of wrong data and errors.

1 // The BLRT3 bonding tester has a customizable interface and a simple, intuitive design

The BLRT3 generates accurate results on complex measurements. Four different ports speed up testing with different clamps suitable for alternate touchpoints. The device automatically detects which clamp is connected. All of the parts are independent from each other, so clamps can be replaced or calibrated without interrupting the testing procedure.

CLOUD AND APP CONNECTIVITY

It would not be a Test-Fuchs device if the feature-set stopped there. The technicians have worked on alternative display solutions and now testing can be executed via a smartphone app.

"PAPERWORK AND OUTDATED STORAGE SYSTEMS ARE NO LONGER NEEDED"

Simultaneously, the company's innovation department took BLRT3 and connected it securely to the cloud. The challenge here is to have all of the key factors in place so the documentation is consistent and comparable. The BLRT3's cloud feature is the first time Test-Fuchs has made the live database entries of all measurements and live statistics from a device, accessible not only on the actual device.

2

2 // The web interface enables remote management of BLRT3s

The service, which is called Data Solutions, allows for active fleet management of devices and clamps and saves costs for calibrating and service control. Updates for all devices can be deployed centrally.

Data Solutions enables data to be analyzed in completely different ways than in the past. Correlation between single measurement points and methods can be calculated. In addition, recurring errors are detected much earlier and much more simply. A graphic illustration of single points and connecting lines makes failure detection simpler and contributes to improving safety.

Data Solutions and BLRT3 are making it easier to switch from paper documentation to electronic records by providing more value. Time-consuming paperwork and outdated storage systems are no longer needed. Required data research and audits become much easier; quality and transparency improves throughout the entire process. For engineers, the solution enables faster measuring and intelligent features as guidance, while second displays and hands-free working makes their tasks easier to perform.

The aerospace industry shows few limits on its ambition to push the envelope and Test-Fuchs is one of a few suppliers that has proven it can provide superior aerospace test capabilities to the entire world. The company has nine service offices in Europe and Asia and just recently set up a production line at its newest facility in Cleveland, Ohio.\\

Ursula Rabi is marketing and sales assistant with Test-Fuchs

MINI-ACCELEROMETER MAKES A MIGHTY HUM

1

Miniature accelerometers and the lightweight expandable rotorcraft diagnostic system combine to make a leading health and usage monitoring system

// LANCE ANTOLICK AND BOB METZ

Health and usage monitoring systems (HUMS) enable effective predictive maintenance strategies in helicopters and fixed-wing aircraft. Early HUMS were a pioneering effort that proved the benefits of the technology. But these early systems came at a high cost in dollars and weight added to the aircraft. These disadvantages limited the implementation of front-line strategies to reduce maintenance costs.

Next-generation HUMS provide more capabilities at a lower cost and weight. Modern HUMS improve safety by alerting maintenance personnel to drivetrain health issues and reduce costs by helping to eliminate precautionary landings and minimizing unscheduled downtime. Additionally, combining these features with flight data to support Safety Management Systems leads to reduced insurance costs.

HUMS enable the recording of flight conditions in excess of approved flight parameters, and they give the ability to check aircraft health status during and after each flight. Typical helicopter HUMS applications include rotor track and balance, shaft balance, monitoring of transmission and engine vibration, and bearing diagnostics.

Modern HUMS comprise a data acquisition device with an onboard processor and high-quality measurement sensors. One leading example is HUMS-supplier RMCI's expandable rotorcraft diagnostic system (XRDS), which measures data using piezoelectric ICP accelerometers, such as PCB Piezotronics' (PCB) Model 355A44 case isolated high-frequency design.

ICP piezoelectric accelerometer technology is a widely accepted standard used in HUMS. These accelerometers are not only easy to adapt to qualification requirements such as MIL-STD-810 and DO-160, they are also optimized for the performance and reliability requirements and packaging particulars of the aircraft platform. PCB developed ICP technology in the mid-1960s, and it has grown into an industry standard. The more generic description of this technology is 'integrated electronic piezoelectric' (IEPE).

1 // PCB's HUMS accelerometer model 355A44 and RMCI's easy-mount method

2 // RMCI's state-of-the-art expandable rotorcraft diagnostic system (XRDS) mounted in the cockpit of a Sikorsky helicopter

The Model 355A44 accelerometer incorporates a microelectronic amplifier that converts the high-impedance charge output from the piezoelectric sensing element into a low-impedance voltage signal. Using hermetic packaging, the high-impedance circuitry is sealed and electrically case-isolated inside the accelerometer. This approach provides excellent performance in the high electromagnetic interference environment common to helicopters. These sensors also have the ability to pass the various environmental and lightning category tests of DO-160.

HUMS accelerometer specifications differ depending upon the particular airframe and desired mounting location. Typical considerations for accelerometer selection include a high resonant frequency for rotating part diagnostics, as well as accurate low-frequency phase data for rotor track and balance. PCB's Model 355A44 features an internal shear mode element that limits strain from irregular mounting surfaces, uses reliable hermetic

"PIEZOELECTRIC ACCELEROMETER TECHNOLOGY IS A WIDELY ACCEPTED STANDARD USED IN HUMS"

2

connectors, and includes a cable that is oil-resistant. The accelerometer also features a single-bolt mount that enables easy installation and cable alignment. This mount is ideal for difficult installation locations, such as on a helicopter transmission. RMCI's through-hole easy-mount solution provides for a safety wire attachment that secures the accelerometer for flight operations (Figure 1). The PCB accelerometer is powered directly by RMCI's XRDS product.

HIGH QUALITY DATA CAPTURE

RMCI's latest HUMS (Figure 2) exceeds the capabilities of legacy on-aircraft monitoring systems. Leveraging PCB's new, advanced sensor and RMCI's patent-pending sensor mounting approach, the XRDS hardware is capable of capturing high-quality vibration data from critical aircraft components.

The XRDS HUMS includes powerful ground station software. The software provides superior analysis functionality to extract actionable information from a wide variety of data. The total XRDS system provides mechanical diagnostics, flight data monitoring (FDM) with regime recognition, and advanced rotor track and balance capabilities. The software architecture supports the integration of performance data and custom, platform-specific algorithms and methods for advanced FDM and flight operations quality assurance. The XRDS solution is certified, commercially available, and currently flying on nine different aircraft models, including both helicopter and fixed-wing platforms.

The RMCI hardware and software system acquires various types of flight, performance and health data. The system then processes the data to produce metrics and maintenance actions to provide the user with timely and accurate feedback via a single interface.

The XRDS solution provides operators with the maximum benefit from aircraft data – at a fraction of the weight and cost of legacy systems. \\

Lance Antolick is vice president of engineering services for RMCI and Bob Metz is director of aerospace and defense at PCB

ELECTRIC AIRCRAFT PREPARE FOR TAKE-OFF

The tightening safety requirements for the use of lithium-ion batteries in aerospace applications make accurate, robust and secure-containment testing chambers a necessity

// BY REGIS PERRAUX

1

The era of the electric aviation pioneers will soon be over... Two years after the end of the round-the-world trip by the most famous exponent of this new form of aeronautics, Bertrand Piccard with Solar Impulse, projects for planes and subsystems powered by lithium batteries are growing. From onboard taxiing systems in landing gear and projects for futuristic taxi-planes, to planes able to carry several dozen passengers, electric propulsion is here to stay in the aeronautics industry.

This raises new safety issues. The use of batteries is not without its dangers and the number of incidents detected in other industrial sectors is increasing as their use becomes more widespread. The calculation is easy: the ferocity of a possible fire depends on the size of the battery used. Anecdotes of overheating telephones are nothing compared with electric car fires, which can occupy dozens of firemen for several hours.

In an advanced industrial sector such as aviation, the use of batteries therefore necessitates safety tests with a tolerance close to zero. At present there is only one solution to carry out these tests. Containment chambers are required, as the engineers need to work on the experimental results. The field remains very empirical.

Indeed, unlike other areas of aeronautics, computer modeling is still in its infancy and does not offer a high level of reliability. This is not the case for tests performed in a containment chamber. In these boxes, which measure several cubic meters, temperature variations can reach 2°C (35.6°F) per minute for every 100kg of load. Such conditions are not detrimental to pressure and hygrometry checks. These chambers are used in many fields and also in more specific cases such as for testing lithium-metal and lithium-ion batteries. Climats has over 15 years of experience in this field.

"CONTAINMENT CHAMBERS ARE REQUIRED TO TEST THESE BATTERIES"

1 // Climats' containment chambers offer reliable testing of lithium-ion batteries

The company already assembles chambers for the French Atomic Energy Commission and many subcontractors in the automotive sector. In 2018, chambers that are specifically designed to test batteries represented 25% of the company's turnover and a number of changes had to be implemented to cope with the increased level of demand.

The monitoring of the warning signs for thermal runaway in batteries leads to the creation of some far-reaching changes in the procedures used to secure chambers and batteries. However, "the possibility of thermal runaway originates in the chemical nature of the battery", says

CONTAINMENT CHAMBER SPECIFICATIONS

- Simulation of climatic environments between -90°C and +250°C (-130°F and +482°F)
- Humidity control from 5-98% between 10°C and 95°C (50°F and 203°F)
- Standard chamber from 140 to 1,800 liters
- 250 standard models and customized solutions

a project engineer from Climats in charge of the specific safety systems for batteries. The chambers must also be adapted to deal with the nature of the product to be tested and the predictable consequences in the event of an accident.

There are several types of safety measures, says the engineer, "They can be passive, such as the in use of materials able to withstand chemical attack, or active." It is the active security measures that require most expertise during installation. "They are more demanding and we must be able to adapt to every specification," he adds. "This ranges from the secure air locks to detection systems connected to an independent fire safety control panel according to the standards for fire systems.

"Attention must also be given to how the smoke, flame or gas detectors are fitted. Sometimes they need to be outside the chamber, which means taking air samples at certain strategic points."

Since 2011, to cope with these issues, Climats has opted to develop its skills, and in particular to monitor the installation of safety systems, in-house. The aim has been to eliminate any intermediary at critical points in its response to specifications.

Through this reorganization, Climats provides effective support to companies wishing to test their batteries or those of their suppliers. Beyond this, the experience acquired by Climats over the past 10 years enables the company to offer innovative solutions in line with the recommendations of the European Council for Automotive R&D (EUCAR), which are at the same time adaptable to its standard range of environmental chambers.

