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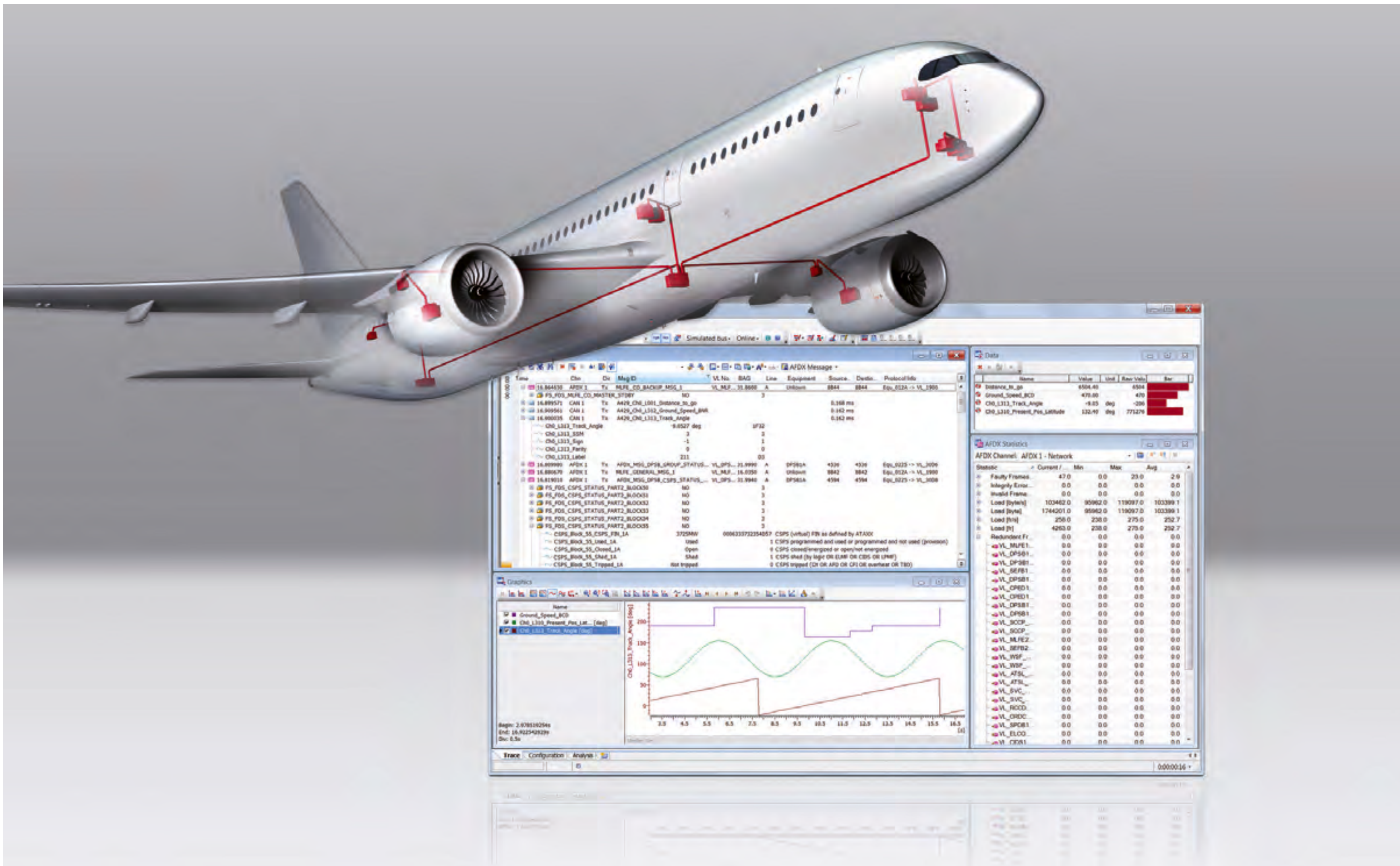

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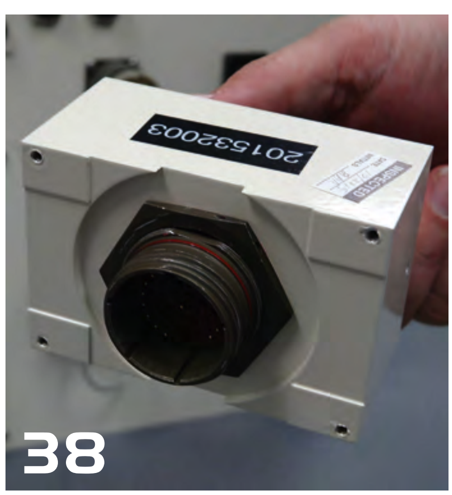
Contents



8 COMBINED TEST TEAMS
The Combined Test Team approach improves efficiency through elimination of redundant testing, and is increasingly deployed in high-profile projects
Garnet Ridgway

16 AIRBUS Q&A: GILLES FREAUD
Gilles Freaud, head of test instrumentation components at Airbus, discusses the testing challenges and trends facing Europe's largest commercial aircraft manufacturer
Anthony James

22 FAC CALIMA T-90
The Colombian Air Force has conducted wing static testing of its new trainer aircraft, the Calima T-90, marking the first full-scale aircraft test ever undertaken in the country
Colombian Air Force

28 NO DATA COMPROMISES
Leveraging new flight test instrumentation technologies can be done without compromising data reliability
Curtiss-Wright

32 DESIGNED FOR LIFE
The launch of Simcenter 3D from Siemens PLM Software offers product management from initial design and simulation to physical testing
Siemens

38 SQUIB CIRCUIT INTEGRITY
A new family of fully automated multimeters uses one sequence to test several connection paths – while reducing the risk of accidental detonations
Space Electronics

42 COMPUTATIONAL CERTIFICATION
Direct testing for new materials can be expensive, but Multiscale Designer offers an alternative computational certification approach that relies on limited experimental data at the coupon level
Altair

46 REVEALING HIDDEN FLAWS
Advances in remote visual inspection and 3D stereo measurement allow greater usability and increase the probability of detection of problems
Olympus

50 TRACKING MICROVIBRATIONS
Microvibrations can hinder improvements in satellite imaging and measurements – piezoelectric dynamometers can help track down the causes
Kistler

54 IMPROVING FLIGHT TESTS
Integrated process management and test planning software tools to create a holistic flight test strategy that saves time and money
TechSAT

58 EASY EXCHANGE STANDARDS
Users can de-couple test automation tools and benches using the generic simulator interface XIL API to better protect their investments and gain independence from tool suppliers
dSPACE

62 MULTICHANNEL MONITORING
An independent vibration monitoring system enables full protection of the test article and shaker
M+P International

66 LORD OF THE RINGS
How a new software module enhances computerized tomography scans for non-destructive testing
North Star Imaging

70 LOW PRESSURE, HIGH HEAT
Modifying an existing data acquisition front-end product in a short timescale to operate in low pressures and high heat was accomplished by making use of in-house capabilities
HGL Dynamics

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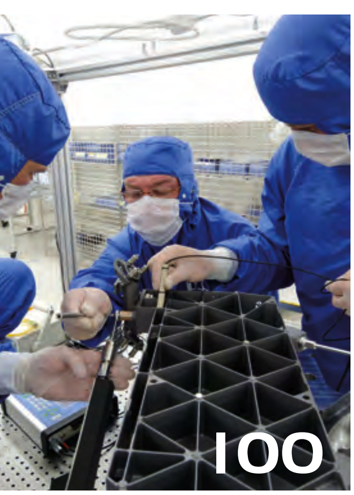


74 NEW PSD ESTIMATION METHOD
New software for power spectral density estimation in a fraction of the time of traditional methods
Vibration Research

78 SPECIALIST INTERIOR TESTING
Teamwork and specialist collaboration can yield some unexpectedly eye-opening results for a wide range of aircraft interiors needs
DAUtec

82 SOLID SHAKERS
A unique solid armature design to overcome the problems of conventional shaker tables
Unholtz-Dickie

86 TESTING THE UNIQUE
A new breed of hybrid aircraft requires configurable and versatile test equipment so systems can be examined in imaginative ways before the first flight
Vector Media

92 THE SPACE POWER FACILITY
Strong vibroacoustic characteristics are needed for testing space systems for vibration and noise, and NASA's facilities have impressive capabilities
Lansmont Corporation

96 MARCHING TO C-BAND
The transition to C-band telemetry has been marked by experiments as new hardware is developed for the testing community
Teletronics Technology

98 UNIQUE AND FLAMING HOT
A quiet corner of the world is offering an innovative, flexible approach to vibration and fire testing
Resonate Testing

100 HOW TIGHT?
Special techniques in ultrasonic testing ensure the maximum advantage is being made of fastener material and loadings
Intellifast

102 FINDING FLAWS
The aerospace industry can benefit from automatic systems part inspections used in other industries if software and imaging tools are improved
Yxlon International

104 MORE RESULTS WITH LESS
TotalTemp offers a unique variety of thermal test equipment to increase accuracy and efficiency for many requirements
TotalTemp

106 RECORDING TOMORROW
TEAC knows what test engineers require in a data recorder and has continued developing dependable recording solutions
TEAC Europe

108 FLEXIBLE UT INSPECTION
Ultrasonic testing remains one of the most effective ways to validate the integrity of aerospace composites
TecScan

110 TIME SAVER
Transient balance techniques to reduce the duration of the fan-balance process, as well as diagnostic and engine run time, customer returns and recurring noise complaints
TEC-USA

112 LOOP TEST SYSTEM
In any aircraft there are thousands of bonding points and ground circuits, which all need to be tested to ensure a low resistance path
MK Test Systems

114 MULTISKILLED INSPECTIONS
Automated and assisted portable NDT tools with networking abilities are essential for making sure in-service aircraft are ready to fly
Testia

Contents

116 CONFIGURABLE ROBOTIC NDT
Advances in NDT include new ultrasonic techniques and configurable robot-controlled testing
Tecnatom

118 CONFORM BEFORE SIGNING
Six laws to consider before signing a Declaration of Conformity when importing ground support equipment into the European Union
Intertek

120 ADAPTABLE CAMERAS
High-speed camera-mounting adaptability is important, but so too are standalone operation and seamless networking integration
AOS

122 ROCKET MOTOR PIEZO SENSORS
Combustor pressure testing for burn stability is needed in any program and reliable testing equipment can ensure success
PCB A&D

124 OUT FOR A SPIN
Balanced constant current is less susceptible to noise pick-up than other techniques and is designed specifically to test rotating machines
Precision Filters

126 ADAPTABLE POWER TESTER
An efficient power compliance testing regime requires versatile equipment to accurately trial both AC and DC systems coupled with an ease of use
Chroma ATE

128 WHEN DATA MATTERS
The Q.series data acquisition system for validation and certification of aircraft structural components
Gantner

130 SMALL TESTS, BIG RESULTS
Sub-scale brake testing is a reliable and affordable alternative to full-scale testing
Link Engineering

132 STRUCTURAL TESTS IN 3D
Optical metrology to accelerate certification tests for new landing gears at Liebherr-Aerospace
GOM

134 LUFTWAFFE TESTS GO NORTH
Updated CH-53GA Luftwaffe helicopters undergo testing in the difficult winter conditions of northern Sweden at the Vidsel Test Range
FMV

136 SPEEDY WING SCANNING
Merging automation technologies to slash inspection times for aircraft wings
NIAR

138 VERSATILE I/O CONNECTOR
How a major European airline turned to an innovative connector to achieve a single standard-based system in its testing program
Virginia Panel

140 CURRENT THINKING
What is the best external EME certification approach to follow for general aircraft?
EMCC

142 NEW ANALOG 6DOF SENSOR
A new versatile analog sensor measures six degrees of freedom and is easily installed for a wide range of applications in testing
Dytran Instruments

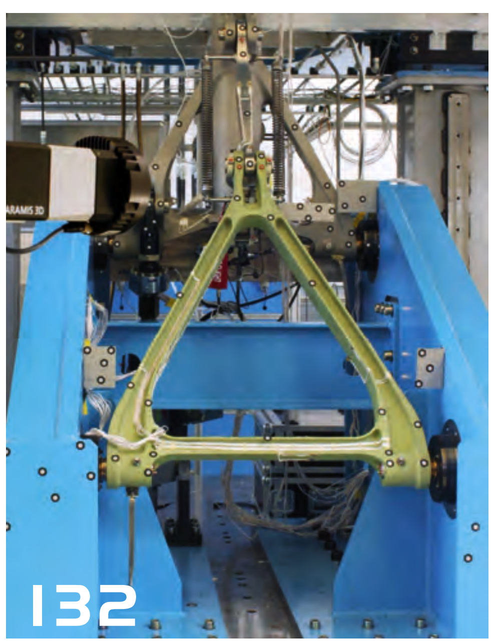
144 TINY CAMERA, BIG IMPACT
Small, rugged and fast cameras designed to capture critical information in previously inaccessible spaces
Vision Research

146 CHANGING THE FACE OF RVI
How a laser-based multipoint system for remote visual inspection helps decide between fix or fly
Karl Storz

114


120


122


132


142

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WINNING COMBINATION

I'd hate to hazard a guess at exactly just how many times the words 'test' or 'testing' appear in the publication you have in your hands right now – suffice to say, it's rather a lot! And that's because every single article you are about to read is completely relevant to what you do. This annual showcase is written *by* testing professionals *for* testing professionals, with the sole aim of highlighting the most relevant and fascinating new trends and technologies to have emerged over the last year with the potential to radically improve and enhance your ability to test more efficiently, more accurately, and more cost-effectively. From fatigue testing to full-scale structural testing, from EMC and lightning testing to environmental testing, and from NDT to vibration testing, we've got it covered.

One aspect of aerospace testing that all those involved in the industry are always keen to emphasize and pay tribute to is the fact that so much of it relies on teamwork and cooperation across departments, companies, even countries.

I must therefore apologize to those team members who we were unable to list as authors of the articles you are about to read – unfortunately there just isn't the space to list every individual involved in a program or new product. This was certainly the case with the exclusive feature you will find on page 22, which details the enormous team effort and considerable challenges facing the Colombian Air Force in realizing the first wing plane full-scale static test to be accomplished in Colombia, for its Calima T-90 trainer aircraft. We weren't able to list each of those involved, however we would like to take this opportunity to congratulate them all in achieving a critical milestone on the road to testing autonomy.

"Overall, [the project] has helped all partners involved acquire basic knowledge about structural static evaluation, helping increase the predictability of structural life, while ensuring continued airworthiness and supporting the certification of the aircraft," writes Cesar Augusto Rodriguez Adaime, principal researcher, FAC.

And that team philosophy is being taken even further with the adoption of a Combined Test Team approach that sees representatives from the customer, design organization, independent technical evaluator and the end user come together into one CTT – and the subject of our opening feature on page 8. "Novel test team construction can provide tangible benefits for a modest increase in program risk and little in the way of up-front cost," writes Garnet Ridgway. "Careful planning is required to ensure that the CTT constitution is appropriate for the task, but the concept is sufficiently mature that it should be considered as a matter of course. Fundamentally, it is a way of empowering aerospace professionals from across organizational divides to collaborate in the delivery of safe and effective test activities – a concept that is extremely hard to argue against."

Finally, another aspect of this industry that I have noticed while editing this magazine is its ability to succor and sustain life-long careers, as a result of the intrinsic technical challenges that engage and keep the brightest engineering minds alert and sharp. Take Gilles Freaud, head of test instrumentation components at Airbus, who kindly answered our questions in an exclusive interview on page 16. Gilles has been with the aircraft manufacturer for more than 30 years – fired by the same enthusiasm that unites all of us that have the privilege to work in such a fascinating and rewarding industry.