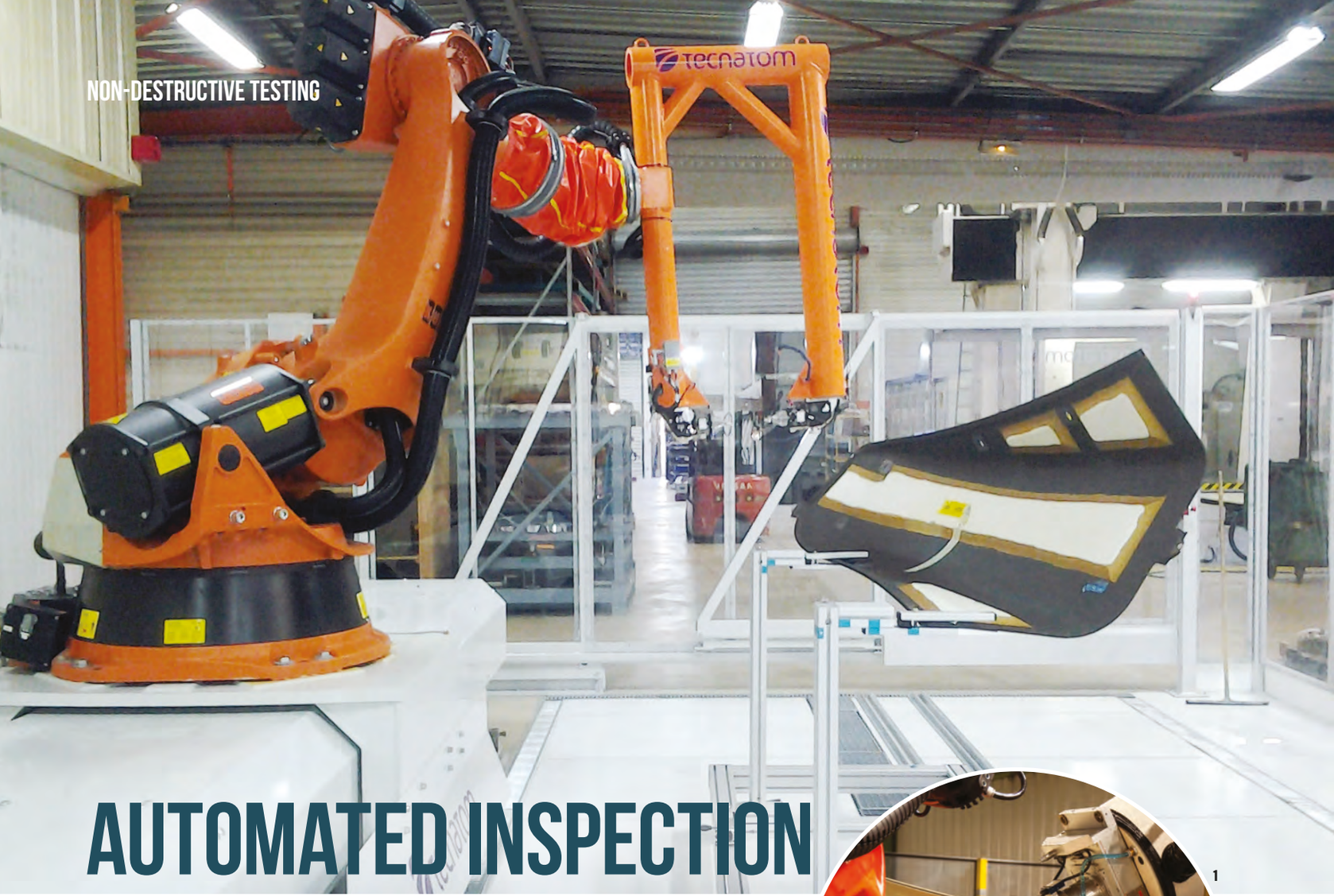
Lithium-ion batteries are gradually making headway into the aeronautics industry and the safety requirements for their use are increasing. The only testing technique that is currently capable of capturing all of the events that may occur in aircraft containing lithium-ion batteries is the use of containment chambers, which must be increasingly accurate, robust and secure.

Climats has been providing dedicated chambers for over 15 years and is an expert in services to integrators and battery developers. \\

Régis Perraux, sales and marketing director at Climats

LATEST HEAT TRANSFER FLUID HAS ENVIRONMENTAL BENEFITS

Climats' latest range of machines, called Excal², uses R 449A gas. This heat-transfer fluid achieves 99% of the characteristics of the same amount of R 404, while reducing the carbon dioxide equivalent global warming potential by 65%.



AUTOMATED INSPECTION

1

2

The latest industrial robots can be equipped with advanced NDT tools to offer aircraft makers and suppliers efficiency gains

// KOEN COMMISSARIS

Since its founding in 1957, Spanish multinational engineering company Tecnatom has provided ultrasonic non-destructive testing (NDT) systems and techniques for the nuclear power sector. Thanks to the experience and knowledge gathered over four decades in this sector, Tecnatom joined the aerospace market in the 1990s with several automatic NDT systems. It quickly positioned itself as one of the market leaders in advanced inspection engineering equipment. These first systems enabled the company to gain the trust of the major aircraft manufacturers and evolve its technology.

Tecnatom counts among its customers aircraft manufacturers such as Airbus, Boeing, Bombardier, Embraer, United Aircraft Corporation and Comac. It also works with some of the sector's most important suppliers, such as GNTP, KAI, TAI, Corse Composites, Premium Aerotec, Daher, Aernnova, Aciturri, Rolls-Royce, ITP and Strata, among others.

Tecnatom performs a range of activities relating to inspection engineering in the aeronautical sector. These include the design, manufacturing and supply of fully automated or portable NDT inspection systems for quality control during manufacturing or maintenance activities.

The company can also draw up the corresponding inspection procedures and provide expert consultancy services to meet the specifications and requirements of the client. Furthermore, Tecnatom offers upgrade services that can develop existing capabilities or incorporate new ones, as well as upgrade systems from manufacturers that no longer exist.

HIGH-QUALITY DETECTION

Tecnatom's robotic inspection systems use the latest mechanical technology, while providing high-quality detection and characterization of potential defects. These automatic, multi-technique robotic systems are supplied fully integrated with all of the tools necessary to cover the full inspection process, with just one operator using one computer.

The latest generation of Taurus robotic systems is suitable for use in the aeronautical sector. The automated system is designed for the ultrasonic inspection of aeronautical components using water jet through-transmission and/or pulse-echo phased-array techniques. It is based on an industrial robot arm mounted on a linear track. The pulse echo (PE) inspections are performed with a range of end-effectors. The through-transmission ultrasonic (TTU) inspections are performed with a yoke.

Taurus can provide coverage of a complete part, including geometrical features such as surfaces with double curvature, edges, cut-outs, radii, T or Ω stringers. In addition, the system can be equipped with functionalities such as a defect marker or a teaching laser scanner. The different inspection modules

1 // A Tecnatom robotic system inspects a part from Corse Composites

2 // The twin robot system is capable of scanning complex geometries

"PULSE ECHO INSPECTIONS CAN BE PERFORMED SIMULTANEOUSLY TO INCREASE THROUGHPUT"

can be easily mounted on to the machine using an automatic tool changer and its associated stand.

The Taurus robotic system can also perform ultrasonic inspections of parts made of carbon-fiber composite using the through air transmission technique. This method is essential for the inspection of special parts such as acoustic panels – because they have a core of paper, it is not possible to use water for the ultrasonic transmission.

Tecnatom's dual robot automatic inspection system, the Taurus Twin, is a flexible, multi-technique inspection system that uses a pair of cooperating robots to scan products with complex geometries. Scanning methods it can use include water jet coupled through transmission using both robots in cooperation, local immersion pulse echo, and phased-array using both robots independently.

3

Inspection times are optimized thanks to the high speeds of the robots.

The robots are also capable of conducting simultaneous TTU inspections and pulse echo inspections over parts. In dual-robot mode, pulse echo inspections can be performed on two parts simultaneously to increase throughput.

3 // The dual robotic system is capable of conducting several types of inspection at high speed

The complete inspection process performed by the robots includes: teaching/probing, scan path generation, post-processing, 3D simulation, complete system control and acquisition as well as evaluation and reporting.

Tecnatom's engineers continue to develop new features for its systems to improve their flexibility and multifunctionality. Features that have been recently added to the Taurus systems include active thermography and shearography, as well as metrology and eddy current inspection capabilities.

Aircraft manufacturers are always on the lookout for more versatility to cover their investments in automated NDT systems and Tecnatom aims to provide the best solution. \\

Koen Commissaris is business development manager at Tecnatom

OPTICAL MEASURING HELPS TO DEVELOP FUEL-EFFICIENT DESIGNS

1

The German Aerospace Center is using the latest optical measuring systems on its ATRA research aircraft to develop more fuel-efficient designs

// NATALIE STECULA

The German Aerospace Center (DLR) has several projects that aim to make aircraft more energy-efficient and eco-friendly. It is using an Airbus A320 called ATRA (Advanced Technology Research Aircraft) as a flexible experimental platform as a testbed for developing technologies that help reduce fuel consumption and thus environmentally harmful carbon dioxide emissions.

Experiments on ATRA have focused on the impact of the surface geometries of aircraft on the airflow resistance. It is essential to optimize the surface geometry to produce as little flow resistance as possible, to achieve improvements. The surface friction on the wings and fuselage slow down the aircraft, which results in an increased fuel consumption. The resistance depends on whether the flow surrounding the aircraft is laminar or turbulent. Whereas turbulent flows form a wider boundary layer because of the turbulences, laminar flows lead to a thinner boundary layer. The wider the boundary layer is, the stronger the frictional resistance, which has to be compensated with an increased fuel consumption. DLR's research activities therefore aim at minimizing the resistance by keeping the flow at a laminar level as long as possible.

LAMINAR TO TURBULENT

A part of ATRA's empennage was taped with a foil to show a defined roughness so the transition from laminar to turbulent flow could be researched. In addition, any waviness and other influencing factors, such as weld seams and rivets, were filled and straightened. Afterwards, the complete surface of the modified component was measured with GOM's optical measuring systems using non-contact techniques.

The 3D coordinates of ATRA's empennage were first measured with the portable Tritop system, which saved time and increased the measurement accuracy. Subsequently, the part was measured with the flexible Atos Triple Scan 3D measuring system, which was operated from a scaffold at the height of the wing to be measured.

GOM's measuring systems can be used under factory and production conditions by taking the measuring device to the object. The Atos Triple Scan's camera sensors and projection technology also meant it required a reduced number of individual scans. This accelerated the measuring procedure. A high-resolution and full-field representation of an area of 1.5 x 3m (5 x 10ft) was made available in less than 15 minutes.

The first measurement provided a precise representation of the wing geometry. Furthermore, the measuring results formed a basis for the subsequent

"THE RESEARCHED EFFECT CAN BE USED TO IMPROVE AIRCRAFT PERFORMANCE"

test series. For the next flight tests, the wing was further adjusted in an iterative process to represent the displacement of the transition point. For this purpose, thermographic measurements were carried out directly during flight. Five flight tests in total involving thermography have shown a positive effect of the geometry change. Modifying the roughness of the surface made it possible to displace the transition of laminar to turbulent flow and to visualize it.

The effect was visualized with the help of a thermographic measurement of the empennage. As turbulent areas cool down faster, significant thermal differences became visible on the infrared image. This method made it possible to identify the exact transition point of laminar to turbulent flow.

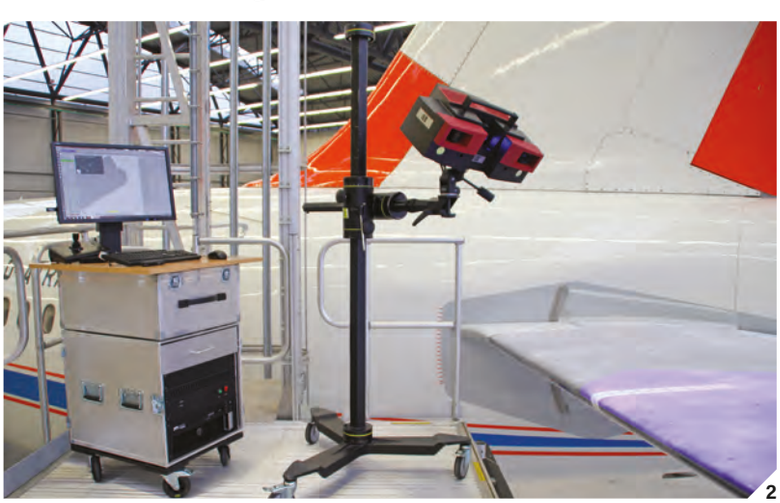
Following the last adjustment of the wing and the last infrared measurement, GOM's Tritop photogrammetry system and Atos Triple Scan were used once again to optically measure the part including the changed geometry. In this way, the researchers also obtained a representation of the empennage, including the geometry changes, and could directly compare it with the representation of the component's initial state.

The qualitative knowledge gained by DLR's aerodynamicists concerning the behavior of the flow around a wing's geometry could be applied to future wing and fuselage designs. As a consequence, the researched effect can be used to improve aircraft performance and to enable more energy-efficient and eco-friendly designs. \\

Natalie Stecula works in marketing at GOM Metrology

1 // GOM supports DLR in its aeronautical research by providing precise measurements of the part geometries

2 // Due to the Blue Light Technology, parts can be measured regardless of the ambient lighting conditions



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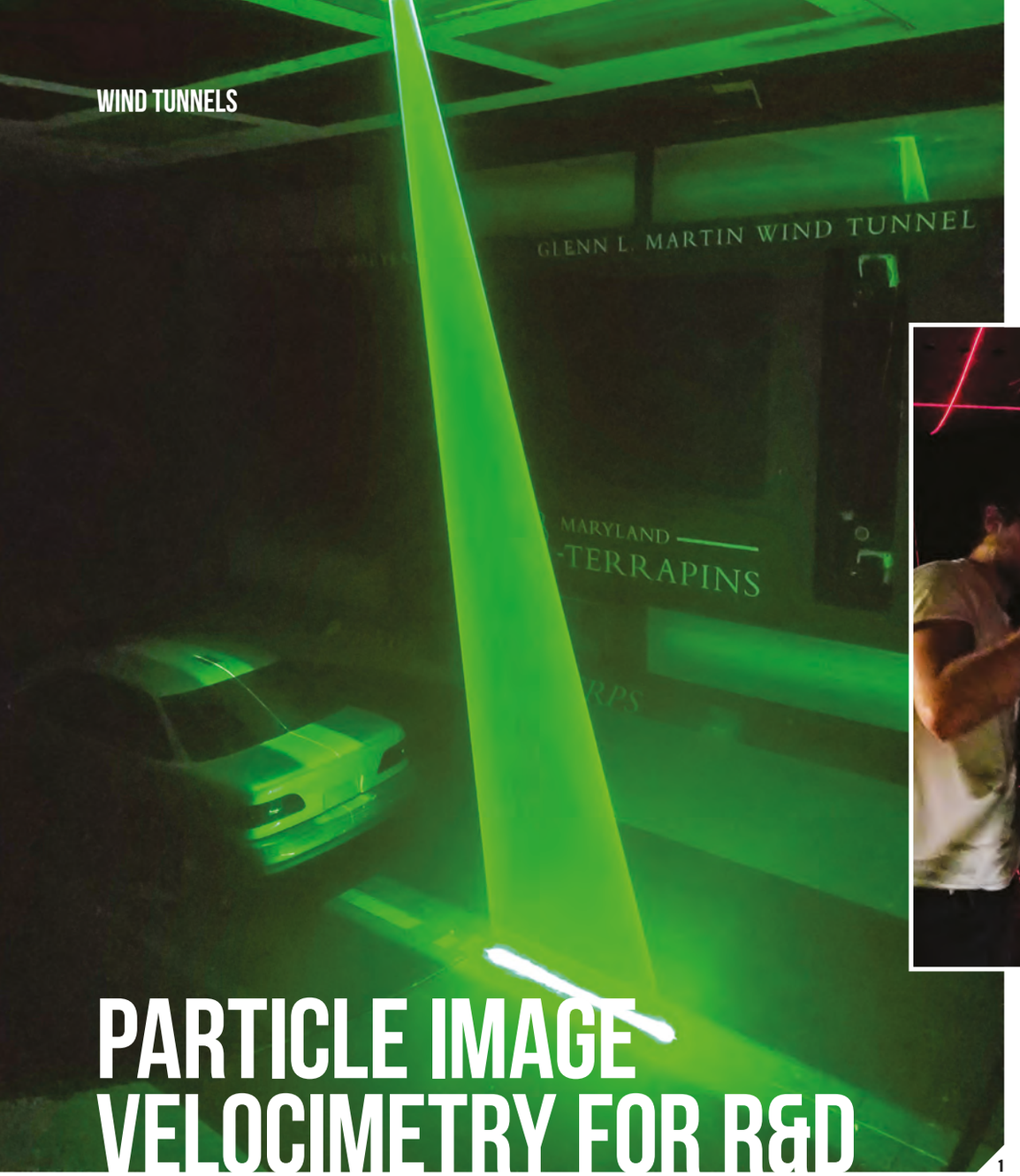

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PARTICLE IMAGE VELOCIMETRY FOR R&D

The Glenn L. Martin Wind Tunnel provides unique insight by measuring unsteady and three dimensional flow phenomena

// ANDREW LIND AND JEWEL BARLOW

The Glenn L. Martin Wind Tunnel (GLMWT) leads experiential efforts in which particle image velocimetry (PIV) measurements play a central role in characterizing unsteady and three-dimensional flow phenomena. The technique of time-resolved PIV uses a high-power, high-speed laser to illuminate micron-scale droplets of vaporized mineral oil. Mirrors and other optical devices are used to steer the laser beam into the test section at a location of interest, which is seen as a triangular green sheet (Figure 1). Once the illumination plane is positioned at the location of the flow feature of interest, a dotted calibration target is used to align the test section with the plane of the laser sheet (Figure 2).

High-speed cameras image the target to relate the camera pixels to precise distances. During data collection, the laser fires hundreds of pairs of short-duration pulses. Each pair of pulses is separated by a few microseconds. The high-speed cameras are synchronized to the laser to capture the image pairs. A correlation algorithm is then used to determine the displacements of patterns of particle images, from which a time history of the velocity field is obtained in a non-intrusive manner.

HIGH SPEED FOR UNSTEADY FLOWS

A key advantage of high-speed PIV systems is their capability to resolve the time histories of unsteady flow features. This is achieved using a high acquisition rate in the order of 1kHz. Time-resolved flow field measurements are especially useful for characterizing unsteady wakes of vehicles, such as automobiles (Figure 1), trucks and air vehicles of all scales. Furthermore, when used in conjunction with time-resolved pressure measurements, time-resolved PIV enables comparison between the unsteady flow field near the surface of a body and the influence of flow structures on the unsteady pressure distribution.

Figure 4 shows an example of a vortex captured on the retreating blade of a Mach-scaled rotor operating at a high advance ratio. Researchers in the Alfred Gessow Rotorcraft Center at the University of Maryland are working to relate the strength, size and trajectory of flow features like this vortex to the surface pressure distribution on the blades. These findings could help reduce vibrations in future high-speed helicopters.

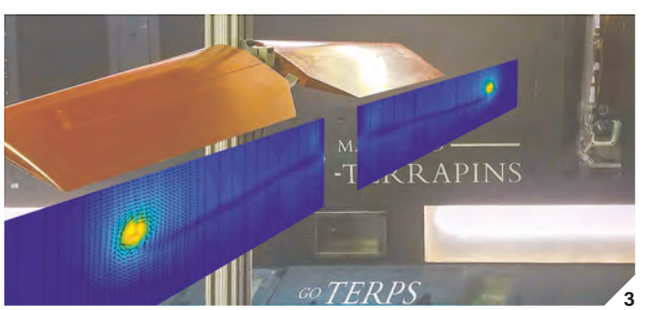
1 // A laser sheet illuminates the unsteady wake downstream of a ⅜-scale automobile model

2 // Alignment of a dotted calibration target

3 // Time-averaged velocity field in the wake of a stabilator

THREE-DIMENSIONAL FLOWS

The use of two high-speed cameras enables stereoscopic PIV measurements. Stereo PIV



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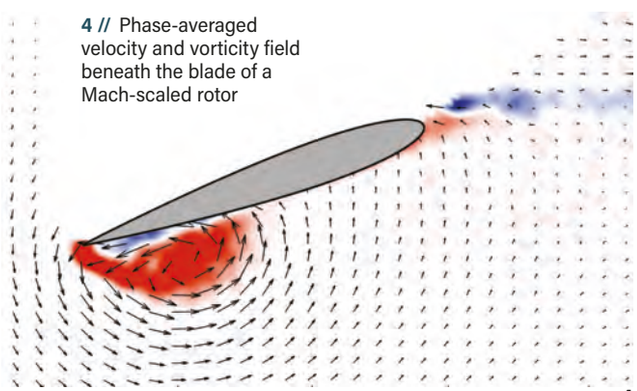
provides three-dimensional flow measurements within a region of interest imaged by the cameras. This can be done because the laser sheet, although thin, has a finite thickness. As particles pass through the laser sheet, use of two cameras enables out-of-plane motion to be measured. Figure 1 shows a stereoscopic setup with two cameras arranged vertically on the far side of the test section. When time-averaged, stereoscopic flow field measurements can be used to reconstruct full three-dimensional volumetric flow fields. Figure 3 shows an example using a model stabilator as a test. Here, the laser sheet was positioned to be aligned in the streamwise direction, but the results show a cross-stream section of the tip vortex and wake sheet.