Anthony James, editorial director

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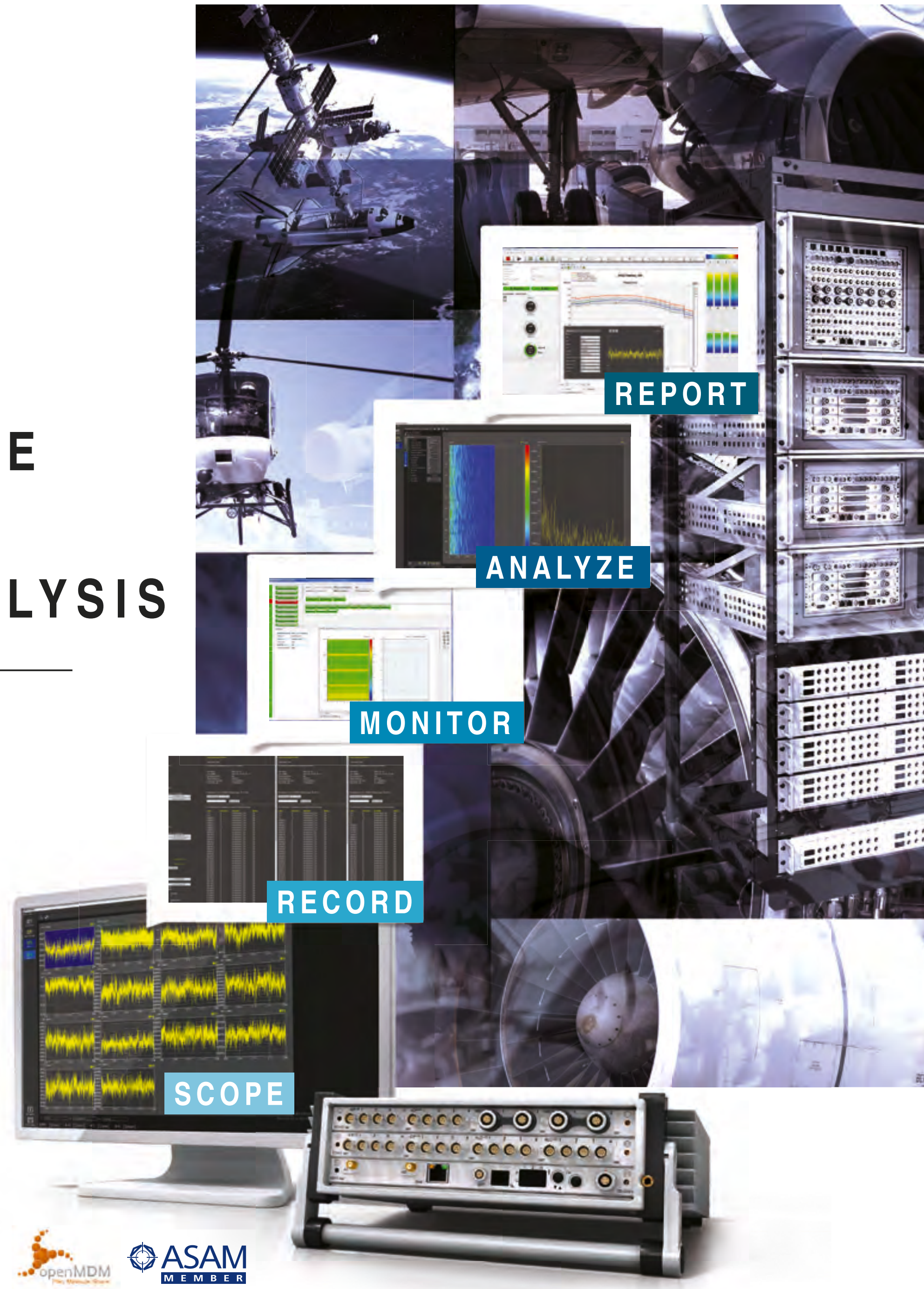

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IMPROVING EFFICIENCY

The Combined Test Team approach improves efficiency through elimination of redundant testing, and is being deployed with increasing success in high-profile projects

BY GARNET RIDGWAY

Aerospace testing is, by its nature, an expensive activity. Employing technical specialists, making use of advanced test facilities and navigating the governance processes required to deliver safe and effective testing can incur vast expense. It is therefore common to seek efficiency savings through technical innovation or, more usually, through a reduction in the scope of testing activities; this will ultimately lead to a reduction in capability for the system under test. But what if there was a way to achieve efficiency savings without accepting a reduction in the scope of testing and operational capability? A concept displaying increasing potential in this area is the Combined Test Team (CTT).

REQUIREMENTS AND STAKEHOLDERS

To take a simple example, the typical stakeholders involved in the release to service assessment process of a new aircraft type can be defined as follows:

The customer: Responsible for defining and managing system requirements, and coordinating the activities of other stakeholders.

The Design Organization (DO): Responsible for delivery of product to satisfy the capability requirements defined by the customer. Additionally, the DO must also demonstrate compliance with these requirements and other applicable standards.

The Independent Technical Evaluator (ITE): Often mandated by the applicable aviation regulatory authority, the ITE provides the customer with an additional layer of assurance as to the safety in role of the equipment under test.

The end user: In a military context, usually referred to as Operational Test & Evaluation (OT&E). Once safety in role has been established, the end-user representative is responsible for assessing the operational effectiveness of the system under test. Additionally, the end-user representative is largely responsible for development of standard operating procedures and training syllabi.

Effective management of the efforts of these stakeholders can be

particularly challenging, and is central to the concept of the CTT.

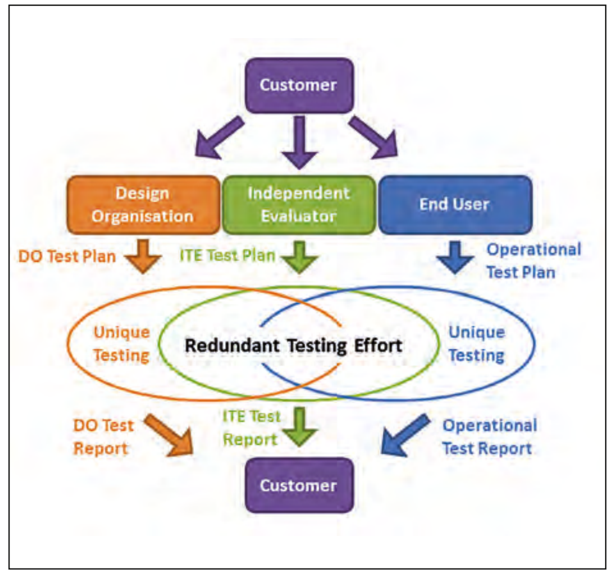
LEGACY MODEL

In a non-CTT scenario, each of the stakeholders conducts their own, sequential, test programs. There is sound logic in this approach; the DO must prove that the system is safe within a defined envelope, and this must be verified by the ITE. Once the safety argument is in place, the end-user representative assesses operational effectiveness within the bounds of this envelope. This is a logical, systematic approach that has endured for many years, but one in which significant inefficiency exists.

For example, the stakeholders are almost certainly not co-located, and may not operate within the same airworthiness regulatory framework, so the process of establishing a test base, defining a test plan and gaining permission from the necessary regulatory authority to operate the system must be undertaken three times. Also, as the stakeholders are operating independently, there is no cross-visibility of test planning or findings, resulting in repetition of potentially expensive and often hazardous trials activity.

MAIN IMAGE: Evaluation of embarked operations requires specialist operator skills and experience

RIGHT: Multiplatform test activities are more likely to succeed through a collaborative approach



RIGHT: The legacy testing concept results in redundant testing through overlap in evaluation scope

> "A HASTILY ASSEMBLED TEAM THAT IS HANDED A SET OF EVIDENCE REQUIREMENTS AND A TEST PLAN IS UNLIKELY TO SUCCEED"

THE COMBINED TEST TEAM

The underlying concept of the CTT is that testing is a source of evidence that can be drawn from by any interested party in order to fulfill evidence requirements. In practice, this means an amalgamation of a subset of key personnel from each of the stakeholder organizations into a single entity: the CTT. However, this amalgamation is not a trivial task, and can determine the success or failure of the test program. The following considerations are particularly critical:

Timely formation: A hastily assembled team that is handed a set of evidence requirements and a test plan is unlikely to succeed. For the priorities, responsibilities and methods to be properly established, it is imperative that the CTT is engaged early in the project lifecycle. This can be achieved through the formation of a cross-stakeholder test and evaluation working group.

Proportionality: A CTT is not a democracy, and stakeholders do not necessarily require equal representation in terms of staffing. Instead, the constitution of the CTT should be driven by the proportion of ownership of evidence requirements – further justification for early CTT formation.

Freedom from commercial pressure: The primary objective of the CTT is to safely deliver the required test program. While any testing professional should be mindful of where their activity sits within the overall program, excessive pressure to meet program deadlines is not appropriate within a CTT. The key message here is that commercial

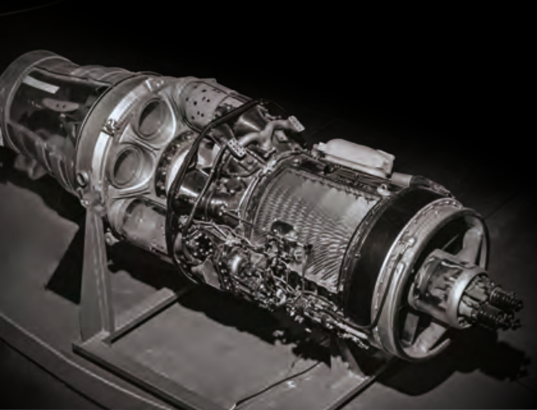
WHEN NOT TO USE A CTT

While the benefits of a CTT approach have been proven on a number of occasions, it is not a "one size fits all" solution. In certain scenarios, an alternative approach may be more appropriate:

Small tasks: For programs in which the capability uplift is small, the process of constructing a CTT may be disproportionate. In this instance, an assessment led by the DO or ITE with oversight from other stakeholders can be more efficient.

Tasks with very specific scope: For tasks such as ship operations, role-specific maneuvers or environmental extremes, it is likely that the required competencies are heavily biased in favor of a particular stakeholder. In this instance, the involvement of other CTT parties may not add significant value.

Tasks with extremely broad scope: The main benefit of the CTT model is the elimination of repetition in testing activities. Therefore, for instances in which the requirements of each stakeholder are disparate, independent test programs may be more effective. Alternatively, it may be appropriate to construct a smaller CTT consisting, for example, of the DO and ITE.

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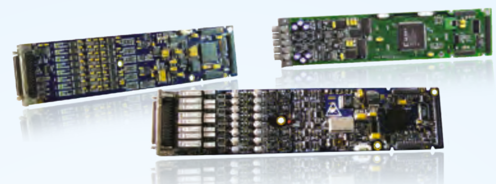

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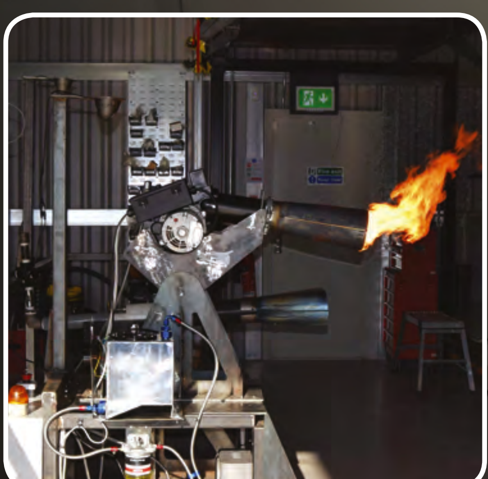

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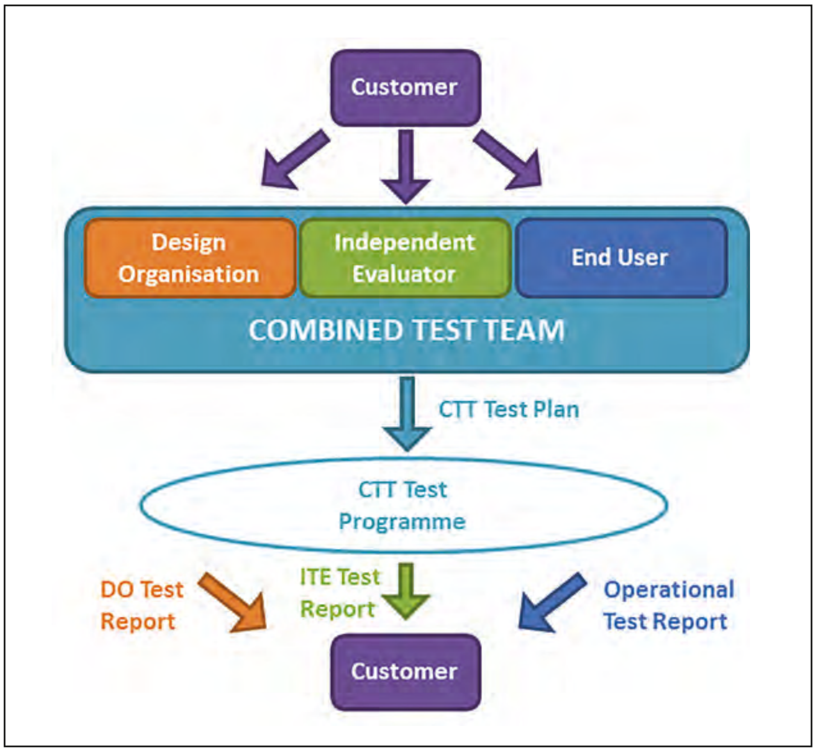

LEFT: The CTT construct reduces the amount of redundant testing

> “A PERSON WITH EXPERIENCE OF WORKING CLOSELY WITH CTT STAKEHOLDERS IS ESSENTIAL”

decisions and pressure should be detached as far as practicable from the CTT.

Leadership: Although the CTT is a collaborative effort, it will ultimately operate under a single regulatory framework and under the leadership of a single responsible person: the CTT lead. The CTT lead must balance the complementary and contrary requirements of the stakeholders, while also filtering program and commercial pressures from above. There are few roles as challenging and diverse in the field of aerospace testing; a person with experience of working closely with CTT stakeholders is essential.

DEVELOPING A JOINT TEST PLAN

With the evidence requirement and CTT in place, it is time to develop a combined test plan. This is an area in which significant efficiency savings can be achieved through intelligent test planning. For example, military aircraft undergoing OT&E will often be required to transit out to appropriate ranges or exercise areas. In the legacy testing model, these transitions could be straight and level flight at altitude, during which no data is captured; in the context of testing, this is a waste of time. The CTT test plan can identify test points requiring straight and level flight, for example engine performance or navigation systems testing.

Similarly, human-machine interface testing often requires the aircraft to be flown in an operationally representative manner; this data can be captured during the OT&E phase of the sortie. Thus, what would have been three or more sorties in a legacy style test program has been combined into a single sortie. This concept can be developed even further with the addition of ‘hanging’ test points – a list of tasks that can be conducted on an ad hoc basis should the opportunity arise. A cautionary note, however; the team must be mindful of the sortie priorities and resist the temptation to compromise safety by attempting to overachieve.

EXPLOITING NICHE CAPABILITIES

A key advantage of the CTT approach is the ability to pool resources between stakeholders, often across organizational divides. This is particularly important for retaining niche capabilities such as test facilities for night-vision systems, electromagnetic compatibility and environmental extremes. Such facilities are few in number and require significant investment to sustain capabilities which, due to their very specific nature, are often under-utilized. The CTT approach opens up such facilities to all stakeholders, increasing utilization and justifying both sustainment and future investment in additional capabilities.

THE FUTURE

As the main benefit of adopting a CTT approach is increased efficiency, future developments are likely to be in this area. For example, where stakeholders are secure in the knowledge that they are to be working together for the foreseeable future, a strategic partnership makes eminent sense. This allows for the establishment of common processes and test methods, reducing the time required to “spool up” CTT activities. Once an effective working model has been established between two stakeholders on a single program, there is no reason that it

RIGHT: For complex weapon firing assessments, elimination of redundant testing brings significant efficiency savings

cannot be transferred to other platforms to spread the benefit of these efficiency savings. The stability assured by such partnerships also raises the possibility of physical co-location, a key ingredient for CTT success.

Many years of shrinking budgets for aerospace products has instilled a culture of driving for efficiency. Although technical innovation can sometimes achieve this, novel test team construction can provide tangible benefits for a modest increase in program risk and little in the way of up-front cost. Careful planning is required to ensure that the CTT constitution is appropriate for the task, but the concept is sufficiently mature that it should be considered as a matter of course. Fundamentally, it is a way of empowering aerospace professionals from across organizational divides to collaborate in the delivery of safe and effective test activities – a concept that is extremely hard to argue against. ∎

ACKNOWLEDGEMENTS

The author would like to acknowledge the efforts of CTT personnel worldwide, for delivering safe and effective capability in the spirit of collaboration.

This article is based upon the personal experience and opinions of the author, and does not represent the views of any company or organization.

Garnet Ridgway works for a UK-based aircraft test and evaluation organization; and writes regularly for Aerospace Testing International

CHINOOK: A CTT SUCCESS STORY

The CH-47 Chinook tandem rotor helicopter provides the backbone of the UK's heavy lift and support capability. The current UK fleet features a bespoke glass cockpit and flight control system, specifically tailored to the Royal Air Force's (RAF) requirements. Given the unique nature of the aircraft and the wide scope of its intended role, a traditional test program would be unlikely to extract the maximum capability for the frontline.

The international CTT, consisting primarily of experts from Boeing, QinetiQ and the RAF, has operated (often simultaneously) from sites across the USA and UK to deliver a diverse test and evaluation program. This includes successfully overcoming the contrasting challenges of operating from Arizona in the height of summer to Wiltshire in the depths of winter.

The impressive nature of the capability delivered by this test program led to the popular phrase among operators: The answer is two Chinooks; what's the question?

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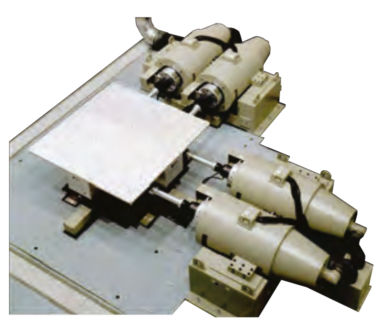

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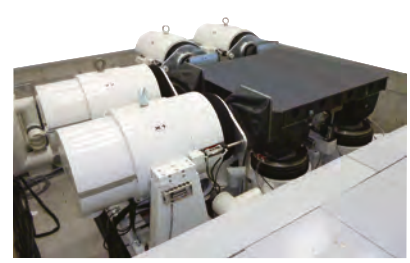

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HAVE YOU MET?

Gilles Freaud, head of test instrumentation components at Airbus, discusses the testing challenges and trends facing Europe's largest commercial aircraft manufacturer

BY ANTHONY JAMES

HOW DID YOU BECOME A TEST ENGINEER?

I had a passion for electronics from a very young age. I practiced at home when I was a teenager and went on to study electronics at school in Toulouse – a city with aviation very much at its heart. So, I merged my technical passion with my dream to work on commercial aircraft.