To achieve this view of the flow, the stabilator was moved so that the laser sheet effectively scanned the wake in the spanwise direction. This provided a volumetric measurement of the wake from which sections could be extracted in any given direction.

"DURING DATA COLLECTION, THE LASER FIRES HUNDREDS OF PAIRS OF PULSES"



4 // Phase-averaged velocity and vorticity field beneath the blade of a Mach-scaled rotor

4

DATA FOR DESIGN DECISIONS

For nearly 70 years, the Glenn L. Martin Wind Tunnel has provided clients with high-quality data to inform design decisions. PIV is one of many modern measurement practices used regularly at the GLMWT. In concert with our high-accuracy external balance, unsteady pressure measurement capabilities and Vicon tracking, PIV serves as a valuable tool to help identify unsteady flow phenomena and quantify their influence on loading and aero-elastic response. \\

Dr Jewel Barlow is director of the Glenn L. Martin Wind Tunnel and Dr Andrew Lind is an assistant research engineer at the facility

FENYX TO EXTEND EUROPEAN AIRBORNE RESEARCH CAPABILITIES

1

A research aircraft being built by the Instituto Nacional de Técnica Aeroespacial (INTA) aims to bring new capabilities to European scientists from diverse fields

// A CORRALES SIERRA AND B MARQUES BALAGUER


2


3

The European research project COPAL (COmmunity heavy-PAyload Long endurance instrumented aircraft for tropospheric research in environmental and geo-sciences) was launched in 2007 to design and build an autonomous, long-duration, aerial research platform suitable for heavy payloads to be used by the European scientific community.

An aerial research platform is a modified and instrumented aircraft used to collect data from Earth's atmosphere. The platform supports atmospheric research and the development of instrumentation that requires testing under real flight conditions.

Eleven national research funding institutions, including Spain's Instituto Nacional de Técnica Aeroespacial (INTA), participated in COPAL. The platform was to be capable of operating anywhere in the world, granting an unprecedented opportunity to countries that lacked this capability. Researchers would have been able to take measurements and make observations from an instrumented aircraft, opening up opportunities to create new international multidisciplinary experiments.

However, after COPAL was completed in 2011, it was not possible to raise the funds needed to launch the new aircraft.

THE FENYX RISES

Recently the Spanish Ministry of Science approved the funds necessary for the commissioning of a new high-payload and long-endurance aircraft, to guarantee the future of atmospheric research in Spain and to grow the country's scientific capabilities. This is the Fenyx (large aircraft for research and experimentation) project. The work package covers the definition of the main technical characteristics of the future aircraft, the modifications to the aircraft that will enable it to carry out INTA's scientific campaigns, as well as the necessary steps to obtain certification for the aircraft.

INTA is currently defining the specifications of the aircraft by collecting information about the present and future interests of its prospective scientific users. The aircraft will be able to carry more than 6 tons of instrumentation and will have a maximum flight time of eight hours. With the use of the aircraft's endurance, it will be possible to carry out studies in areas of the ocean far from the coast or over remote land areas, particularly polar areas.

Although the cost of an hour of flight time in Fenyx will be greater than that of the C-212 currently used by INTA, it will be possible to carry out several campaigns simultaneously and divide the total cost.

The aircraft also needs to include a rear ramp to facilitate the loading and unloading of bulky or heavy equipment and have STOL (short take-off and landing) operation characteristics to make it possible to operate in remote areas.

As the aircraft will be a research platform, it will be necessary to modify

1 // INTA's Stemme motorglider is part of its existing fleet

2 // The research organization also operates two C212 aircraft

3 // The new Fenyx aircraft will be capable of carrying more than 6 tons of instrumentation

"THE HIGHER PAYLOAD OF FENYX WILL HELP VERIFY COLLECTED DATA"

4 & 5 // The new aircraft's remote sensors will be used to produce images of use to researchers from different scientific areas to maximize value

it with features such as wing hard points and holes in the fuselage and windows so that it can carry scientific equipment. In addition, the aircraft will feature the latest avionics system, an avionics data recording capability, the latest communications equipment, a flight test instrumentation suite, electrical power for scientific equipment, a cabin that can be configured to accommodate up to eight scientific experiments, ice-core sampling equipment, a nose probe and a GPS antenna.

During the entire project, including its adaptation for scientific campaigns, safety must come first. The nature of research aircraft requires the constant introduction of modifications and the installation of equipment. The aircraft must have an appropriate airworthiness certificate.

After the specification phase, INTA will present a proposal to potential suppliers, selecting the most suitable aircraft to meet these requirements. This will be followed by the acquisition, modification and certification phases. Fenyx is expected to enter service in December 2020.

Fenyx will greatly extend the capacity and operation of the existing research aircraft fleet in Spain and Europe by adding to the characteristics of the aircraft currently available in Europe and in terms of payload capacity and increased autonomy.

The higher payload of Fenyx will help verify collected data, because the aircraft can carry more instrumentation. Interdisciplinary research will also be strengthened thanks to the coexistence of several scientific groups on board. For example, microbiological studies will be able to be carried out at the same time as meteorological or atmospheric physics experiments. International cooperation will also be reinforced, as flights can be made with groups from different countries.

The Fenyx project has been funded by the General Sub-Directorate of Large Scientific and Technological Infrastructures and the ICTS-PAI of the Spanish Ministry of Science. \\

A Corrales Sierra and B Marques Balaguer are aeronautical engineers at INTA

FONDO EUROPEO DE DESARROLLO REGIONAL
Una manera de hacer Europa
Unión Europea

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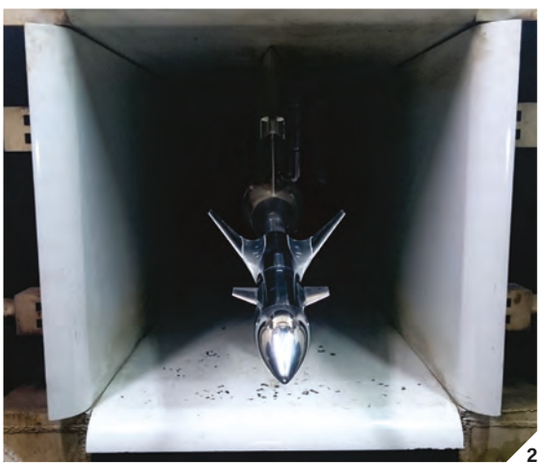

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SUPERSONIC UPGRADE

Romania's National Institute for Aerospace Research, Elie Carafoli – INCAS – has upgraded its wind tunnel so that it can help develop the next generation of space vehicles

// CATALIN NAE

The INCAS supersonic wind tunnel (SWT) has a high level of performance, a good flow quality and an operations team full of specialists who are recognized experts in their fields. These assets are proved by the completion of almost 150 test programs, consisting of more than 10,000 test runs, that have been carried out for national and international clients during 35 years of activity.

The SWT is a pressurized facility capable of high Reynolds numbers exceeding 100 million per 1m (3ft) chord. The facility can operate from low subsonic compressible regimes up to Mach 3.5.

Transonic tests at continuously varying Mach numbers between 0.5 and 1.4 can be carried out in the 1.2 x 1.2m (4 x 4ft) test section, the walls of which are perforated with 60° inclined holes to provide variable porosity. Subsonic and supersonic tests from Mach 1.4 up to Mach 3.5 are carried out in the 1.2 x 1.2m solid wall test section downstream of the flexible nozzle.

Upgrades aimed at enhancing the SWT's testing and demonstration capabilities were recently installed. The facility is now capable of performing advanced simulations involving hot exhaust plumes and afterbody rocket regions. It is hoped that the upgrade will lead to a better understanding of complex fluidic interactions, base drag evaluation and new configurations for launchers and space vehicles.

BASE DRAG UNCERTAINTY FOR LAUNCHERS

One of the most important aerodynamic performance characteristics of a space vehicle during atmospheric flight is the total drag. The fluidic interactions in the afterbody area are governed by extremely complex physical and chemical mechanisms, highly dependent on the mission profile and responsible for a large part of the overall drag of the vehicle.

The base drag is a major contributor to the total drag, particularly at transonic speeds. Flight tests with common geometries have shown that the base drag may account for up to 35% of the total drag. Base drag, arising from flow separation at the blunt base of a body, can also be a sizeable fraction of total drag in the context of missiles and the afterbodies of rockets. For example, the base drag component can be as high as 50% of he total drag for a missile with power off. Most importantly, as seen in CFD analysis performed at INCAS on a test configuration, small changes in the base area or mass flow injection may have a major role in aerodynamic performance, especially at transonic speeds (Figure 3).

Currently INCAS uses cold plumes to simulate the conditions in transonic to supersonic flight during tests. However, from aeronautical programs on supersonic jets and published flight measurements on space launchers such as Ariane 5 it has been concluded that this approach underestimates the base pressure and hence overestimates the vehicle drag. This is because of the influence of the plume

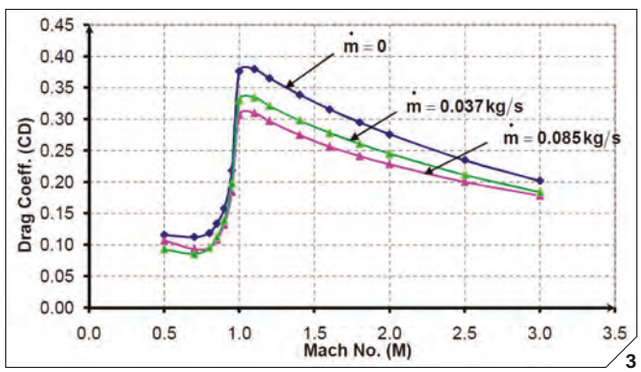
1 // INCAS supersonic wind tunnel is capable of operating at up to Mach 3.5

2 // The wind tunnel has solid walls and interchangeable porous test sections

"THE FACILITY IS NOW CAPABLE OF PERFORMING ADVANCED SIMULATIONS INVOLVING HOT EXHAUST PLUMES"

temperature on the complex flow field surrounding the base region, leading also to a large uncertainty in the heat loads and fluctuating loads on the nozzle.