I subsequently discovered the measurement world when I joined [aerospace manufacturer] Aérospatiale. I very quickly became an expert in this field and this passion is still very much alive.

WHAT WAS YOUR FIRST EVER TESTING JOB?

I started by working in the development team at a small electronics company, then I moved quickly to Rockwell Collins. This period also saw the beginning of the A320 adventure at Airbus and I wanted to be part of this aeronautical future. So I moved to Aérospatiale in the 'tests means' domain.

At that time magnetic recorders were the norm in flight test installation and I worked with these first-generation 'digital' recorders in the area of error code correction. This kind of system was really painful to adjust, and the big 1in tape reel system could only hold 10Gb of data.

It was also around the time of the changeover from analog to digital and test personnel were not used to digitally sampling their signals. So we had to spend a lot of time explaining and training company staff in the Nyquist sampling theory rules, especially as we were also just starting to use digital telemetry.

WHAT WERE SOME OF THE MOST VALUABLE EARLY LESSONS YOU LEARNED FROM THAT PERIOD?

When you start in this kind of job you see very quickly the importance of a flight test. A rule that never changes is that you have to do everything to avoid losing the data of a flight. I also saw the power of working in a team with various kinds of people. In flight tests you must be prepared to see some surprises; we don't always find what we expect – which is the whole point of real testing. The advice I would give to any newcomer to the testing industry is that the measurement data must tell the truth – therefore the reliability of the data is key!

WHAT IS YOUR CURRENT POSITION AND WHAT DOES IT INVOLVE?

I manage a team of 45 people. I spend time working on budgets, managing people, and ensuring the availability of the instrumentation equipment to perform flight tests. The job is to develop, support and repair the measurement components used on flight test installation. Behind the words 'instrumentation' and 'measurement' there are a lot of various functions such as sensors, data acquisition, networks, recorders, telemetry systems on board, and the wide reception network including antennas, video, trajectography, etc. As a manager, a big part of my job is to support the teams in their daily work, to foster innovation, to simplify things, and to prepare for the future.

PLEASE DESCRIBE A TYPICAL DAY.

When I enter my office I always think of our motto: "Excel in testing and test for excellence". A typical day starts by

> **"THE ADVICE I WOULD GIVE TO ANY NEWCOMER TO THE TESTING INDUSTRY IS THAT THE MEASUREMENT DATA MUST TELL THE TRUTH"**

Gilles Freaud, pictured with the A320neo, for which he is currently helping to perform flight test

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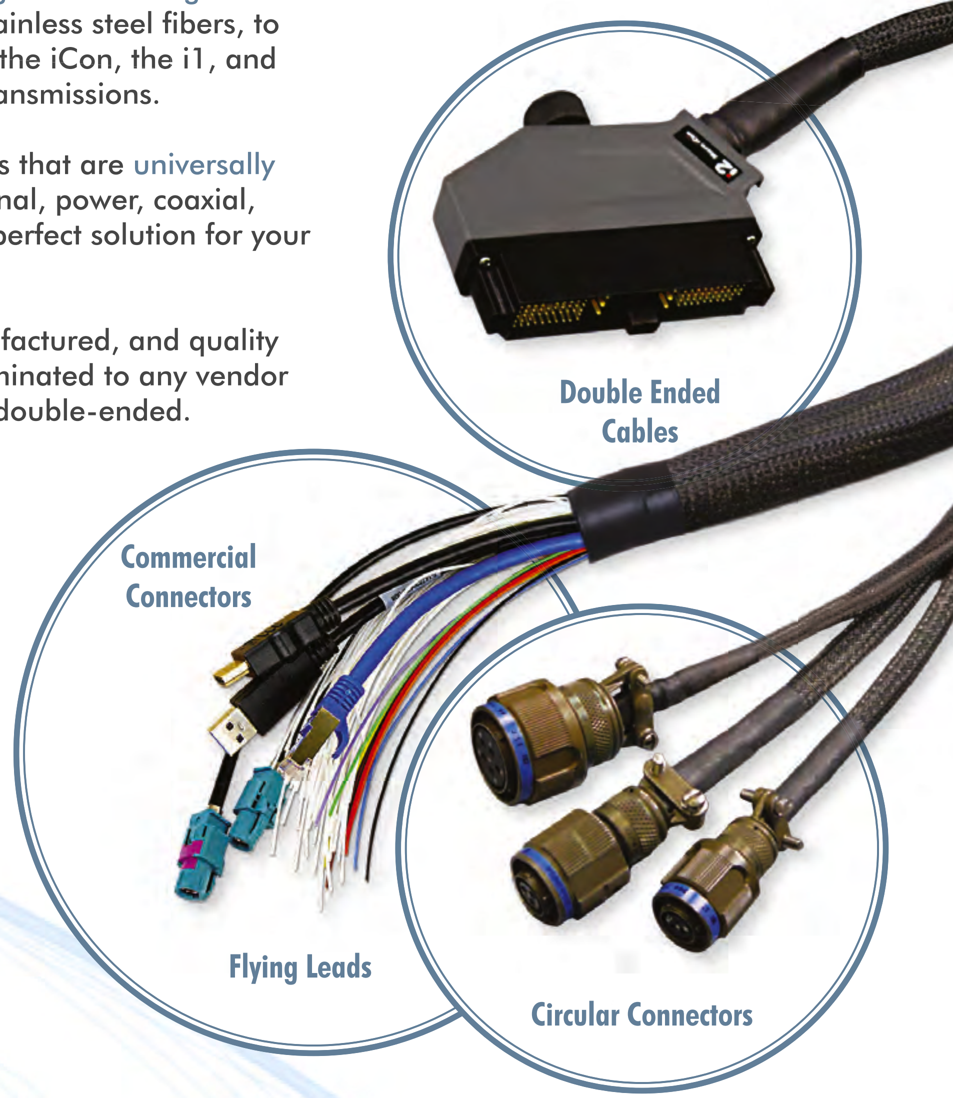

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CONNECTED ORDER

ABOVE: Ethernet networks have helped reduce test system wiring inside the cabins of test aircraft

BELOW: Gilles has worked at Airbus for 30 years

> "FOR FLIGHT TEST INSTALLATIONS, THE LONG-TERM TREND IS THE REDUCTION OF WIRING"

reading the reports of the flights of the previous day to ensure that everything worked well. Our mission is to provide dependable and reliable instrumentation so the flight test can run smoothly. We have therefore defined an operational reliability (OR) system to accurately monitor the performance of our equipment.

I will then typically attend some meetings regarding future needs, project development or costing.

Then I might meet suppliers to learn about their future proposals and gauge how our industry is working. Suppliers are really key since we don't develop our own measurement products, so the link with our suppliers is more like a partnership. We try to convince them to invest in our future needs and to find a 'win-win' situation. Moreover, in our business, since we often have unpredictable situations, we don't know what can happen on a test aircraft, so reactivity is vital and we have to find quick solutions with our network of partners.

WHAT MAJOR PROGRAMS ARE YOU CURRENTLY WORKING ON?

Our way of working is to develop a catalog of instrumentation products and to use them on all Airbus programs. So, currently we are working on the A320neo family, for which we certified the Pratt & Whitney PW1100G engine last year, and the CFM LEAP-1A engine was certified at the end of May this year.

We are also preparing the first flight of the A350-1000, which will take place later this year. In addition, we are developing the flight test instrumentation of the A330neo, which will fly in 2017. However, we work in parallel on all aircraft programs, including the A320ceo and A380, such that we are performing tests on all programs to continuously improve them.

We also have a major research program called Breakthrough Laminar Aircraft Demonstrator in Europe (BLADE) in the frame of the EU's Clean Sky initiative. The goal of the project is to demonstrate the laminar flow on the modified wings of Airbus's A340 test aircraft, and for this we have to develop very innovative instrumentation. This project requires a large variety of sensors and measurement, as well as optical diagnostic and visualization equipment. The scope of the test equipment is probably the widest ever involved in R&D flight tests with Airbus aircraft.

HOW HAS DATA CAPTURE CHANGED?

For flight test installations, the long-term trend is the reduction of wiring. We have moved from a centralized acquisition concept in the cabin to a distributed one throughout the aircraft, in the wing, in the engines, in the tail, etc. Today, we use Ethernet networks everywhere in the aircraft, drastically reducing the number of wires.

Another major change regarding flight test installation has come with databuses such as Avionics Full-Duplex Switched Ethernet (AFDX), which enable us to dramatically increase the amount of data we can collect throughout the aircraft. And by using AFDX buses, the number of tapping points to address is less than with previous Arinc 429 buses. The recording devices have considerably improved their reliability as a result of their solid-state memory.

WHAT ARE SOME OF THE KEY CHALLENGES YOU FACE?

A challenge we are facing today is the marked reduction of the certification cycle, which requires a high level of maturity of the instrumentation used. However, achieving that maturity is a challenge – especially when we develop

> "ON A TYPICAL FLIGHT WE HAVE 160MBPS OF DATA COMING FROM BUSES, SENSORS AND TAPPING POINTS"

a new concept because we have to develop the instrumentation in parallel with the aircraft we need to test. The cost reduction is also a key driver in our business, requiring optimized management of the instrumentation pool. The big question in our business today is how will the world of the Internet of Things change our way of working? We will use more and more digital sensors and wireless networks in a bid to realize the cost savings behind those technologies. As ever, the need to reduce costs continues to drive our innovation.

HOW DO YOU HANDLE DATA?

Data is the 'product' that we provide at the end of the test to analyze the physical phenomena. On a typical flight we have 160Mbps of data coming from buses, sensors and tapping points. In addition, we also have 200Mbps of video data. We also have a very powerful telemetry system working in C-band (around 5GHz) and using an incredibly efficient modulation called Coded Orthogonal Frequency Division Multiplexing (COFDM), which allows us to transmit data without errors. We are able to transmit 20Mbps from three aircraft at the same time.

ABOVE: **Airbus uses a C-band telemetry system for the transmission of test data**

BELOW: **Gilles pictured on board an A320neo test aircraft**

HOW MUCH DATA IS CAPTURED DURING A TYPICAL FLIGHT TEST?

The data captured during a typical flight test is 300Gb for sensors and buses and 360Gb for videos. We store all the data on a centralized solid-state memory, called 'NAS' (network attached storage). The world of data management is changing, according to the big data concept; this will allow our testing teams to better use the large amounts of data collected during a flight test. This is a major game-changer in our business, which is helping our industry to improve the maturity of the systems involved. ∎

Anthony James is editorial director at UKIPME, the publisher of Aerospace Testing International

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NATIONAL TREASURE

History was created earlier this year when the Colombian Air Force conducted wing static testing of its new trainer aircraft, the Calima T-90, marking the first full-scale aircraft test ever undertaken in Colombia

BY CESAR AUGUSTO RODRIGUEZ ADAIME, PRINCIPAL RESEARCHER FELLOW, FUERZA AÉREA COLOMBIANA

The Colombian Air Force (Fuerza Aérea Colombiana – FAC) has been using the T-34 Mentor and T-41D Mescalero aircraft to train new pilots for four decades. However, late in 2006 it decided to replace them, beginning a project to manufacture a new aircraft for training purposes – the Calima T-90 – and marking a crucial first step in raising the capabilities of the Colombian aerospace industry in terms of its knowledge and infrastructure.

In a commercial agreement between the FAC, the Aviation Industry Corporation of Colombia (CIAC), and US aircraft manufacturer Lancair International, four non-commissioned officers specializing in avionics, opposed engines and composite materials were sent to Lancair's facilities to begin the design and manufacture of components for the new airplane. By September 29, 2010, the first Calima T-90 was manufactured and delivered to Colombia. Since that moment it has been fulfilling its function as a training aircraft in many new pilots' courses in the FAC's Military Aviation School, which is based in Cali, Colombia. A total of 26 T-90s have now been delivered.

In 2012 an agreement was made by the CIAC, FAC and the Military Industry of Colombia (INDUMIL), for a project to design an alternative manufacturing process of the principal, central forward spar of the Calima T-90,

ABOVE: More than 90% of the Calima T-90's structure is constructed in carbon and glass fiber-reinforced polymer

ABOVE: The Colombian module for static wing plane static tests was named Icaro, after the Greek legend of Icarus

LEFT: The Calima T-90 is license-built by CIAC in Colombia for the Colombian Air Force

to better suit atmospheric conditions in Colombia, with a view to keep the original configuration spar, manufactured in Oregon.

A number of thermomechanical studies were undertaken as part of the project to produce two spars more suited to local conditions. The first spar was sectioned into coupons that were subjected to laboratory tests to collect data for simulations. The second was subjected to a full-scale flexural load test to better understand its properties. This structural testing confirmed 10% more strength in bending and a 2 lb weight saving compared with the original spar, while failure under static load was also more suited to local flying conditions. All tests were conducted in the University of the Valley in Cali, Colombia.

This work paved the way for another new project in 2014 – the design and implementation of the Calima T-90 wing static test. The project was sponsored by Colciencias (Administrative Department of Science, Technology and Innovation), along with the CIAC and FAC, and was a critical step in the development and engineering of the new training aircraft.

The objectives of the project were fourfold. First, to design and build a module for static tests to enable the verification of the failure load of the wing plane; second, to manufacture one wing plane with the same characteristics as in one of the 26 Calima T-90s already flying, and to subject it to loading in the module, but implementing the new spar from the previous project; third, to use the built module to run the wing plane static test, controlling and monitoring loads, deformations and deflections up to the maximum level; and fourth, to create and share the report of the assessment process and test results.

With the building of this module for static tests, which can also undertake dynamic tests, the capacity to realize full-scale aerospace tests was born in Colombia. In recognition of the ingenuity involved, the wing static test module is named Icaro, because it can show on the ground what Icarus [Ícaro in Spanish] discovered in the sky.

STATIC TEST MODULE DESIGN

The test module was designed for easy disassembly and is also scalable, while it is also wider than the dimensions estimated in the initial proposal, so it can be employed for positive load testing for the Calima T-90, as well as for airplane components with root lengths up to 1.7m and a lift load capacity up to 20 tons. With a relatively modest investment of resources it could be scaled up to perform negative load and dynamic tests, as the hydraulic actuator and metallic structure were designed to meet this goal.

The positive load wing test was successfully executed on April 12, 2016, marking the first time a full-scale aircraft wing plane test was performed in Colombia. The test employed a hydraulic actuator with one whiffletree to distribute the load. Thus, the development of the test module and

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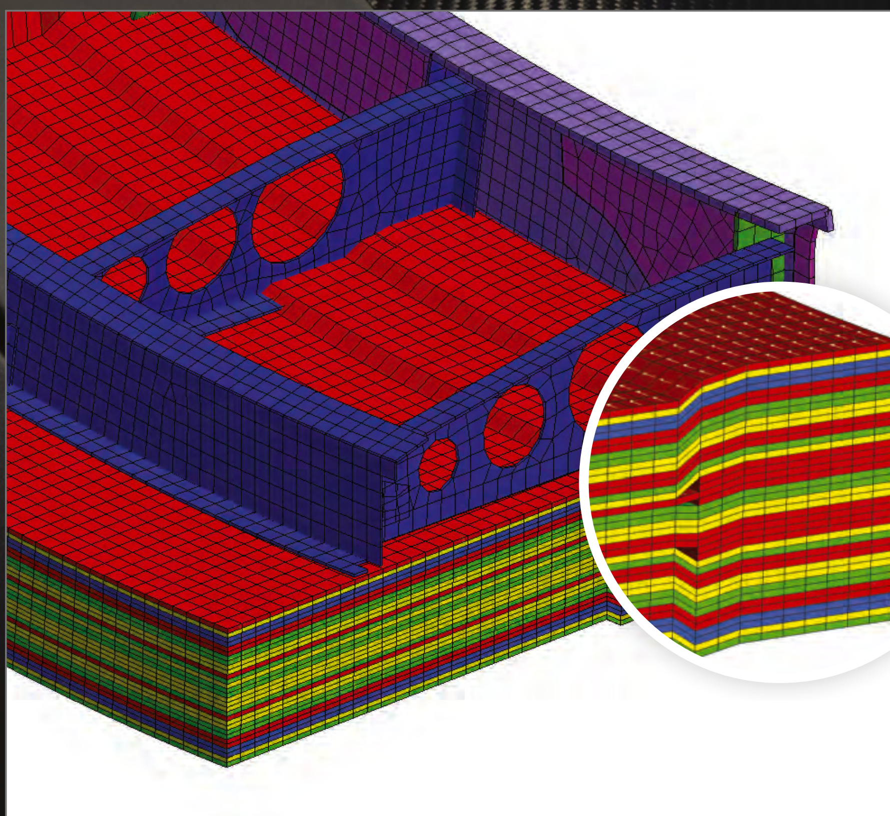

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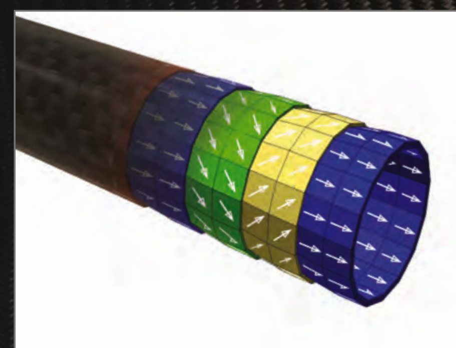

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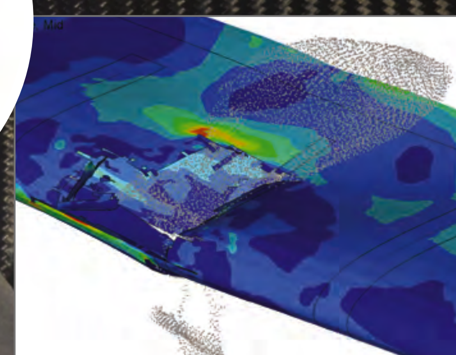

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LEFT: The wing plane of the Calima T-90 exceeded the ultimate load for more than three seconds and showed to be very safe for the critical flight conditions, reaching 6.3*g* at a very critical load condition

its use in the static test of a wing of the Calima T-90 aircraft was used to provide valuable information required to obtain FAR 23 certification for the Calima T-90.