With a given set of external-flow conditions, the initial shape of the jet boundary is determined by the ratio of specific heats and the nozzle exit pressure ratio of the jet flow. Duplication of the slope of this segment of the jet boundary is all that is required in studies of the base and boattail drag of afterbodies, without appreciable flow separation and external interference effects associated with the initial shock. This finding is of great practical significance with regard to simulator selection, in as much as a jet with an incorrect ratio of specific heats can be used to simulate the boundary of a real jet, because the correct initial boundary shape can still be obtained by operating the simulator at some arbitrary exit pressure ratio.



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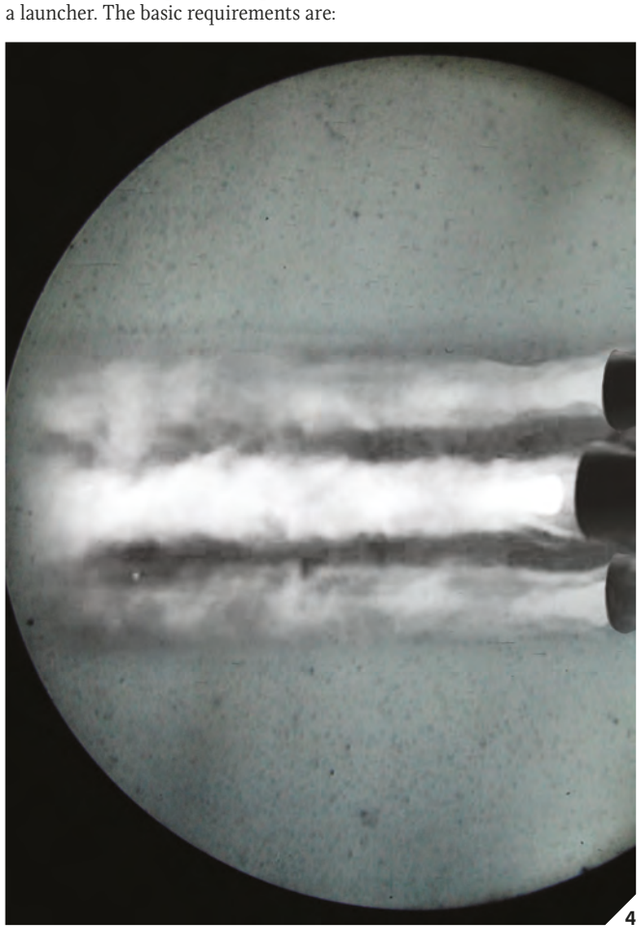
3 // Graph showing base drag variation for a launcher configuration

4 // Example of a nozzle flow pattern captured from the wind tunnel

WIND TUNNEL UPGRADE

Further development of the INCAS SWT is based on meeting the testing needs for a launcher. The basic requirements are: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- Operation in transonic and supersonic regimes (Mach 0.6 to 3.5);
- Enabling Reynolds numbers similar to the profile of real launcher missions, i.e. Re greater than 10;
- Enabling similar characteristics between hot test plume and flight plume;
- Enabling similar characteristics between plume and freestream flow conditions;
- Geometric scaling for afterbody geometry.

With respect to the proposed model and instrumentation, the following capabilities were required:

- Drag evaluation under hot plume simulations;
- Static and dynamic base pressure measurements;
- Monitoring of engine parameters such as temperature and mass flow rate;
- The measurement of surface pressure on the body.

The INCAS facility's operational envelope (Figures 5 and 6) means that it now conforms fully to ESA's requirements for launcher testing. Also, since this is a blowdown wind tunnel, the facility is capable of using hot engine simulators for testing, with a maximum duration for the tests of 90 seconds in transonic regimes. This gives sufficient time for simulations to be conducted on complex instrumented wind tunnel models.

The INCAS facility already had a supply system for jet simulations, using cold air from a dedicated storage area of 2m³ (70ft³) at 150atm. This capability may be used for dedicated models equipped with internal air balance and/or special sensing instrumentation. Air is supplied to the model using a dedicated sting, able to provide mass flow rate according to a specific diagram.

ROCKET ENGINE SIMULATOR

Selected hydrogen peroxide rocket engine concepts are really steam rockets, with the steam being produced by a violent exothermic reaction of the peroxide. When passed through a catalyst pack, the peroxide decomposes into superheated steam and oxygen. This high-pressure steam is expelled supersonically through a de Laval nozzle, which produces thrust. For each volume of liquid injected at the catalyst, 5,000 times that volume in gas is expelled at the nozzle.

The INCAS SWT is able to provide hydrogen peroxide as a monopropellant in engines and features a new model support, able to provide peroxide inside the model.

The engine simulator uses a bespoke gas generator. The liquid enters the generator at the inlet orifice, which is designed to provide a pressure drop of about half the chamber pressure at the design flow rate. This drop will prevent pressure oscillations called chugging. The catalyst bed is made of 20-mesh 3mm (0.11in) diameter wire screens of 99.6% silver, activated with a samarium nitrate treatment. The coating treatment enables faster starts, which prevent the screens from fusing together under the high temperatures that result from peroxide decomposition.

SUPPLY SYSTEM FOR ENGINE SIMULATOR

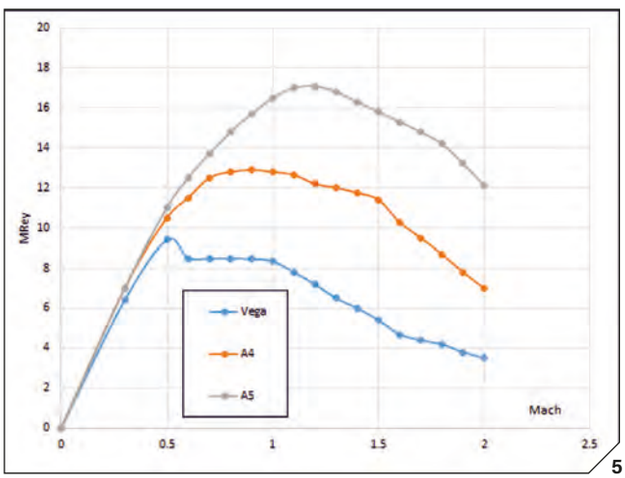
This is the major external addition to the INCAS SWT's auxiliary systems. The supply system has compact supply lines and is designed to be easy to operate. The jet pressure ratio is controlled by varying the weight flow through the system.

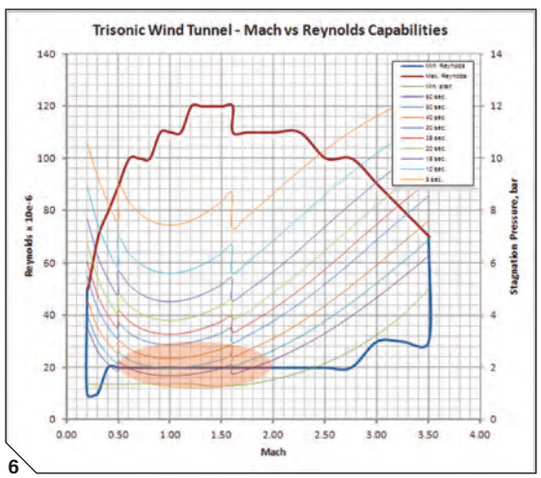
The products of the decomposition of hydrogen peroxide, steam and oxygen, are safe in a wind tunnel. The amount of water added to the airstream does not affect the operation of a large wind tunnel cooled by an air exchange system, although the operation of a hydrogen peroxide jet in a pressurized closed-circuit tunnel could increase the dew point above the tunnel's tolerable limits.

The hydrogen peroxide supply system for the engine simulator (Figure 7) is portable, with a maximum flow rate of 1.5kg/s (3.3 lb/s), a maximum pressure of 20 bar and a total volume of 2m³.

REFERENCE MODEL AND RIG DESIGN

Based on initial evaluations, a reference model was developed to allow for the installation of a 50mm (2in) diameter TASK balance and enough room for the internal air passage. This enabled the complete range of Mach and Reynolds numbers to be simulated in the wind





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5 // Graph showing the Reynolds-Mach envelope for Ariane 4/5 and Vega

6 // Graph showing the INCAS SWT's Reynolds-Mach capabilities

7 // The SWT's supply system for the engine simulator

tunnel. The reference wind tunnel model consists of a thrust balance, a peroxide gas generator and an exit-nozzle tailpipe, all within an ogive-cylinder shell. It has a depth of 200mm (8in), a length of 950mm (37in) and includes compressed gas injection to simulate plumes from propulsion system nozzles. It is possible to perform this with external gas injection, with a special setup that allows for the loads on the balance and/or model support. However, the basic option is for hydrogen peroxide engine simulator integration.

The model collects detailed base pressure and thrust data. Also, global loads can be measured by configuring the model so that the TASK balance can be used at the same time with the pressure scanning devices. The model has provision for testing angles of attack, using a variable device installed in sidewall mounted configurations.

The final setup can provide flow visualization data if required, particularly of air-breathing rocket plumes, because the active part is in the location corresponding to the schlieren windows.

The thrust balances attached to the gas generators are designed to eliminate inlet-momentum corrections of the liquid and Bourdon tube effects and minimize ambient and differential heating effects. The thrust balance and the decomposition chamber are machined from one block of high-temperature alloy to eliminate welds and a single peroxide passage is provided through the balance. The strain gauges are mounted on webs on the sides of the liquid passage. This design improves the accuracy of the thrust measuring system.

A dedicated test campaign was designed to collect as much useful data as possible on the nacelle wake, base pressure and base drag characteristics across a range of operating Mach numbers.

TEST CAMPAIGN SUCCESS

The major interest in the first test campaign was for transonic tests at Mach numbers between 0.5 and 1.4, carried out in the 1.2m x 1.2m variable porosity, perforated wall transonic test section. The variable porosity cancels reflected shock and expansion waves between Mach 1 and 1.4 and enables the study of flow at transonic to low-supersonic Mach numbers.