TEST PROCEDURE

The test itself lasted more than 12 hours, and to achieve certification for the wing plane, which was awarded by the Section of Aeronautics Certification of Defense – SECAD – it had to adhere to strict technical and documentary protocols based on FAR 23 and its supporting references as advisory circulars, among others.

During the test, the wing plane was subjected to forces equivalent to those expected in normal flight loads. Specifically, the Calima T-90 was subjected to a first stage equivalent of 4.05g, and during the force application the operation of the control surfaces – the flaps and ailerons – were tested. All responded smoothly and without any loss of functional capacity. Then the wing plane was inspected, receiving approval to proceed with the next step of loading – a cycle to reach the ultimate load of the wing plane, corresponding to 6.075*g*.

A new inspection saw the continuation of the test to a third stage, in which the aircraft was subjected to increasing loads to achieve rupture, which occurred at

"BREAKAGE WAS CONCENTRATED IN A PREDICTABLE AREA WITHOUT ADDITIONAL FAILURES IN THE REST OF THE WING, WHICH SHOWS THAT THE EFFECTS ARE CONCENTRATED IN ONE PLACE"

RIGHT: The wing plane of the Calima T-90 was subjected to a first stage equivalent to 4.05*g*, while the operation of the control surfaces were tested

6.3*g*. During every second of the test, video and sensor data were captured and stored in a datalogger, recording every movement the wing plane made as a result of the loading.

"The results show that the aircraft under critical flight conditions for a category normally behaves very well and has a structure with a very good performance," says project director Cesar A Rodriguez, principal researcher, Colciencias-FAC 666-2014. "The information collected will define critical areas and opportunities for improvement of the aircraft, as well as valuable information to ensure continued airworthiness. Breakage was concentrated in a predictable area without additional failures in the rest of the wing, which shows that the effects are concentrated in one place – this is the first step for many studies that the analysis of the

ABOVE: Colombia now has the capacity to conduct full-scale aerospace tests on home soil

information collected during the test may bring forward."

CONCLUSION

The construction of Icaro and the successful execution of the wing plane test to failure loads has helped the Colombian aerospace sector acquire some vital new skills. It has helped fully explore the airplane's design, and to better understand load distribution, security factor, deformation and critical points of the aircraft structure. The project has also delivered the capacity to design and build a test module to expand the capacity of the original module, as well as benefit from the experience and knowledge that comes with executing and monitoring the static test, and evaluating the development of the wing plane according to new design conditions.

Overall, it has helped all partners involved acquire basic knowledge about structural static evaluation, helping to increase the predictability of structural life. Furthermore, it has generated a new business unit to sell similar services and kit, but most importantly of all, it ensures accurate prediction of the reliability, durability and performance of the Calima T90 against possible failures that could result during stable flight conditions. ■

Cesar Augusto Rodriguez Adaime was the principal researcher in the design and implementation of the T-90 wing static test

MEET THE TEAM

The Icaro research team comprised two military personnel – Sonia Ruth Rincón Urbina (metallurgical engineer and FAC principal leader of the research project), Manuel Fernando Caro Rincón (FAC assistant engineer of the military leader) – and civil researchers including Cesar Augusto Rodriguez Adaime (materials engineer, principal investigator, proposer and executor of the research project), Arlex Leyton Virgen (mechanical engineer and designer, who modeled and simulated different conditions of the metallic structure when subjected to loads), Edwin Jairt Bastidas Bonilla (industrial engineer, who conducted and simulated the economic study), Daniel José Salcedo Valencia (mechanical engineer, research assistant who supported the principal investigators in the research development), Jhon Jairo Obregón Valencia (mechanical engineer intern, who supported the construction drafts and simulation) and Jean Andrés Segura Duarte (electronic engineer intern, who supported the DAQ and control system).


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NO DATA COMPROMISES

Leveraging new flight test instrumentation technologies can be done without compromising data reliability

BY STEPHEN WILLIS

Evolving technologies and user requirements are bringing innovative changes to how traditional flight test instrumentation (FTI) hardware functions. As the number of parameters being captured during tests grows, new capabilities are helping FTI engineers keep up with increasingly complex configurations. New advances, such as the integration of processing power into the data acquisition unit (DAU) chassis, increased network connectivity via Ethernet, and improved interoperability between heterogeneous DAUs, are helping to bring flight test campaigns into the 21st century. More importantly, this improved DAU performance and flexibility is helping to reduce the need for costly repeat test flights.

The high cost of test flights also means that it's not enough to simply add new features to FTI hardware. The resulting next-generation system must also provide the robustness and reliability that FTI engineers demand from their test equipment.

The success of a test flight depends on data being gathered reliably and accurately – not an easy task in harsh environments where power brown-outs are an ongoing threat. Predictable data acquisition with minimal loss of data during power dips is essential because lost data can mean the need to repeat a flight – which can cost dearly both in revenue and time. The challenge for FTI system vendors is to help make the FTI engineer's job easier and more efficient by delivering enhanced hardware that does not compromise reliability.

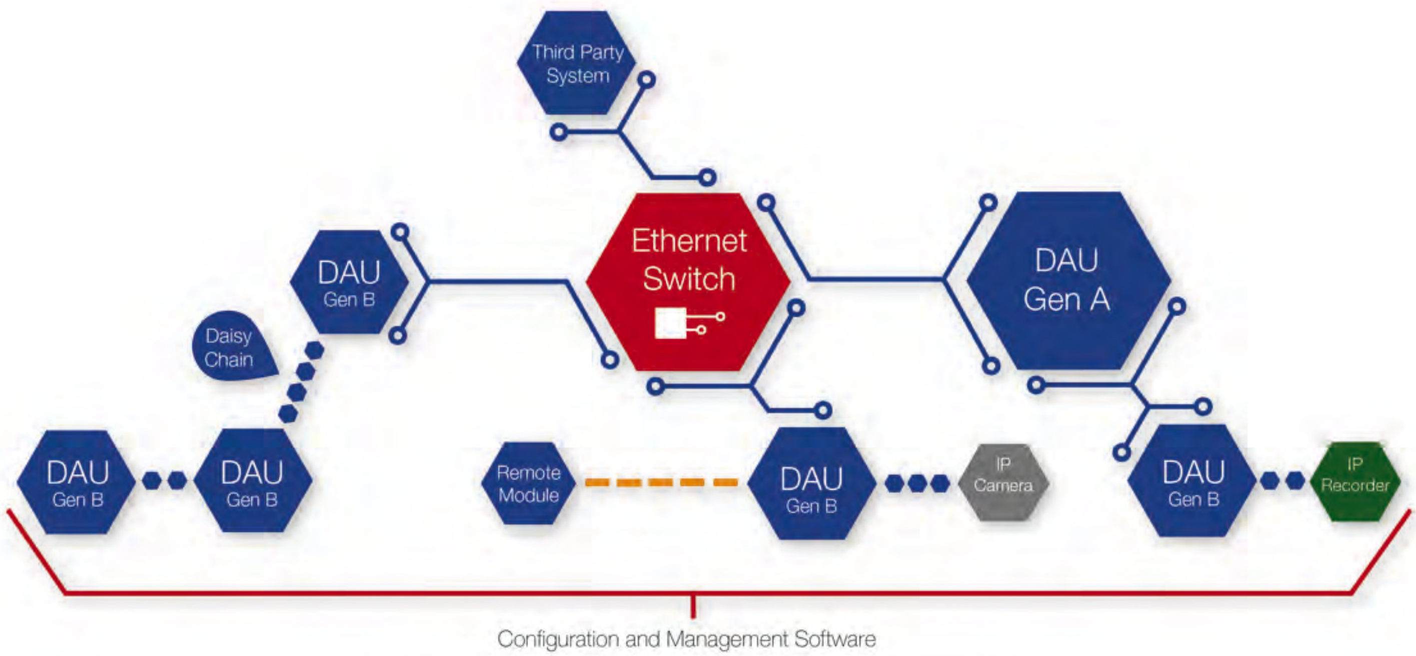
Newer technologies can lead to smaller, lighter and faster DAUs

MOBILE POWER

Many tasks that previously relied on a desktop-bound PC can now be done virtually anywhere. Thanks to more powerful multicore microprocessors, and the associated decrease in their size and power requirements, it is now practical for DAUs to host relatively powerful microprocessors. Only 10 years ago the data storage, working memory and processor speed that can be easily integrated into a modern DAU would have been prohibitively expensive and power hungry. In essence, the FTI market is now able to leverage the same technology trends that are causing the proliferation of low-power processors in phones, TVs, and automobiles.

The presence of a powerful processor in the DAU brings with it additional flexibility and performance. A wide range of software now becomes available to provide the FTI system with new features to increase efficiency. For example, running web server software in the DAU enables a user to opt for a phone or tablet-based browser to view a chassis configuration, change settings, view parameters in real time, or check continuous built-in test status. Assuming the system's hardware architecture can support standard programming interfaces, such as the RESTful API, users will be able to create powerful custom applications to suit their needs. This flexibility opens up new possibilities such as a mobile application for an OEM that rapidly displays system topology, the details of a DAU module's settings, or real-time preflight data to ensure that all is ready to go prior to commencing a test flight.

For many users, one of the most exciting advantages of having a processor integrated into the DAU is the ability to run custom software to process real-time or collected data. This makes possible advanced diagnostics such as the use of machine learning to detect possible wiring or sensor faults. Custom event flagging can be used to alert a pilot of a



"THIS IMPROVED DAU PERFORMANCE AND FLEXIBILITY IS HELPING TO REDUCE THE NEED FOR COSTLY REPEAT TEST FLIGHTS"

ABOVE: Standards protocols and synchronization strategies enables different generations of DAUs, recorders and switches to be used together in one system

potential safety concern. It also becomes possible to implement a number of custom data formats and transmission protocols to serve data to other systems, such as a video replay station or a central database server.

RELIABILITY

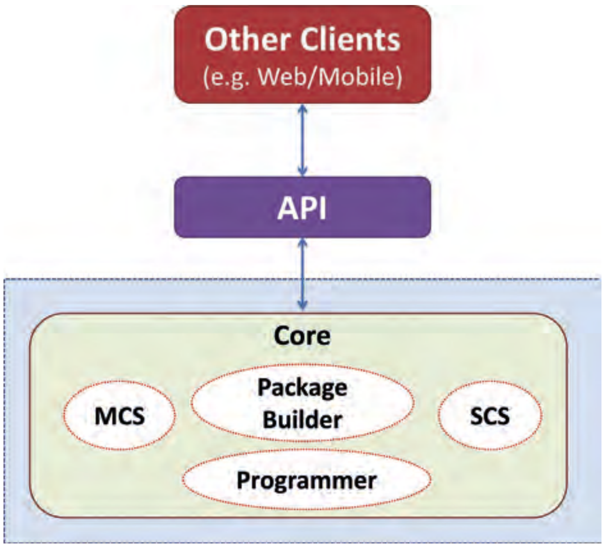
While many of these new processor-based features are desirable, and some are even likely to be required by a future iNET implementation, the most important feature of a DAU remains the reliable acquisition of data. If a DAU malfunctions during flight, the test points have to be reflown. To avoid the pain and cost of additional test flights, data acquisition is better handled by FPGA-based finite-state machines (FSM). FSMs are more desirable for data acquisition than microprocessors because their behavior is deterministic and predictable. If a system gets into an unforeseen state due to a power dip, the FSM will cycle out of that state and begin operating normally again. In a worst case scenario, a processor-based data acquisition system won't recover fully after a power dip. But even if the system is able to reboot and recover, there could be potentially harmful gaps in data which will have been introduced during the downtime.

The good news is that is possible to provide all the advantages of a microprocessor in a DAU while mitigating risks to the reliable capture of data. The key is to isolate the processor and the FSM functions. In this approach the processor can be thought of as a PC or laptop that is connected to the DAU via a network switch. Processor-based functions, such as altering system configuration and programming, can be run during preflight checks, while programs that see parameter values can be run during data acquisition. As data access at this level is embedded in the heart of the DAU, custom programs are best kept to a separate processor module that can pull and push parameters through the system bus. In the event of a power brown-out, the DAU will begin acquiring and transmitting data as soon as power returns. After the power disruption, there will be a delay in the function from any processor element, but this will typically pose only a minor issue as the main data acquisition function will be unaffected.

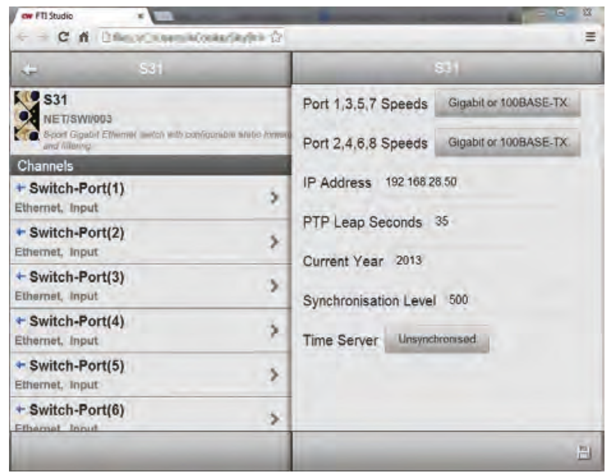
THE NEED FOR SPEED

With earlier FTI hardware limitations such as data storage and post-flight processing power now largely eliminated, the biggest challenge facing FTI engineers today is dealing with the huge increase in the number of parameters being acquired during a flight test. For example, the number of flight test parameters required in one major OEM's development programs has increased from under 10,000 to over 180,000 in less than a decade.

"THE MOST IMPORTANT FEATURE OF A DAU REMAINS THE RELIABLE ACQUISITION OF DATA"



ABOVE: By separating the core configuration software from a GUI, it is possible to use an API to create highly customized user interfaces



ABOVE: Integrated web servers can allow interfacing with DAUs using mobile devices via wi-fi and web browsers

The advantage of all this additional data is that there is more evidence for flight certification. The large number of parameters can also help avoid the need for an unscheduled flight to investigate unexpected phenomena. In addition, there are also non-flight test reasons for wanting greater amounts of data. Compared with the potential benefits for troubleshooting and simulations, including less time in the air for the aircraft, it takes relatively little extra effort to implement a system to provide an OEM's avionics and aeronautical departments with more extensive data.

One way to increase data parameters is simply to increase the number of DAUs on the aircraft. This has the advantage of using existing, proven and familiar technologies. The disadvantage is the resulting increase in the size and mass of the system and the increased complexity of its installation and management. Another approach is to increase the data collection capability of each DAU. While this option adds data capacity without incurring volume, mass and installation overheads, it also requires the use of new technologies and/or a hardware evolution. For example, gigabit serial links can theoretically pass data from modules at rates as high as 1Gbps. Today, though, an aggregator in the DAU is likely to act as a data throughput bottleneck. In coming years these bottlenecks are likely to be reduced, resulting in as much as a tenfold increase in speed over contemporary technologies. Fortunately, for many of today's FTI sensors, such high data rates are not needed, enabling existing DAUs to be reused for many years to come.

THE INTEROPERABILITY CHALLENGE

Understandably, aircraft OEMs would like to protect the investment they have made in their existing stocks of DAU hardware. Ideally a new type of DAU from a third-party vendor could easily be used with the OEM's legacy hardware, either as a replacement or as a simple addition to an existing system. Such compatibility would enable any number of new DAUs to be added to an existing FTI network. The challenge is incompatibility between configuration software standards. The solution is to use currently available open standard metadata formats, such as iHAL, MDL, TMATS XML and XidML.

Programming software that can interpret these metadata formats can in theory configure DAUs and other systems from multiple vendors. This would make it possible to program different DAU types using the same configuration software, resulting in an entire configuration stored in a single configuration file. The network synchronization protocol IEEE 1588 - the Precision Time protocol (PTP) - could be used to synchronize each DAU so that each chassis has the correct absolute time signal. However, it will also be necessary for the different DAUs to use the same sampling strategy to ensure that all the parameters can be correlated.

In many ways, the simplest way to ensure interoperability between DAU equipment from different vendors is for it to operate as a full network node in an Ethernet system. This is the aim of an iNET working group striving to define a superset of standards to enable a consistent interface on flight test equipment from all vendors. It is logical, therefore, that any DAU compatibility strategy should provide support for these iNET standards.

CONCLUSION

Higher levels of device integration and requirements for greater numbers of data parameters are changing how FTI hardware functions. At the same time, the fundamental need for robust and reliable data acquisition systems remains of paramount importance. While FTI hardware will never exist in a similar market space to smartphones, where new and revolutionary technologies debut every year, there are exciting new and emerging enhancements for data acquisition that are making it easier to meet the needs of FTI engineers and test programs. ■

Stephen Willis is product marketing specialist for Curtiss-Wright Defense Solutions, Avionics & Electronics

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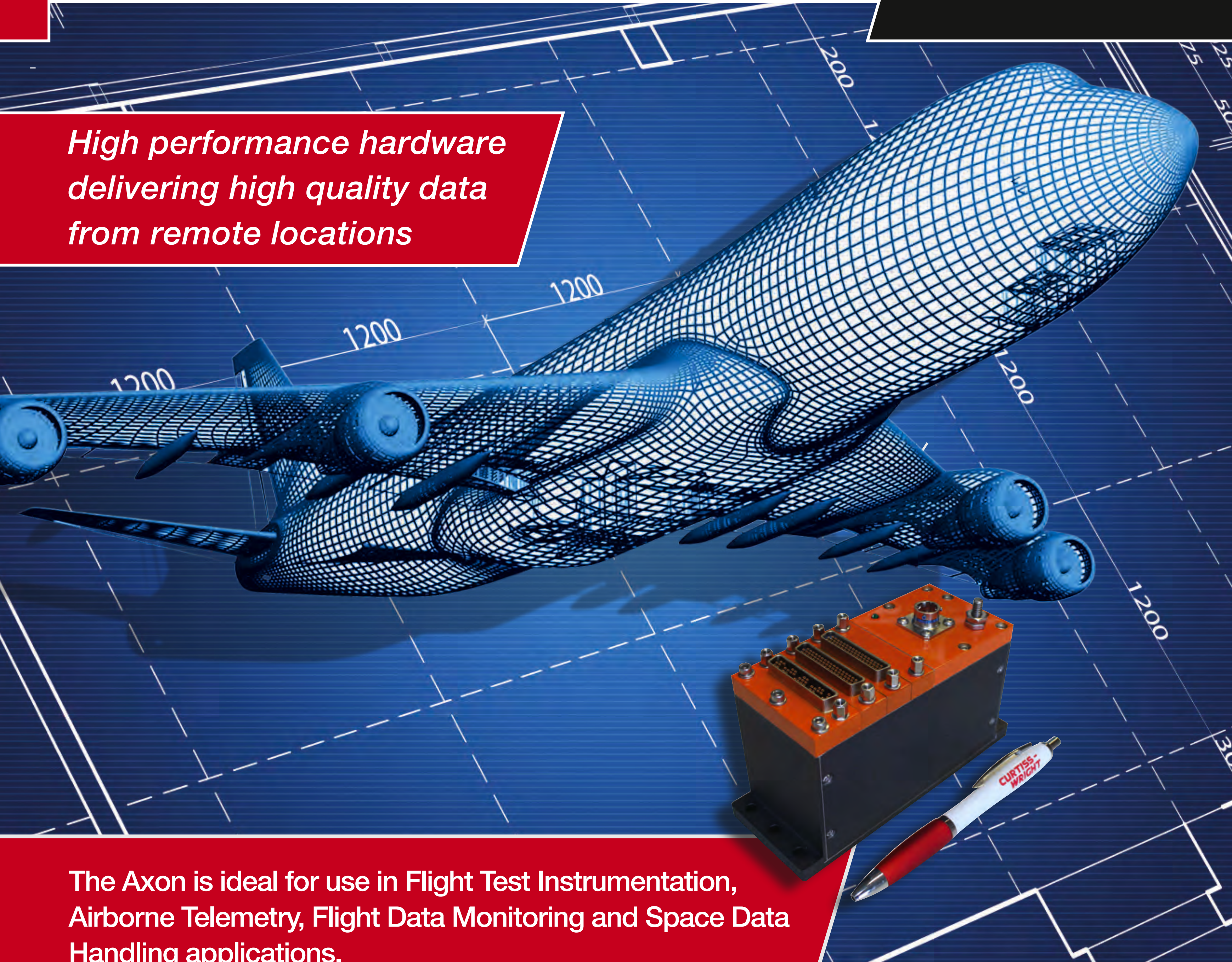

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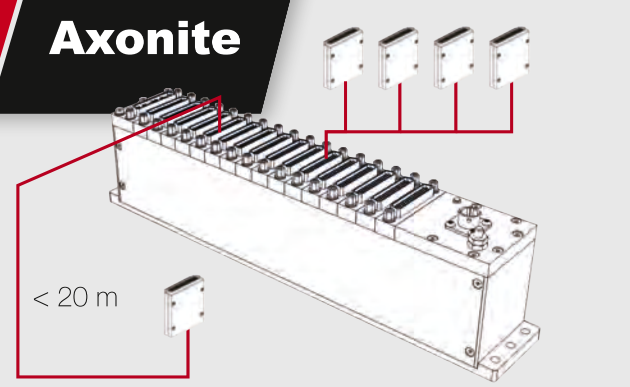

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DESIGNED FOR LIFE

Jan Leuridan talks to *Aerospace Testing International* about Siemens' recent launch of Simcenter solutions for product development from initial design and simulation to physical testing

BY MICHAEL JONES

Ultimately deriving from software acquired over several acquisitions, Siemens PLM Software has created Simcenter solutions, an integrated portfolio encompassing preliminary design, simulation and testing solutions. "With this brand we have brought together quite a lot of applications for 3D CAE, 1D simulation and testing into a single solution set," says Jan Leuridan, senior vice president for Siemens PLM Software. The acquisitions that enabled Simcenter include many well-known design, simulation and testing products. "The holistic set of technologies and applications we have supports multi-skill simulation, so customers can carry out simulation at very early phases of development, all the way to more detailed stages of development and validation with physical prototypes," says Leuridan.

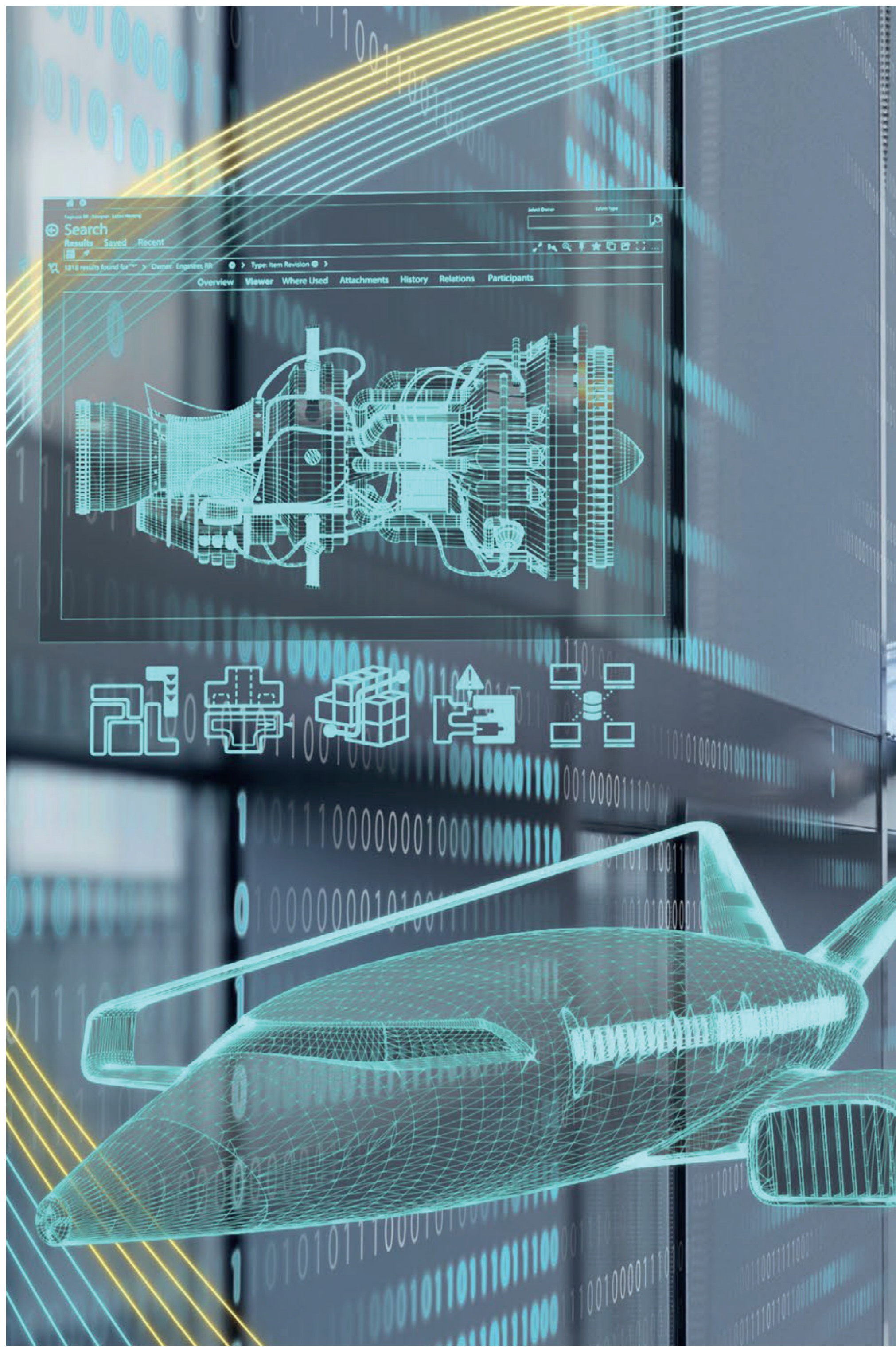
SIMCENTER

The Simcenter portfolio offers 1D simulation, 3D CAE and testing to help develop products and predict performance across all critical attributes and throughout a product's entire working life. This is done by combining physics-based simulations with insights gained from data and analytics, to optimize design and deliver innovations.

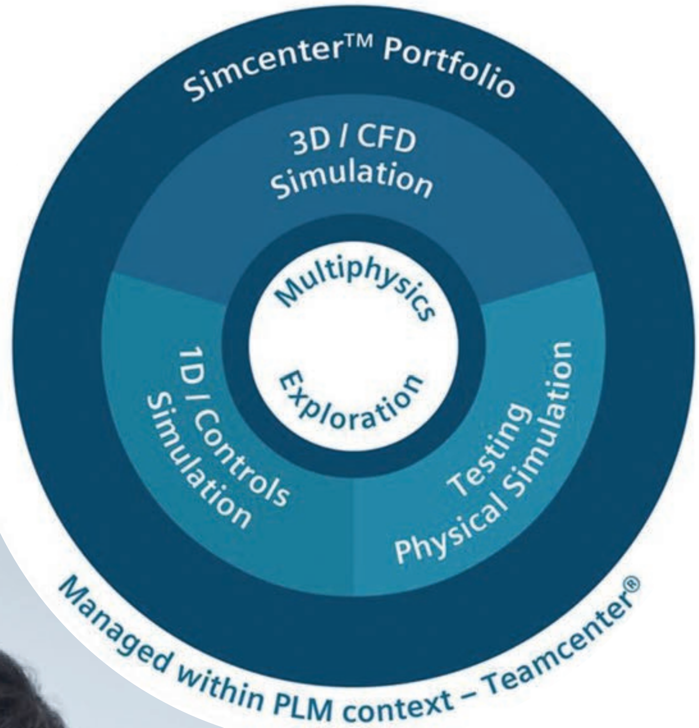
Simcenter encompasses three areas: 1D system simulation, 3D simulation and CFD simulation, and physical testing. Along with the Simcenter portfolio was launched Simcenter 3D, the next 3D simulation software. "Simcenter 3D is our next-generation 3D CAE solution. It is based on the NX platform and expands on the heritage of NX CAE, NX Nastran, LMS Virtual.Lab and LMS Samtech," explains Leuridan.

1D SIMULATION

Within Simcenter are applications and tools for what Siemens calls 1D system simulation, including the ability to connect to controls, because nowadays products increasingly combine mechanics with software and controls. "In terms of simulation, you basically need to be able to represent the



The Simcenter portfolio allows predicting product performances across all critical attributes and throughout their entire working life



LEFT: The Simcenter Portfolio encompasses simulations of a variety of stages in development, including the ability to perform multiphysics explorations for design optimization

"THE HOLISTIC SET OF TECHNOLOGIES AND APPLICATIONS WE HAVE SUPPORTS MULTISKILL SIMULATION, SO CUSTOMERS CAN CARRY OUT SIMULATION AT VERY EARLY PHASES OF DEVELOPMENT"

complex product in all its physical aspects," Leuridan explains. By including LMS Imagine.Lab Amesim, Simcenter offers 30 libraries with over 4,500 multiphysics models that can be combined to simulate hydraulics, pneumatics, thermal, electrical, mechanical and signals. They can evolve from simple map-based models with standard parameters to fully detailed physics models as data becomes available.

LMS Imagine.Lab software is a leading multiphysics simulation software with built-in application expertise. Modeling of physical components can be done using a block diagram approach for control systems, which can then be coupled to a comprehensive workflow.

"The power of this approach has for example been demonstrated by coupling LMS Imagine.Lab with CFD in the context of powertrain systems, battery systems or fluid systems," explains Leuridan.

3D SIMULATION

Simcenter 3D provides tools for predicting the performance of 3D geometry-based designs with a multidisciplinary performance approach. There is preprocessing and a large variety of powerful solvers and application-specific post-processing give efficient simulation processes that are strengthened by industry embedded expertise. This new platform was built on decades of 3D simulation experience. NX CAE and NX Nastran were acquired from Unigraphics, and in 2012 LMS solutions, including LMS Virtual.Lab and LMS Samtech, joined the fold. "Early in 2016 we announced the acquisition of CD-adapco, bringing a rich portfolio for computational fluid dynamics [CFD] into Siemens PLM Software," says Leuridan.

Simcenter 3D provides a range of 3D CAE methods, including finite element analysis, boundary element analysis, CFD and multibody dynamics. All are accessible by general analysts and discipline experts.

Linking the 3D simulations to 1D modeling and the testing solutions will achieve unparalleled accuracy.

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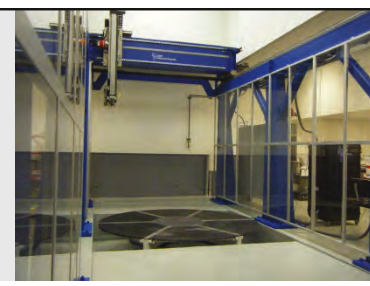

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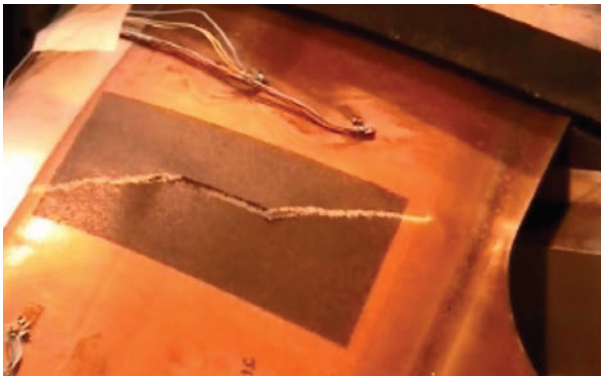


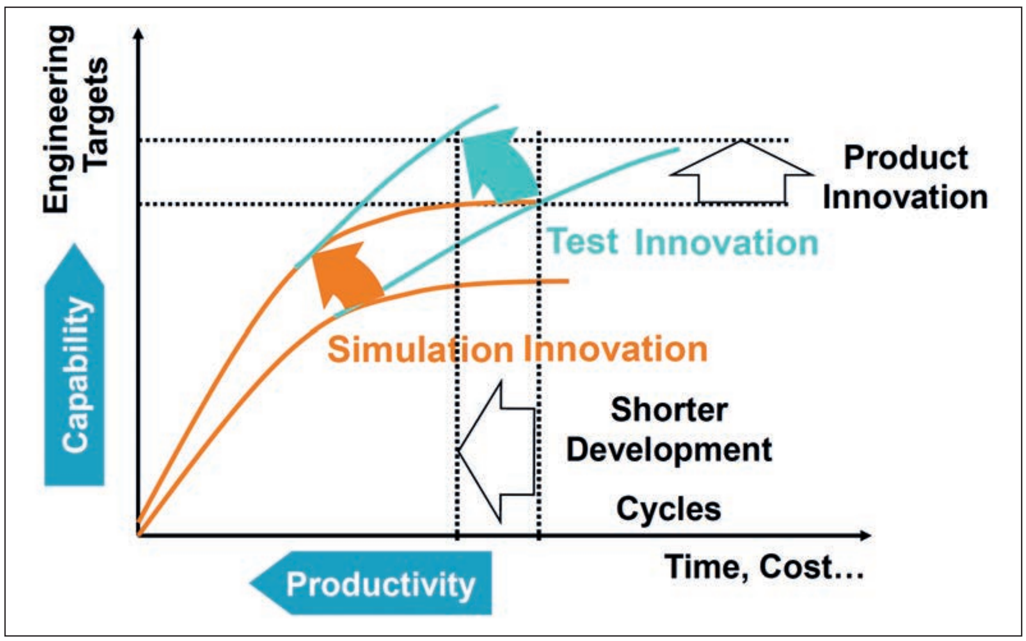
LEFT: Virtual testing is an essential tool to decrease the number of physical tests on composite components

> "SIMCENTER PROVIDES THE ABILITY TO CLOSE THE LOOP IN TERMS OF SATISFYING THAT A DESIGN MEETS REQUIREMENTS"

unmatched simulation accuracy and to effectively conduct component and final product validation. Simcenter testing solutions offer a complete, integrated environment for test-based engineering and design.

"We think about Simcenter as providing the ability to close the loop in terms of satisfying that a design meets requirements, doing so in all stages of the development process in a true behavioral simulation," commented Leuridan. In making the bridge from the virtual to the physical, Simcenter also supports the later stages of development, such as testing applications, and there is a big focus on enabling real-time simulation. "This is very important because we see our clients increasing their use of hardware-in-the loop simulation setups," says Leuridan.