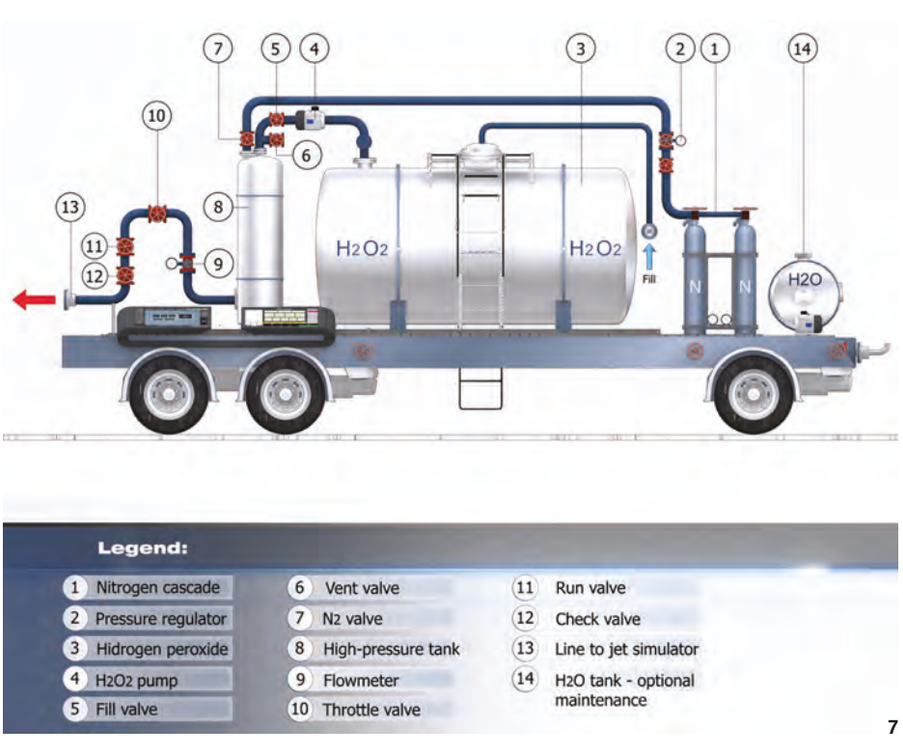
For lower subsonic and supersonic tests from Mach 1.4 up to Mach 3.5, tests can be conducted in the 1.2 x 1.2m solid wall test section downstream of the flexible nozzle.

TESTING FOR SPACE PROGRAMS

INCAS has identified and aims to satisfy a real need for a facility able to provide active model simulation capabilities for space applications. The development program has enhanced the INCAS SWT's capabilities so that in the short to medium term, at a very competitive cost, the SWT can participate in the testing campaigns and development of space programs, focusing on hybrid engines, single stage to orbit, and two stage to orbit concepts. \\

Dr Catalin Nae is president and CEO of INCAS

"THE SWT CAN PARTICIPATE IN THE TESTING CAMPAIGNS OF SPACE PROGRAMS"



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1

FLEXIBLE IN THE FIELD

The integration of multiple, complementary capabilities into instrumentation can provide cost reductions, easier SWaP designs and increased functionality to meet demanding test environment requirements

// CHRIS LLOYD

Due to the technology limitations of the past, ground and airborne instrumentation systems comprised an array of single-purpose units that were used to make up the system. But thanks to greater component miniaturization and system-on-a-chip (SoC) technologies, Telspan Data has developed a range of products with a multi-disciplined architecture that provide flight test instrumentation with more capabilities and performance improvements over legacy hardware.

These capabilities can range from adding GPS, and network timing to an Ethernet switch and including field-programmable gate arrays (FPGA) for protocol translation and data filtering schemes. They can also include the provision of a high-speed recording capability with simultaneous filtering, processing and conversion for telemetering data. There are several solutions offered by Telspan that can help cut the budget of any test program by decreasing box counts, which reduces integration effort, benefits SWaP (size, weight and power) and constrains system implementations. Furthermore Telspan Data's latest instrumentation products can achieve all these benefits while still increasing the capabilities of the overall system.

INTEGRATED ETHERNET SWITCH

In test network implementations, switches were typically single-purpose units for routing Ethernet traffic. In the case of managed switches, the user could implement traffic policing policies, set up virtual Local Area Networks (VLANs), and assign traffic priorities, among other management functions.

The integrated Ethernet Switch (iES) not only provides layer 2/3 switch management, but also adds a GPS receiver, independent hardware-based IEEE-1588 time engines with Grandmaster capability, and Inter-Range Instrumentation Group (IRIG) time-code generation (TCG). Data-driven and user-commanded discrete outputs, GigE Vision discoverable device and pulse code modulation (PCM) serial inputs/outputs extend the capability of the switch. The iES includes an FPGA interface, which is tied directly to the switch fabric, providing content-level data filtering and processing across the switch ports.

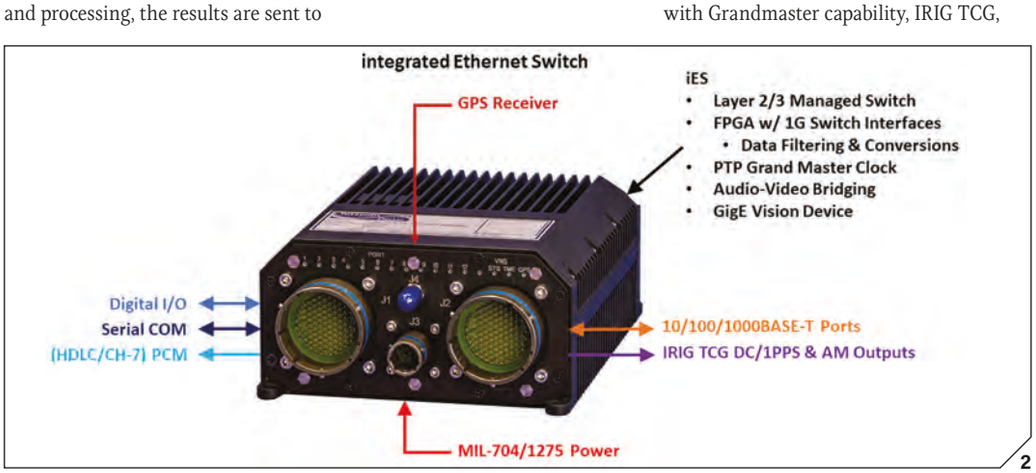
Following the content filtering and processing, the results are sent to network destinations and/or a merged data subset is transmitted via PCM or ISO/IEC 13239 high-level datalink control (HDLC).

1 // The MITR's multi-disciplined architecture enables it to adapt to different test requirements

2 // Telspan's iES-12 is a rugged 12-port layer 2/3 managed Gigabit Ethernet switch suitable for demanding applications

MODULAR INSTRUMENTATION TRAFFIC RECORDER

Traditionally recorders were single-purpose boxes that stored data in proprietary formats. The Modular Instrumentation Traffic Recorder (MITR) is another example of a modern multi-disciplined product architecture.
The MITR is a high-speed, high-capacity IRIG 106 Chapter 10 compliant recorder/publisher with Removable Memory Module (RMM), TAP and Interface module (TIM) and Management Bay. Much like the iES, MITR's Management Bay includes an integrated layer 2/3 managed Ethernet switch, GPS receiver, independent hardware-based IEEE-1588 time engines with Grandmaster capability, IRIG TCG,



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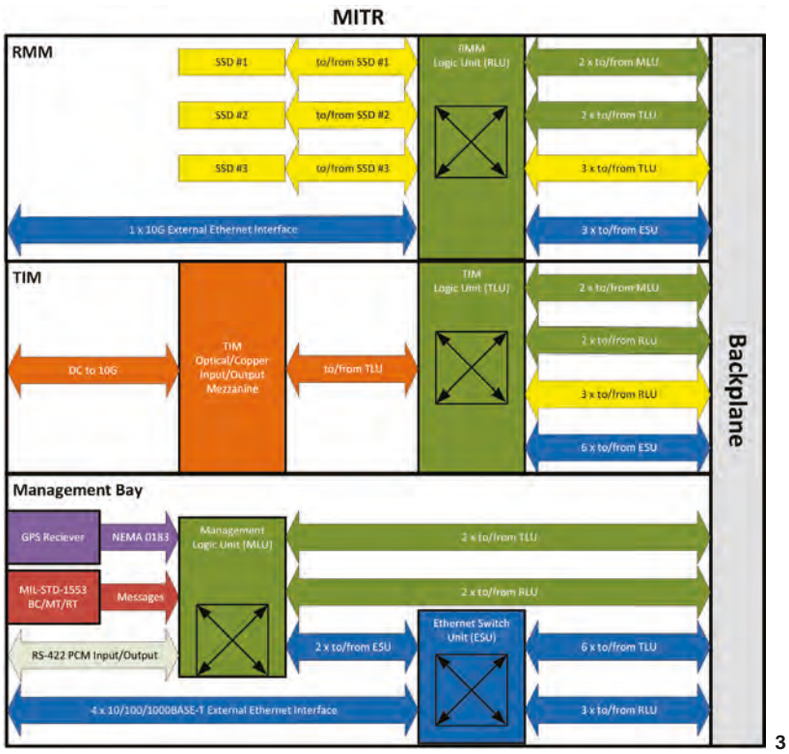
"A MULTI-DISCIPLINED ARCHITECTURE PROVIDES FLIGHT TEST INSTRUMENTATION SYSTEMS WITH MORE CAPABILITIES"

multiple Ethernet interfaces, MIL-STD-1553 remote terminal or bus monitor operations, and bidirectional PCM serial encoding/decoding of published IRIG 106 Chapter 10 or Ethernet traffic using HDLC or IRIG 106 Chapter 4/7 formats.

The optical TIM provides up to 12 channels of DC-10G protocol independent transceivers as an in-line TAP or up to 24 channels of receive end points. The signaling protocols reside within the logic fabric for Ethernet, Fibre Channel, Firewire, Serial Front Panel Data Port (sFPDP), and others. Other TIMs, with eight channels of 1G copper Fibre Channel, 12 channels of 10/100/1000BASE-T and optical/copper are available. Since the transceivers are protocol independent, the TIM channels can be configured to all be one protocol, or mixed/matched and changed with a firmware load, easily allowing the MITR to adapt to many test requirements.



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3 // The MITR's switched data fabric provides 230Gbps of bandwidth across its data lanes

4 // The iGU is a configurable gateway between instrumentation and Ethernet networks or telemetry transmitters

The RMM, with a current total capacity up to 64TB and recording bandwidths from 1.5GBps (SATA) to 9GBps (NVMe), consists of one to four drives in a single carrier. Each carrier includes a built-in 10GigE download port, eliminating the need for expensive, standalone debrief stations. Data channels can be written to individual drives for very high aggregate rate recording. MITR's RMMs can also be configured as network attached storage.