Siemens supports physical testing with its LMS Test.Lab integrated test-based software platform. The solution offers comprehensive support for noise, vibration, structural dynamics, rotating machinery, acoustics, sound quality and more. By combining LMS Test.Lab with the Simcenter 1D and 3D simulations, users will be able to make their models more efficient and realistic. The software is seamlessly integrated with LMS SCADAS data acquisition hardware. This can support a large variety of transducers combining analog and digital signals, so vibration, forces, strain, temperatures, CAN signals and more can be captured.



ABOVE: Simcenter can increase simulation accuracy, leading to reduced physical testing, greater innovation or reaching increased engineering targets

WORKING WITH SIMCENTER 3D

The analysis preprocessing in Simcenter 3D can be associated dynamically with a CAD model geometry that can be obtained quickly from any source.

A CAD assembly can be converted into a mechanism for motion analysis and there will be extensive functions for mesh generation, assembly and model preparation.

The preprocessing for the built-in, industry-standard solvers is done as a shared application-oriented environment that supports a wide variety of disciplines. Subject-specific postprocessing provides quick insights.

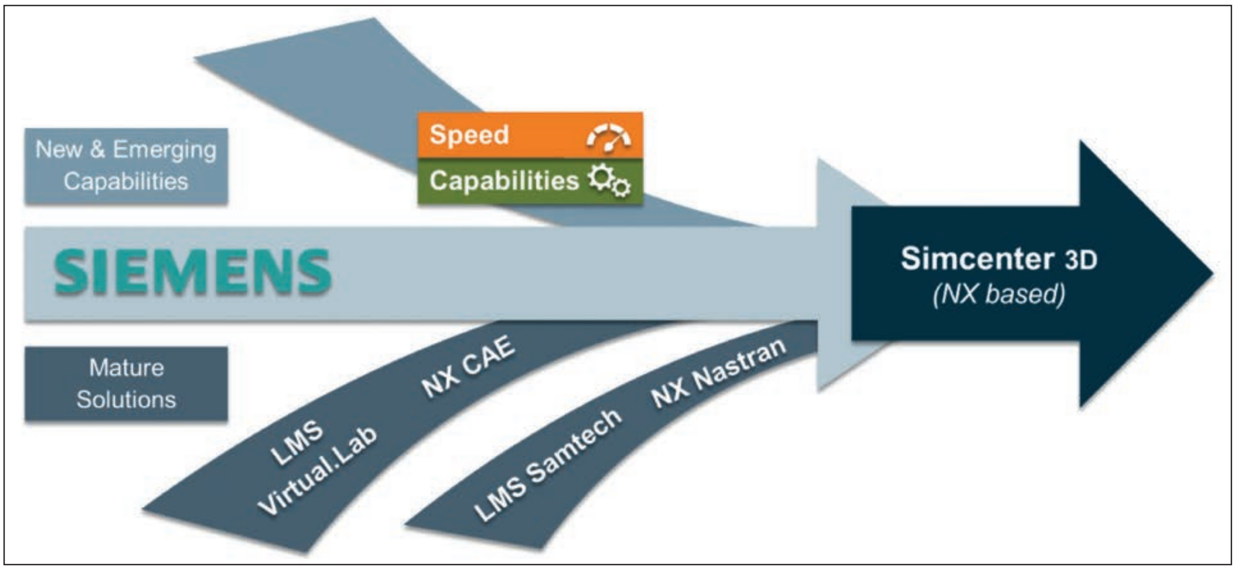
Included with Simcenter 3D is functionality for modeling laminar composite structures and an ability to communicate with Siemens' portfolio of composite engineering software such as the Fibersim portfolio.

Traditional CAE preprocessors may generate large monolithic models, but Simcenter 3D creates finite element (FE) assemblies by instancing and connecting component models – much like CAD assemblies. Even after component changes, these FE assemblies can be easily updated.

Solutions that can be simulated include structural, thermal, flow, acoustic, motion and other types of analysis – all with a common interface and the same file structure and data management schemes.

MULTIDISCIPLINARY EXPLORATION

Simcenter includes an efficient and easy-to-use multidisciplinary exploration framework, called HEEDS MDO, that easily integrates with



ABOVE: Simcenter 3D encapsulates the strong simulation solutions from well-known programs while adding enhanced speed and a greater range of capabilities to explore designs

> "OUR CUSTOMERS ARE INVOLVED IN PRODUCT INNOVATION BY PUSHING ENGINEERING TARGETS, AND THE RELENTLESS PRESSURE TO SHORTEN DEVELOPMENT CYCLES"

current design and simulation tools, thus protecting a company's existing investments and generating a higher return on investment in high-performance computing infrastructure.

Keeping models and results in sync is achieved with data management integration through the Teamcenter data management environment. Capturing and managing data and processes permits organizations to build long-term knowledge and value.

Improving a single component or a complex system becomes easier as Simcenter can automatically explore the design space within the constraints of specified goals, such as reducing costs while maintaining stresses below certain levels.

HEEDS MDO software can help manage conflicting targets such as mass, cost, manufacturability and performance. "It works with all of the different simulation applications we have by taking them through different simulation cycles to do exploration for design optimization," he said.

REPORTING AND EXPLORATION

Data analytics, reporting and exploration are becoming increasingly important because, as Leuridan explains, "You basically gather lots of data over the entire product lifecycle." Siemens continues to invest in advancing the software's ability to process simulation, testing and use data, so as to gain insights that can improve the next design.

SERVICES

In parallel to the software applications, engineering services are "a strategic part" of the business: "Through this activity we always have the opportunity to work with our customers on real engineering problems. By doing so, we get a good understanding of where our customers are heading, and of the needs they have for what they want to do," says Leuridan. "That understanding has always been critical in terms of driving innovation in what we do in simulation and testing." Through Siemens' engineering services and technology exchange with the industry, the maturity levels of some of the more advanced areas of simulation could be dramatically improved.

"We have the ability to work with clients in aerospace and automotive on real engineering problems. With our assistance, clients can become more proficient with certain types of simulation," says Leuridan.

In the aircraft industry, Siemens also has an extra set of applications to support the simulation of composite structures, a large part of which have been developed in cooperation with Airbus over many years.

FUTURE STRATEGY

Besides a further integration between disciplines, there is continuous investment to improve each of the applications, whether 1D simulation, 3D CAE, CFD, physical testing or controls development. Siemens is committed to keeping the portfolio the most competitive in the field in which these applications are being used. "We see our customers are involved in product innovation by pushing engineering targets, and the relentless pressure to shorten development cycles," Leuridan says. "To do that, one needs to innovate with simulation and testing. This is the kind of dynamic that we see with our customers and is why we focus on that within Siemens PLM Software."

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SQUIB CIRCUIT INTEGRITY

A new family of fully automated multimeters tests several connection paths in an aerospace system with one automated sequence – while dramatically reducing the risk of accidental detonations

BY DEAN JORGENSEN AND BRANDON RATHBUN

Before Lockheed Martin delivers a Terminal High Altitude Area Defense (THAAD) interceptor to the US Army, and before the US Navy loads a Raytheon SM-6 missile into the Aegis vertical launch system, technicians must first ensure that the resistance and stray voltage in the system's multiple electrical circuit paths are all within allowable limits. Responding to the demands of aerospace system OEMs for a turnkey test management solution that integrates with their sequence control interface, Space Electronics has developed a new family of multichannel aerospace system circuit test equipment.

The SQB Series of testers measures electrical continuity, isolation, and stray voltage between any two test points using protection circuits that guarantee no inadvertent triggering of firing circuits. Already a key element of OEM quality assurance (QA) and integrated logistics support programs for a host of weapon systems that includes THAAD, Standard Missile 3, Standard Missile 6, and the Evolved SeaSparrow Missile, the SQB Series is designed for subassembly, system, and field level testing of any aerospace system with an integrated firing circuit: aircraft with fire suppression systems, ejection seats, and emergency oxygen systems; space systems with external booster and stage separation explosive bolts; and any cable harness that is connected to squibs.

ABOVE: **Model 132-SQB-BTP 32 test point circuit tester**

SAFETY

The primary method of initiating a detonation sequence is by passing an electrical current through a thin wire that is bonded to a small explosive. The heat generated by the flow of electric charge provides the threshold energy needed to initiate the explosive train. Electromechanical trigger circuitry controls the timing of the current pulse. Typically, the firing of a small explosive device triggers a much larger explosive. These firing circuits are of varying complexity, ranging from the simple low-component-count mechanisms found on 'dumb' bombs to highly complex, very versatile circuitry seen in modern battlefield smart weapons, military aircraft, space launch systems, and spacecraft.

The safety and reliability of these devices can be verified by electrically testing the detonators, wire cabling, and control circuitry at various points in the aerospace system's lifecycle, including QA tests during component manufacture, QA tests during final assembly (for example, explosive load, assemble, and pack), integrity testing during and after storage in warehouses or depots, and point-of-use testing prior to deployment.

It is critical to recognize that this method of testing applies electrical current to the device in a manner similar to that which initiates detonation. The only way to safely accomplish the test is to severely limit the test current to a level several hundred to a thousand times lower than the detonation threshold. The current-limiting circuitry has to have high safety redundancy with known failure modes that always fail to a safe condition. Furthermore, in many cases the accuracy of the required measurement is quite high, often approaching one one-hundredth of an ohm. Under normal circumstances, measuring resistance to this level of accuracy is difficult. The use of these low test currents only serves to exacerbate the problem in direct proportion; that is, lowering the test current by a factor of one one-thousandth increases the difficulty of the measurement by a factor of 1,000.

The measurement system design engineer must then contend with lower internal signal-to-noise ratios, rendering unacceptable several common but unsafe methods for controlling the injection of external noise. For this reason, the SQB Series of testers incorporates a sealed 'failsafe' module, which limits test current to safe levels even if every active element in the measurement circuit fails at the same time.

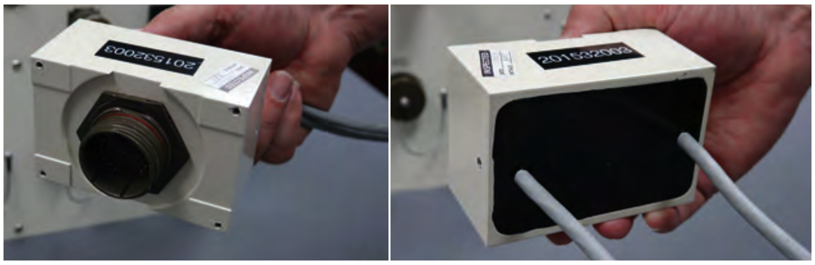
DESIGN AND FEATURES

A squib or igniter circuit tester is a special-purpose ohmmeter capable of making extremely accurate measurements of low resistance values, while limiting test current to a value significantly lower than the minimum detonation current of the igniter being tested. With the addition of voltage and diode testing as well as a matrix switching system, the SQB Series of testers can test several connection paths in a completed assembly with one automated sequence. Features of the SQB Series include:

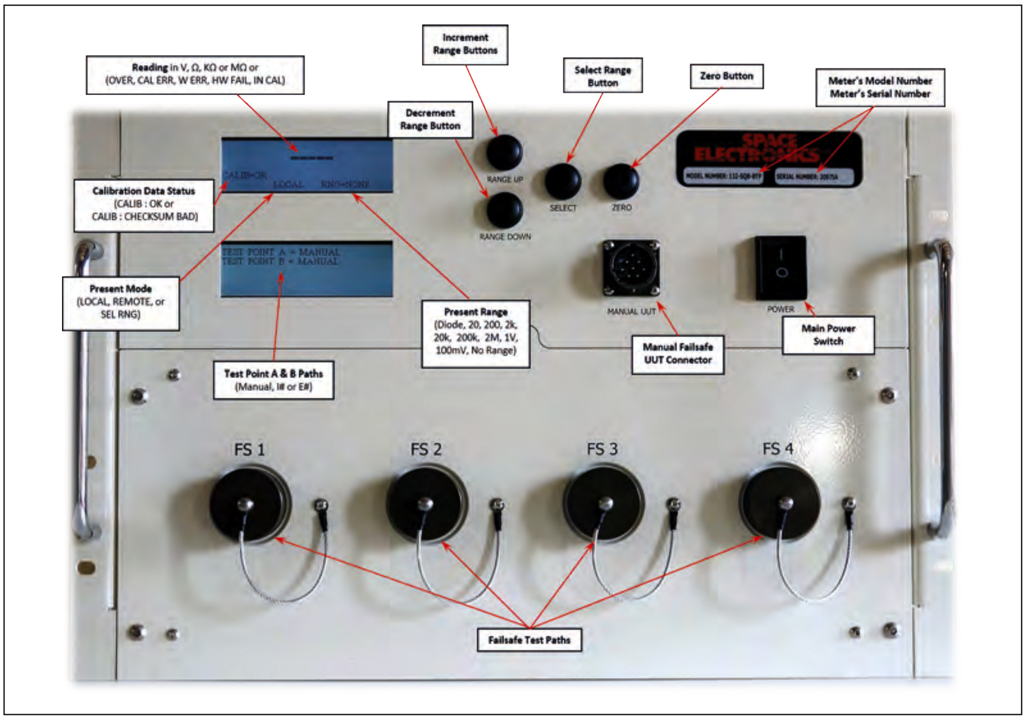
- Multimeter functionality – six resistance ranges, two stray voltage ranges, and diode testing;
- Fiber-optic connection between the control computer and tester – ensuring safety isolation between computer power and the system;
- Lead resistance compensation – Kelvin four-wire cable arrangement that automatically compensates for lead resistance;
- Fast readings – stabilized in less than two seconds;
- Digital calibration – insensitive to thermomechanical drift of calibration trim potentiometers;
- Modularity and scalability – supports from eight to 1,024 test points.

The SQB Series of multichannel circuit testers also features an innovative manual measurement mode (including test cables) that allows the user to verify test circuits without the need for a separate meter. It also takes a novel approach to safety: redundant circuits and mechanisms, going beyond the single-point-failure methodology to guarantee that test current is always less than 2.5mA, a 400:1 firing current-to-test current ratio for a 1A firing current.

The power system design ensures protection against power surges and inadvertent operator error, including attaching the tester to a source of voltage or current higher than allowed. The design also incorporates multiple ground isolation barriers to ensure that there are no potential current paths through ground paths that could exceed the rated failsafe current. To prevent damage to the circuit tester's current-limiting circuitry, these failsafe devices are encapsulated and mounted directly at both the tester's input power and the system's test signal connection points. This means these barriers are after the matrix selector system, yielding an additional level of safety.



ABOVE: Failsafe connectors are housed in fully sealed potted assemblies



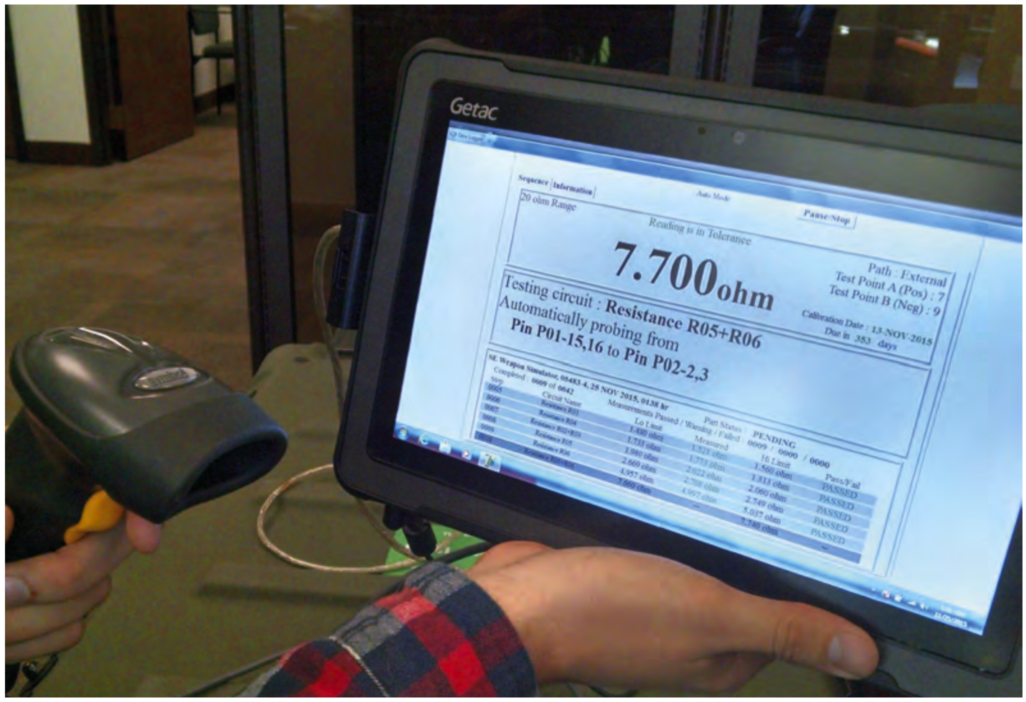
BELOW: SQB Series features and functions

HOW IT WORKS

For manual operation, the supplied test leads are attached to the instrument. A measurement range is selected. The circuit resistance is then displayed on the digital readout. An internal microprocessor stores calibration and zero offset values for all ranges. Four-wire test leads automatically compensate for test lead resistance so there is no need for the subtraction of the test lead resistance. The SQB Series supports from eight to 1,024 failsafed test points, which can be selected through software in any configuration of two-wire test paths. The combination of any two test points creates a four-wire measurement path.

'Test points' are not the same as 'channels'. Earlier igniter circuit tester designs connect to test circuits through multiple sets of four-wire channels. If three paths to test connect to a single common pin, then each of the three four-wire sets has two wires connecting to that common pin, for a total of six wires to that single pin. If more paths share this common pin, the wire count becomes unmanageable.

In a test point arrangement, only a single set of two wires connects to each pin. The matrix system allows these two wires to connect either to positive excitation and positive sense or to



RIGHT: Optional barcode scanner and rugged control computer

negative excitation and negative sense. This brings down the cable conductor count while still maintaining the four-wire measurement system.

THEORY OF OPERATION

All test circuits use the same fundamental concept. The circuit is constructed of a known precision current sensing resistor in series with the unknown resistor. The processor measures the voltage V1 across the current sense resistor ($R_{CURRENT.SENSE}$) and the voltage V2 across the unknown resistor using a high-accuracy differential amplifier. The Ohm's law calculation is then performed by the processor and the result is displayed on the LCD.

The diode measurement circuit uses the unknown resistor amplifier circuit to directly measure the voltage across the diode using a failsafe-compatible current source. A four-wire or Kelvin method of measurement avoids lead resistance errors. Any voltage drop across the main current carrying wires will not be measured by the circuit and therefore does not factor into the resistance calculation.

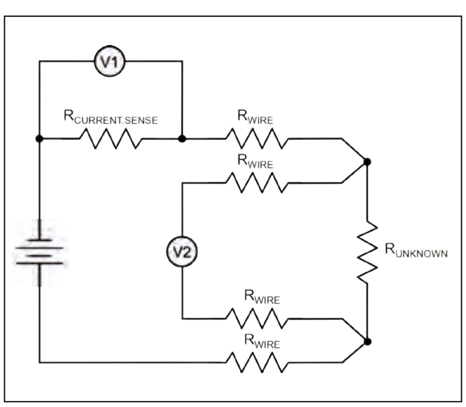
The manual Unit Under Test (UUT) failsafe and several automated failsafes (FS 1, FS 2, …, FS n) are the last connections between the meter and the UUT circuits. They are housed in fully sealed potted assemblies that cannot be bypassed without purposeful disassembly. The failsafes limit test current to the UUT using fusing resistors that are selected for measurement performance and failsafe protection. In the event of a worst-case failure of all active components, the measurement test circuit is reduced as shown below. The worst-case measurement circuit failure results in the maximum power supply voltage of 7V at point $V1_{MAX}$ feeding a series circuit of 1,197Ω and the $R_{UNKNOWN}$ load. Assuming the load to be less than 1Ω, the failsafe current is 5.8mA.

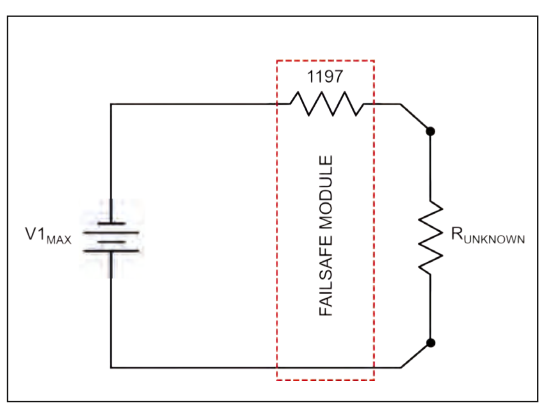
US DOD CERTIFICATION

Lockheed Martin Space Systems, Raytheon Missile Systems, and Textron Systems are some of the companies which currently rely on the Space Electronics SQB Series of aerospace system circuit testers for systems deployed worldwide with the US Army, Navy, and Air Force. That reliance is based in large part on the legacy of Space Electronics' 101-5HJ single-channel US Navy Igniter Circuit Testers – with more than 5,000 instruments placed in service in the past 40 years without incident.

The SQB Series' revolutionary approach to safety – redundant circuits and mechanisms – coupled with its multiple ground isolation barriers and encapsulated failsafe devices has contributed to the US Department of Defense's approval of this family of fully automated circuit testers that dramatically reduces the risk of accidental detonation without compromising performance. ▮

Dr Dean Jorgensen is director of business development and Brandon Rathbun is executive vice president of engineering and product development at Space Electronics





FAR LEFT: Typical test circuit

LEFT: Simplified measurement circuit for safety analysis

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Measure mass properties with extreme accuracy…

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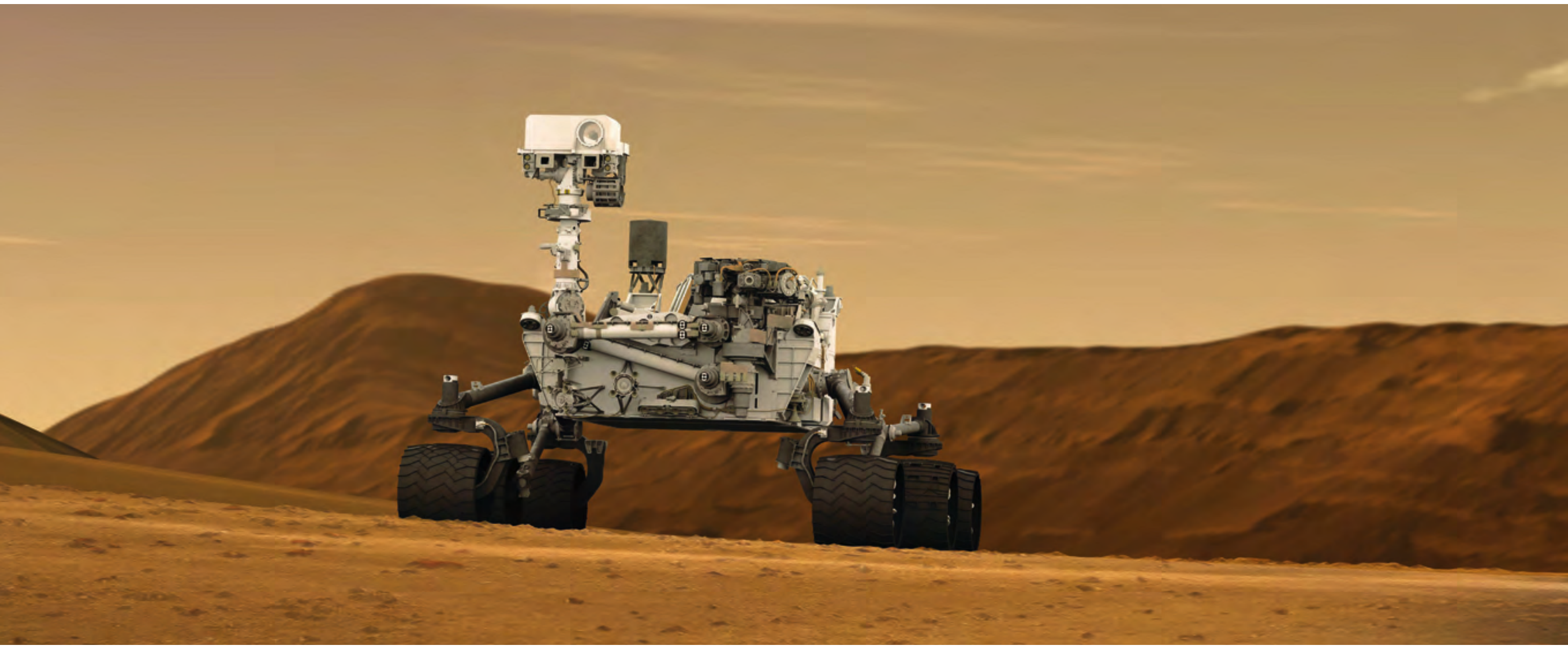

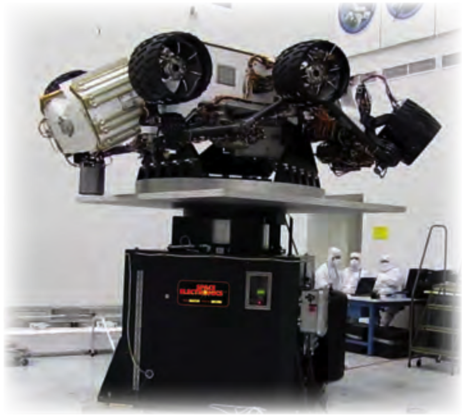

NASA JPL Curiosity Mars Rover on POI12000 spin balance instrument

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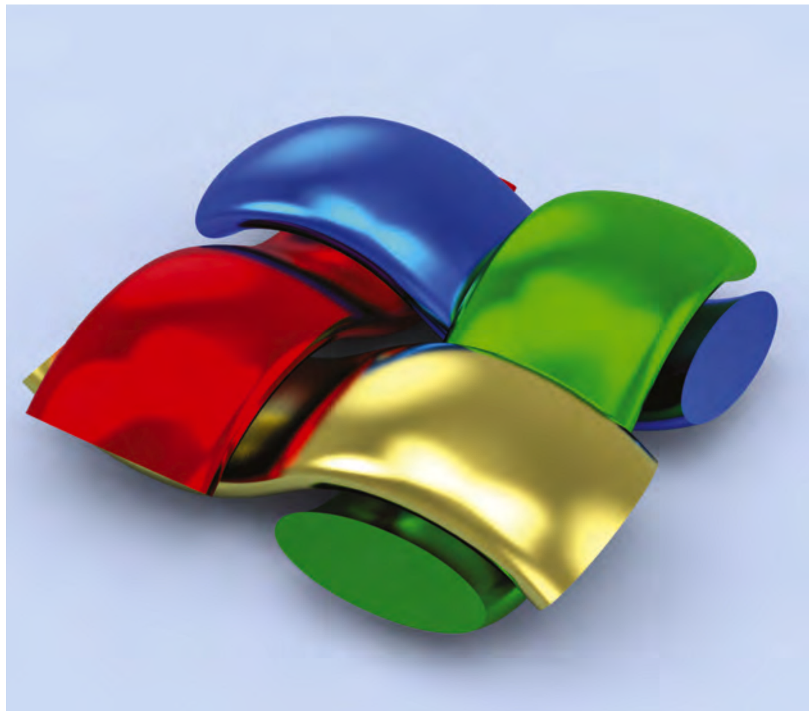
COMPUTATIONAL CERTIFICATION

Direct testing for new materials can be expensive, but Multiscale Designer offers an alternative computational certification approach that relies on limited experimental data at the coupon level

BY ROBERT YANCEY, JEFFREY WOLLSCHLAGER, COLIN MCAULIFFE, JACOB FISH



ABOVE: A rendering of composite fiber construction

With the application of composites in aircraft structural components, material qualification requirements have been a costly burden on airframe manufacturers. Substantiation of such structures requires analysis at multiple levels of FAA building-block diagram (Figure 1). As one proceeds up the building-block diagram, the number of samples is reduced since structural complexity increases. For example, the greatest number of specimens is usually tested at the lowest level when factors such as batch variability and environment are included in the test. Typically, the number of specimens approaches 1,000 mechanical tests at this lower level. In contrast, only one test article is used at the highest level of the building block diagram (Figure 1), which usually consists of a full-scale test.

To account for variability in strength, fracture toughness, fatigue life and durability, arising from geometrical variability and stochastic nature of materials, the usual standards adopted are the A-basis and B-basis allowables. The most popular B-basis allowable is defined as the value above which at least 90% of the population is expected to fall with 95% confidence. To determine B-basis allowables, a relatively large sample size is needed. For instance, to obtain a B-basis value, a minimum of 29 test replicates are required. If the measured values fit Weibull, Normal or Lognormal distribution, the B-basis value could be calculated with a smaller sample size. However, since the variance of an estimation using data from a test with a small sample size could be rather large, the B-basis value would be much lower than that estimated with a large sample size, resulting in an underestimated strength owing to insufficient statistical information.

SIMPLIFYING COMPOSITE TESTS

In practice, design allowables are determined directly from the tests at a desired level (for instance, the scale of bolted joints). Since substantial testing is needed, this direct test approach appears to be too expensive. For a single fastener and a given composite material in a static test, variables to be investigated include hole size, laminate lay-up and thickness, environmental factors, load form, geometry, fastener head type, joint type, etc. For each test configuration, between five and nine test replicates are required.

As an example for a single bolt joint, double-lap shear test, the Bearing/bypass Laminate Strength Test Matrix given in the *Composite Materials Handbook (CMH 17)* lists 113 configurations and 725 tests. Thus the direct approach is too expensive. It is possible to somewhat simplify the direct test approach by estimating the average strength from full-scale tests with a small sample size and then approximating the variability in strength from the variability of the strength at a lower level in the FAA building-block diagram (Figure 1).

VIRTUAL MATERIAL MODELS

To circumvent the need for an exhaustive experimental database, which is often not available, a current area of interest and research is the use of virtual material models to generate the material and structural allowables. Virtual models can be substantiated with available test data and then exercised to produce virtual allowables for new material systems or different material or structural configurations. Experimental validation will always be needed, but the goal is to allow for allowable generation with a much smaller set of physical tests. Multiscale Designer from Altair Engineering offers an alternative computational certification approach, which is schematically depicted in Figure 2, that relies on limited experimental data at a coupon level.

The Multiscale Designer approach consists of three salient features:

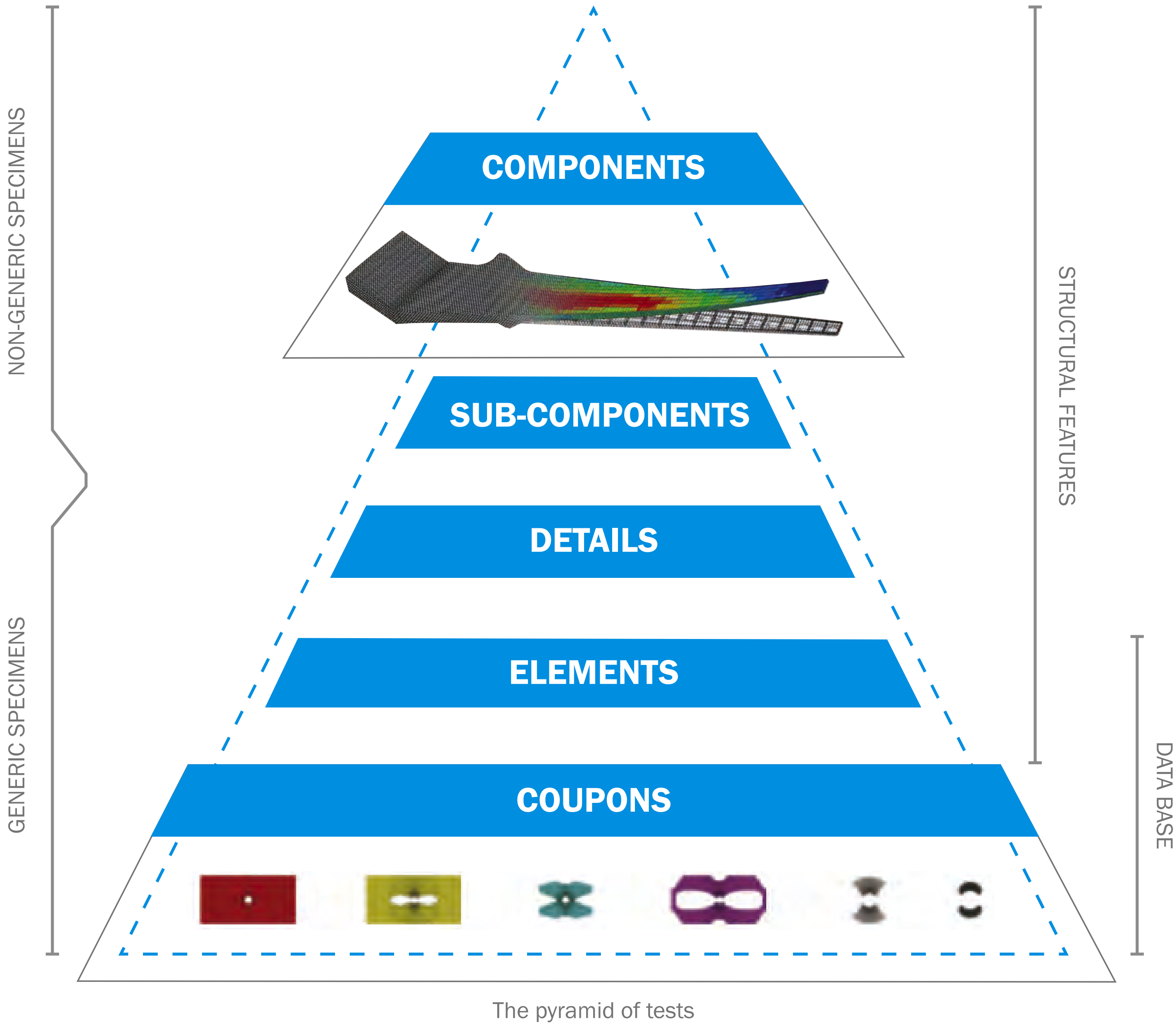


FIGURE 1: **The building blocks of testing and analysis**

First, a high-fidelity deterministic multiscale solver based on the reduced order homogenization (ROH) method is aimed at efficient solution of multiscale problems. The ROH constructs residual-free stress fields and thus eliminates the need for costly discrete equilibrium equations in the representative volume element (RVE). This removes a major computational bottleneck and thus permits accounting for arbitrary micro-mechanical details at a cost comparable to the phenomenological modeling of non-linear composites. Furthermore, ROH possesses considerably fewer material constants that need to be experimentally calibrated than a single-scale anisotropic model, and thus, deterministic or stochastic inverse analysis can be conducted with relative ease.