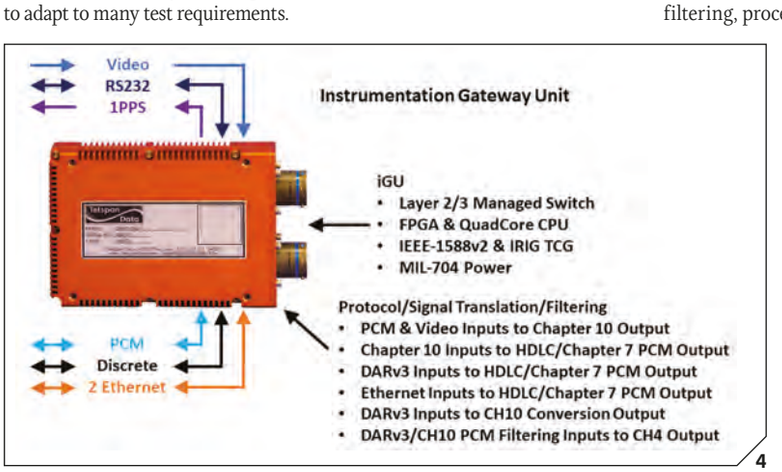
MITR contains a unique logic-based Switched Data Fabric (SDF) between the TIM, the Management Bay and the RMM. The high-speed SDF currently provides 230Gbps of bandwidth across its data lanes, which enables line speed filtering, processing, recording and publishing of incoming high-speed signal data. The inclusive/exclusive filtering setup consists of a conditional frame level, upper protocol level and data content level from all the physical channels and multiple virtual channels.

User-programmed channel groups can consist of physical channels from the TIM and or Ethernet switch interfaces, along with virtual channels derived from the physical inputs. The channel groups are linked to destinations across the fabric to include individual or all RMM drives, IRIG 106 Chapter 10 data streaming publish ports in the Ethernet switch and encoded serial outputs. This means that truth data and filtered 'quick-look' data can both be recorded and/or simultaneously published/telemetered.

INSTRUMENTATION GATEWAY

Multi-disciplined product architectures can also be implemented on a much smaller scale for gateway-type applications, which typically perform protocol or signal translations. The instrumentation Gateway Unit (iGU) provides Ethernet interfaces with network timing, video input, PCM input/output, and a layer 2/3 managed switch. These interfaces are tied together in the SDF to the integrated FPGA and CPU, providing a wide array of capabilities in a single unit.

The FPGA and CPU provide real-time data processing, conversion and translation tasks, including IRIG 106 Chapter 10 publishing, Ethernet to IRIG 106 Chapter 7 PCM and HDLC output. This enables a user to combine sources of data, such as video or other proprietary data formats, and convert them to Chapter 10 while sending to a recorder over Ethernet and outputting PCM to a transmitter for telemetering of that data. Additionally, data filtering and

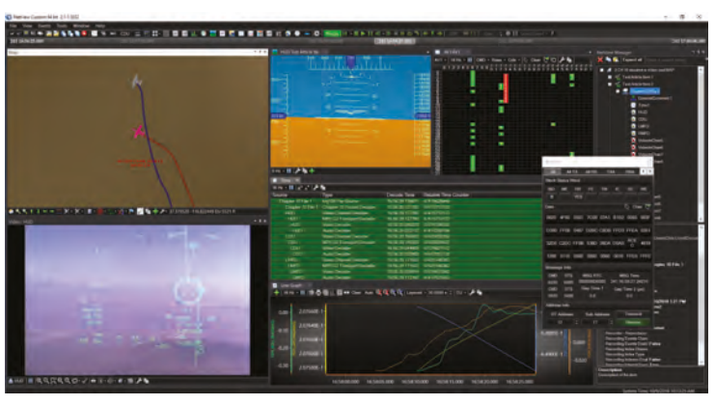


4

NETVIEW DATA FUSION

A modern instrumentation system contains many potential sources of data – recorders, real-time streams and other network-based instrumentation devices which generate tons of data. Managing all that data is easy with NetView Data Fusion & Display. NetView provides real-time decoding, processing, display and distribution from multiple IRIG 106 Chapter 10 data sources and network-based instrumentation systems. It decodes, time aligns, processes and displays multiple independent data source types and formats in a single processing and display environment.

NetView is a turnkey software application with real-time data displays capability including; video, 2D/3D map, HUD, XY plot, line graph, etc. Raw data displays provide the ability to drive down into the word/bit level of PCM, 429, 1553 and 1394 data streams. NetView capabilities are extended with a complete SDK allowing the user to develop their own custom GUI displays and access the data structure for end user defined decoders and special processing of measurements.



“THE PRODUCTS LEVERAGE OPEN STANDARDS AND THE LATEST TECHNOLOGIES TO GIVE FLEXIBILITY”

merging of network-based data into a subset IRIG 106 Chapter 4 PCM frame and any number of other user-driven processes are possible with an iGU.

DATAHUB

The multi-disciplined architecture is not limited to rugged airborne and ground vehicle products. Range and laboratory products can also benefit from this approach to reduce the number of individual single purpose systems. The DataHUB is an open standards-based telemetry ground system with IRIG 106 Chapter 10 recorder/reproducer capability. It also provides IRIG Chapter 10 publish/subscribe, data filtering/processing, IRIG 106 Chapter 7/HDLC encoding/decoding, GPS, IEEE-1588 PTP, NTP and IRIG time generation.Being multi-disciplined, the DataHUB adds Best Source Selection (BSS) in accordance with IRIG 106 Chapter 2 Data Quality Metrics/Data Quality Encapsulation (DQM/DQE) all in a single 1U rackmount unit.

The 1U DataHUB provides up to eight bidirectional PCM channels, two analog channels, two video channels and three Ethernet channels. A 2U version of DataHUB adds a signal expansion card capability, increasing the PCM channel counts to a total of 32, providing digital bit synchronizers or adds multiple RF/IF analog input channels. High-speed data is addressed by using multiple 3GBps NVMe solid state hard drives – recording and reproducing speeds are increased by a factor of five times that of SATA 3.0.

The DataHUB core system is driven by an SoC and Linux. Command, control and status are via external discretes, Command Line Interface (RS-232 or TELNET) or a browser-based Graphical User Interface (GUI). The DataHUB provides all of the capabilities that are needed in a modern telemetry ground recording, reproducing and distribution station.

Instrumentation engineers have always faced integration challenges because of the multi-unit architectures of the various system components, such as data acquisition units, time generators, recorders, protocol convertors, GPS receivers, video compressors and data distribution units. SWaP is becoming more of a concern due to the smaller test articles and the limited space for adding expanding instrumentation requirements. Single-vendor integrated solutions are problematic because of their proprietary processes and because they don't use open standards, which prevents the system designer from selecting the “best in breed” technologies.

Telspan Data's multi-disciplined products leverage open standards and the latest SoC, data transmission and processing technologies. These products give instrumentation engineers unparalleled flexibility and capability with a means to upgrade/modify the behavior of hardware in the field as the requirements of a testing program change and grow. \\

Chris Lloyd is director of sales and marketing at Telspan Data

5 // The DataHUB Recorder/Reproducer system features an internal GPS receiver and an IRIG-A/B/G time code generator

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1

TOMORROW'S RECORDERS

Knowing what test engineers require in a data recorder has influenced the ongoing development of recording solutions

// **BERND STEPP**

The WX-7000 series of instrument data recorders is designed to provide multichannel, high-bandwidth recording solutions for the testing and monitoring requirements of aerospace, defense and industrial acoustics/vibration-based applications. TEAC has been providing data recorders for the aerospace testing market since the reel-to-reel tape era and continues to develop and provide machines that use the latest and most reliable technologies.

In the past, PC storage capacities were small and data transfer rates were slow. In aerospace testing many signals are recorded at high sampling rates, but earlier computers did not have a high enough performance level to record the volumes of data. Instrument data recorders were therefore the main data acquisition system and the files created were analyzed on a computer after the testing was completed. Now the ubiquitous PC is the front end of the acquisition system, analyzing the data in real time, while the instrumentation data recorder has become the important backup system.

FEATURES AND CONNECTIONS

The TEAC WX-7000 series has many features that enable it to provide reliable data recording with protection from catastrophic data loss, including a wide dynamic range and high resolution. A unit can have 128 channels, and synchronization between two units enables 256 channels to be recorded. The WX-7000 offers a longer recording time than is possible with tape recorder technologies.

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

DATA SAFE STORAGE

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

APPLICATIONS

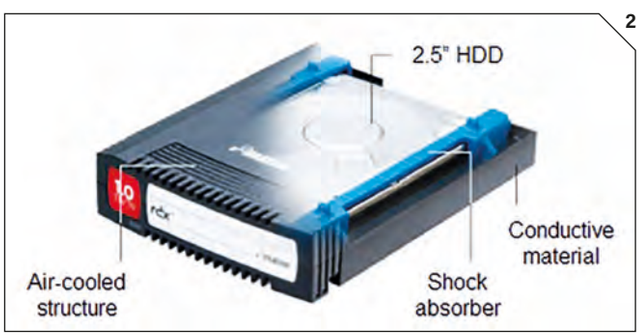
TEAC WX-7000 data recorders have been used for developing the Japanese LE-X rocket engine. Vibration testing and analysis is one of the most important parts of development. If levels exceed certain thresholds, vibrations might lead to decreased engine efficiency and damage.

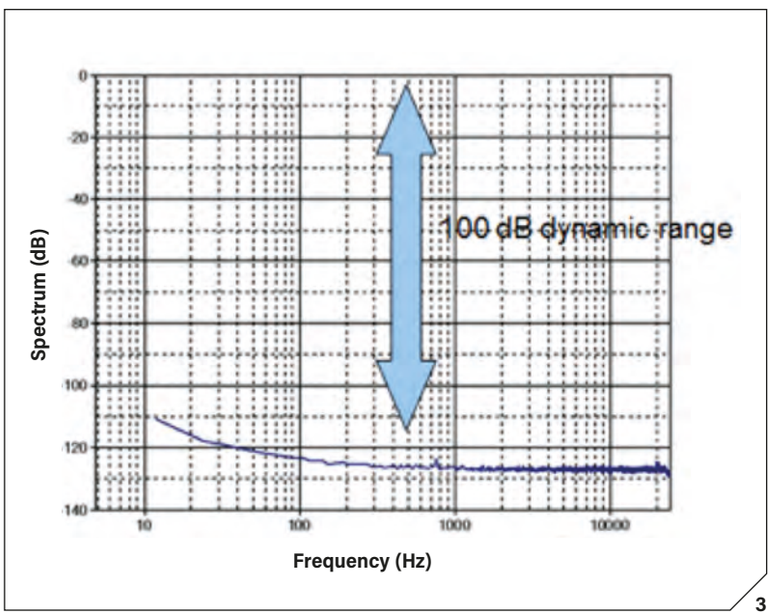
"IF A POWER OUTAGE OCCURS, THE RECORDED DATA IS SAVED FROM THE MINUTE BEFORE THE LOSS"

1 // The WX-7000 main unit, shown with 16 channels, is configurable to 128 channels using eight 16-channel input/output cards

2 // Data is stored on an RDX server-grade removable disk

2





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The test data collected can increase the reliability and durability of components, but they have to be performed under the same conditions as encountered in flight, such as extremely low temperatures, high nozzle pressures and high rotation forces when the rocket is launched. The time and cost involved in this kind of testing needs dependable and secure data recording.

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

Bernd Stepp is service manager at TEAC Europe

3 // The dynamic range of the WX-7000 is over 100dB

1

2

BENCHTOP THERMAL TESTING EVOLVES

The latest hybrid chambers and digital controllers offer much greater benefits to test engineers than the early thermal testing equipment

// JOHN BOOHER

Product verification at extreme temperatures is required for aerospace, military and other sectors. Life testing and functionality testing must be carried out over temperature ranges of up to 200°C (392°F) and as low as -85°C (-121°F).

The earliest temperature chambers were as simple as an insulated box with heaters, fans and a basket with dry ice as a coolant… the ice pick and leather gloves were sold separately. Some early test requirements of the day were actually written to the temperature limits that were achievable using dry ice. Then, when liquid CO_2 and liquid nitrogen became readily available in a portable low-pressure liquid tank, temperature chambers quickly began to use these coolants.

Eventually, mechanical refrigeration systems capable of the cold temperature ranges required by test engineers were developed, promising to eliminate expendable cryogenic coolants. However, these systems have often suffered problems with reliability and take a longer time to achieve temperature stability. If electricity costs, maintenance and additional loads on building air-conditioning systems are considered, the cost-effectiveness of compressor-based refrigeration systems compared with the use of expendable coolant can be questioned. Liquid CO_2 and LN_2 supplied by a distribution system is often a cheaper option.

TEMPERATURE CONTROL

When thermal platforms that use expendable cryogenic liquids became available in the late 1970s, they quickly became a commonplace alternative to temperature chambers for devices with flat thermally conductive surfaces. Since heat transfer by conduction is inherently a more efficient process, these systems can easily sit on the bench at a workstation and are easier to use than a chamber.

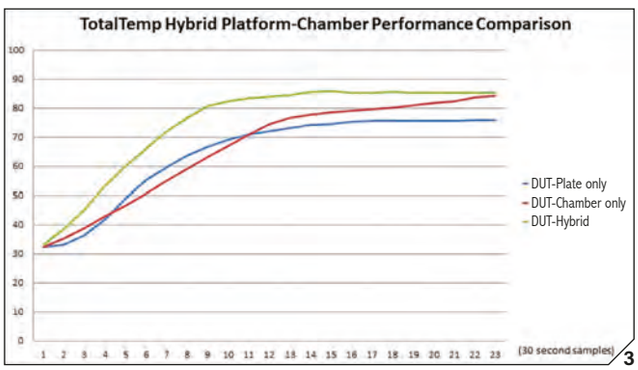
Perhaps the greatest area of improvement for thermal platforms has been the controller systems, which have truly evolved from the first electromechanical controls used. Electronic analog controllers advanced thermal platforms in terms of reliability and accuracy, but are now scarcely used because of how difficult they are to calibrate. They are also unable to receive firmware updates.

1 & 2 // Hybrid benchtop chambers use both convection and conduction to achieve a target temperature

Digital temperature controllers have more functionality and offer better repeatability and reliability. They represent some of the greatest steps forward in the evolution of benchtop thermal testing.

Digital temperature controllers can be programmed to run automated processes. They offer features such as: thermal control algorithms to assure the best transition to the required temperature; logging functions to make printed verification of the test; more convenient front panel setpoint and local ramp/dwell programmability; solid communication protocols for integrated automation with a test set; and compatibility with different temperature sensors.

"COMBINING CONDUCTION WITH CONVECTION RESULTS IN FASTER AND BETTER CONTROL"



3 // Hybrid benchtop chambers are able to achieve temperature stability at faster rates than when using conduction or convention alone

In addition to automation features, there have been a number of key functionality enhancements to thermal platforms over time. These include improved clamping systems, covers and thermally conditioned purge systems.

THE NEXT EVOLUTION

While the systems with mechanical refrigeration cooling have evolved, compressor-based systems often have difficulty matching the heat removal capability of Liquid CO_2 or LN_2, especially at temperatures below -40°C (-40°F). However, the development of autocascade refrigeration systems with phase separators allows multiple refrigerants to flow in one compressor, enabling colder temperatures down to -90°C (-130°F).

Whether mechanical refrigeration liquid nitrogen cooling is used more in the future remains to be seen. The overall reliability of all electromechanical systems is improving with better quality electrical connections and wear items such as solenoid valves, power switching devices and longer-life motors. But, to assess the next step in the evolution of thermal testing and performance improvements requires a return to the study of physics.

While not all devices are suitable for testing on a thermal platform because they lack a flat thermally conductive surface, the combining of conduction and convection together on the benchtop with a smarter temperature controller can halve test times. Combining conduction with convection results in faster heat transfer and better control of thermal gradients.

TotalTemp's hybrid benchtop chambers combine convection and conduction to greatly enhance the basic job of getting the device to the required temperature as quickly as possible.

Figure 3 shows the device under test achieving temperature stability much faster than with conduction or convection alone. Using the advanced Synergy Nano Temperature Controller, the air and the platform temperatures can be the same or different, depending on test requirements. The hybrid chamber can provide a solution to many thermal testing requirements, simplifying tests where a device must be exposed to two different temperatures. \\

John Booher is chief technical officer at TotalTemp Technologies

1

FLEXIBLE AND RELIABLE AIRBORNE HIGH-SPEED CAMERAS

High-speed cameras have to be easy to integrate into aircraft and must also meet the latest standards for data and communications

// STEPHAN TROST

In complex systems such as fighter aircraft, it is essential that the camera is adapted to the aircraft and not the other way around. This is true for the electrical and control interface, as well as for the mechanical outlines of the camera.

Cameras today fulfill additional requirements such as delivering live video to ground staff for analysis, while recording the high-speed event in the internal camera storage, without having to add an extra surveillance camera.

Some types of tests require the camera to be designed with connectors straight out of the back. Other mounting positions require the connectors to protrude out sideways for a 90° view. Due to space limitations, almost every camera position requires a specific outline and mounting pattern. A lens sticking out of the camera makes the whole ensemble larger than necessary. For camera designs looking sideways, a recessed lens mount is therefore indispensable. All designs meet the environmental and electromagnetic specifications to be aircraft-ready. Furthermore, sometimes it is highly desirable to have aircraft-specific connectors on the cameras for ease of integration.

Camera system designers must take all these requests into account. One approach is to offer a semi-customizable camera platform where functionality and the identical operation of each camera is assured. The cameras perform reliably under given environmental conditions and are commercially attractive to the user. These cameras must seamlessly fit into specific compartments. To reach this goal, a camera design must first meet a high degree of flexibility in terms of electronic design. Such modules satisfy the highest possible adaptation to mechanical design demands to make the camera fit in the required space. Interface parts must be easy to adapt to given connectors and power requirements coming from the aircraft. Such a camera design approach is highly beneficial for users.

SMART FEATURES

The camera design used also raises the issue of how to ensure effective operation for different scenes under different

2

1 // Airborne high-speed camera with recessed lens mount and CFast memory card slot

2 // Typical airborne camera from AOS Technologies with custom specific MIL connectors

conditions. Smart features in the camera maximize its flexibility during standalone operation – they do not interfere with flight operation, but provide the precious image data required. This is especially true when integrating the camera in an unmanned combat aerial vehicle. The smart features are pre-programmed on the ground by flight engineers. No network control or data transfer to a control unit is required.

NETWORKING STANDARDS

For cameras intended to operate in a networked environment, it is important to standardize communication to the latest ANCS 466-15 standard for airborne applications. Cameras must meet new networking standards for downloading image data via a network to a central control unit. In such cases, the captured sequences are downloaded to the control unit and new commands are sent to the camera for the following take.

"SMART FEATURES IN THE CAMERA MAXIMIZE ITS FLEXIBILITY"

The protocol allows for enhanced video data collection during the flight. In UAV applications where data download to ground stations for a live view is a must, the camera must manage the bandwidth of the image data sent to telemetry systems. It is important to remember that images are large data files that may jam telemetry systems and block sending of other vital parameters to the ground. By integrating smart algorithms into the camera, such problems are less likely for the operators.

DATA FORMAT

For the subsequent analysis of test data, easy-to-achieve correlation between video and other data is important.

Synchronization to IRIG-B or GPS signals is standard nowadays. Until recently, users had to work with a variety of data formats, sometimes in the manufacturer's proprietary format, making the exchange of data complicated.

Here, the IRIG-106 chapter 10 data is a viable base for data gathering and subsequent analysis. A common data format eases the use of analysis tools and achieves secure correlation of measurements, while taking different sensors and cameras into account.

Overall, this is an economical way to produce results and gain insight. More importantly, comparisons between measurement data are far easier to perform. Semi-customizable cameras are the most suitable option for inflight image data acquisition for both manned aircraft and UAVs, offering the perfect fit for each application while remaining economical. \\

Stephan Trost is CEO of AOS Technologies

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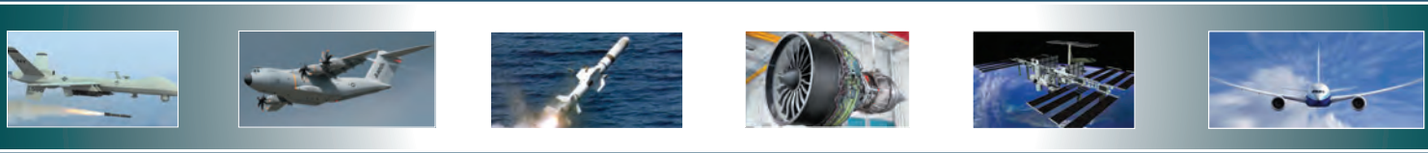

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