Second, the stochastic inverse multiscale solver is aimed at reverse engineering (or identifying) probabilistic density functions of micro-constituent elastic and inelastic properties based on the observations of quantities of interest at the macroscale. The non-intrusive inverse multiscale solver is based on the measure-theoretic approach. It takes advantage of the fact that the likelihood function, which relates the model parameters to observations, is a deterministic map defined by the mathematical and computational model, which permits computations of the inverse problem with relative ease. The non-intrusive stochastic inverse solver possesses adaptive features including identification of a nearly optimal sampling domain using enhanced ant colony optimization algorithms for multiscale problems, incremental

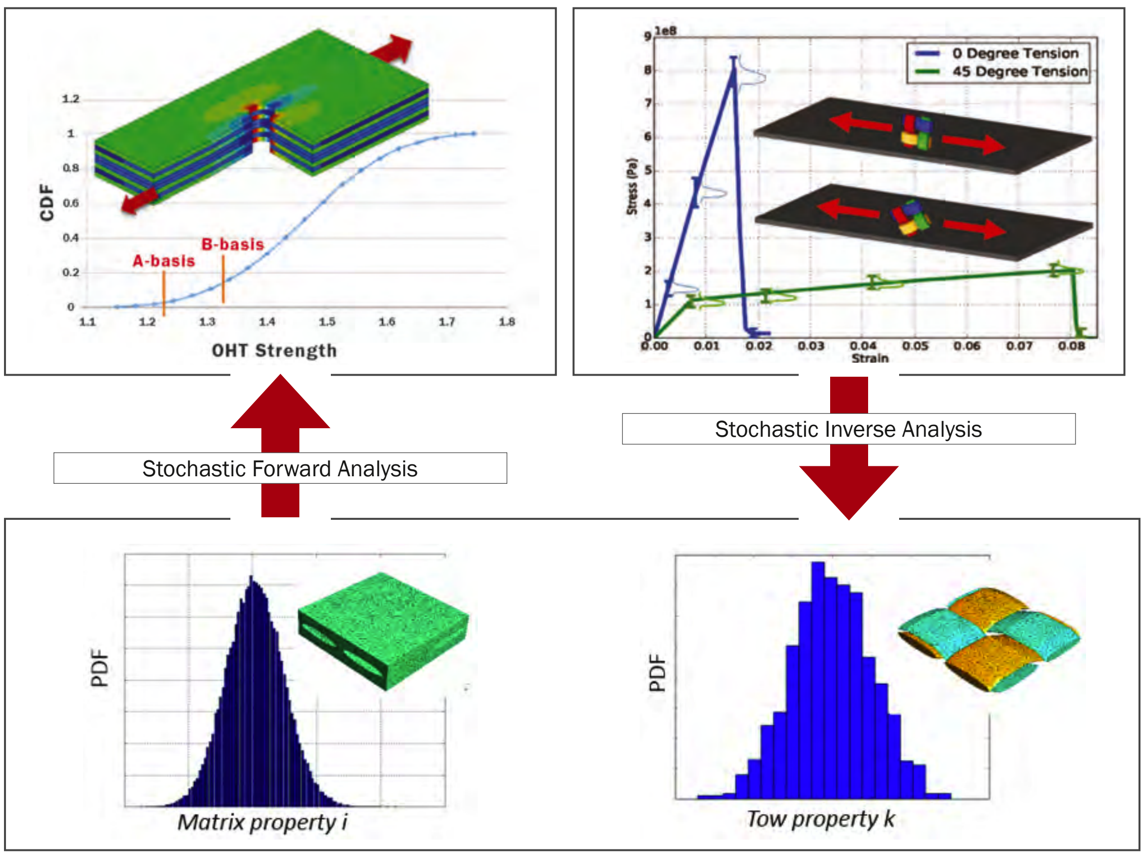


FIGURE 2: **Computational certification by Multiscale Designer: Given experimental data at a coupon level in tow and matrix dominated modes (top/right), microstructural stochastic properties (bottom) are identified using stochastic inverse analysis. Once the microstructural properties are identified, the A- and B- bases are predicted using forward stochastic multiscale analysis**

Latin-hypercube sampling methods, adaptive discretization of the parameter and observation spaces, and adaptive selection of sample numbers.

Third, a stochastic forward multiscale solver based on the Stochastic Collocation approach, which, when combined with the Sparse Grid approach and the Karhunen-Loeve expansion, outperforms other non-intrusive methods.

The workflow of a computational certification process offered by Multiscale Designer is schematically illustrated in Figure 2. Given experimental data for a composite material of choice, Multiscale Designer is first invoked to reverse engineer the probability density functions of microstructural properties, such as elastic properties and parameters of inelastic constitutive equations of damage, plasticity, or some combination of the two. Multiscale Designer has an extensive built in library of inelastic constitutive laws that can be assigned to various micro-constituents. Once stochastic microscale material properties have been identified, Multiscale Designer conducts virtual experiments by sampling over the points in the space of random parameters to compute A- or B-basis.

The sophisticated mathematical approach is implemented in an easy-to-use framework, where available test data can be input and the required functions are computed and applied to the data to generate the A- and B-basis allowables. This method can also be used to predict damage initiation and progression, fatigue performance, damage tolerance, and other material and structural responses to load that are typically tested physically. Given the complex nature of current aerospace systems and the heterogeneous materials used, a virtual testing framework is required for practical applications of new materials and new structural configurations. The multiscale approach discussed here is a major step forward in reducing physical tests and taking full advantage of the computational power that is available to us today. ∎

Robert Yancey is vice president – composites, Jeffrey Wollschlager is senior technical director, Colin McAuliffe is multiscale scientist with Altair, and Jacob Fish is a professor at Columbia University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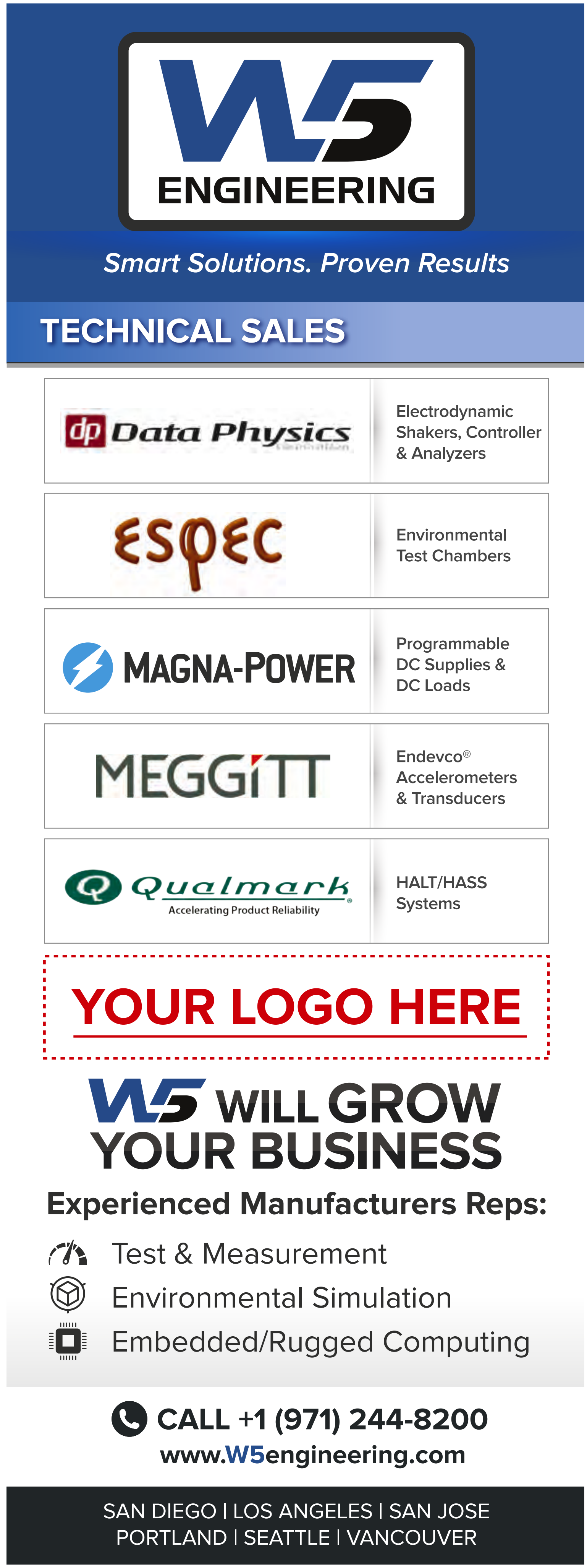
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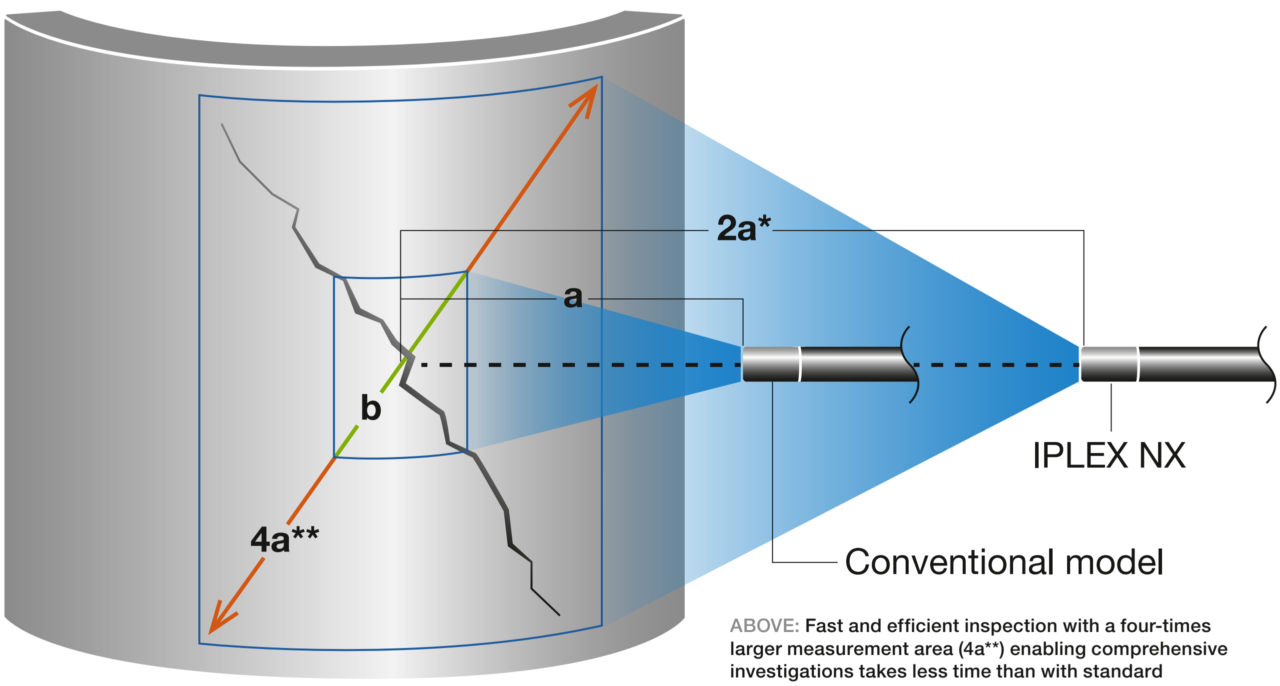
REVEALING HIDDEN FLAWS

Advances in remote visual inspection and 3D stereo measurement allow greater usability and increase the probability of detection of problems

BY LIAM G HANNA



ABOVE: Fast and efficient inspection with a four-times larger measurement area (4a**) enabling comprehensive investigations takes less time than with standard videoscope distance (a) and view (b). IPLEX NX measurements are achieved from a distance (2a*)

Remote visual inspection (RVI) is a valuable tool for inspecting aerospace equipment, reducing cost and time, and doing away with the need to disassemble components such as gas turbines, engine cylinders and fuel tanks.

As RVI technology has advanced, the latest generation of videoscopes has been engineered with ever greater inspection quality and better efficiency. High-quality optics and bright illumination are coupled with mechanical workings, allowing fine articulation and increased efficiency, which vastly increase both usability and the probability of detection (PoD). Building on these innovations, the introduction of new super wide field (SWF) 3D stereo measurement represents the next stage of videoscope evolution. Revealing and quantifying previously undetectable details provides the confidence that every component is fit for its designed performance, increasing aircraft uptime and ensuring safe and secure air travel.

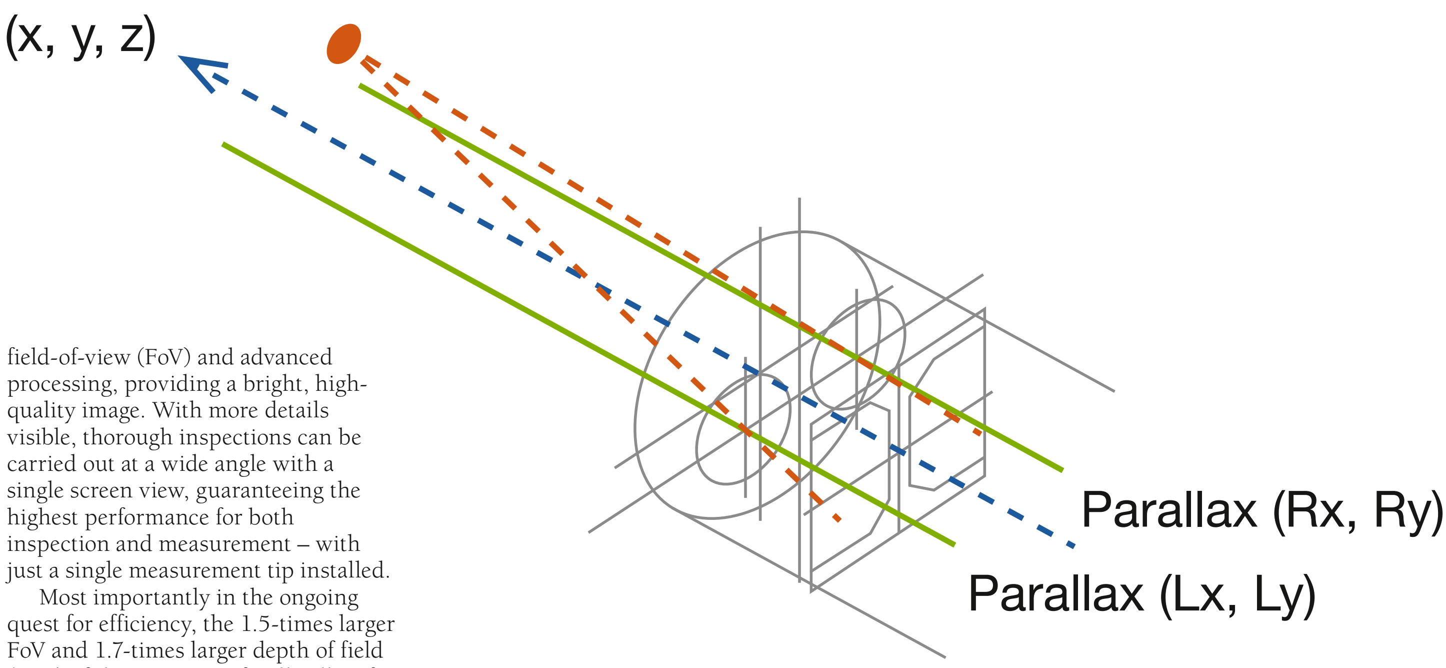
A MORE EFFICIENT WAY OF WORKING

The next generation of videoscope has incorporated a range of features to address every aspect of inspection, beginning with maneuverability. Fundamental to supporting comprehensive inspections with speed and efficiency, improving accessibility of hard-to-reach areas directly increases PoD. Navigating through tight spaces is now achieved by the operator, using a combination of increased flexibility and control, while the unit is protected by unparalleled abrasion resistance afforded by a 42-strand tungsten mesh. The operator can easily direct the scope to visualize more of the component than previously possible, with direct sensitive control of articulation through a 360° range.

Beyond improved usability, a breakthrough has been achieved in operational efficiency by merging inspection and measurement capabilities into a single operation. Historically, flaw inspection was time-consuming, requiring two different tips to ensure accuracy. Once flaws were identified with a standard inspection tip, the scope was removed and the flaw reanalyzed with a measurement tip in place. Single tips for inspection and measurement presented a major step forward in visual inspection, yet one of the drawbacks is when used for standard inspection, these systems provided relatively dark poor-quality images.

Contrary to popular belief, these do not offer a viable solution for inspection, and in many cases, poor image quality negates any other time saving benefits of these so-called single screen one tip solutions, so that an inspector can often misinterpret a defect or miss the defect entirely.

Providing the best of both worlds in terms of quality observation and measurement abilities, the latest videoscope with integrated 3D stereo measurement technology solves this problem. The new Olympus IPLEX NX features an upgraded charge-coupled device (CCD), allowing for much greater resolution. It has a high-illuminance laser diode, super wide



RIGHT: Quantifying flaws with 3D stereo measurements that utilize triangulation and parallax, and acquiring information on x, y and z positions of a point, is achieved with quality optics, the CCD and a processor. Perspective shift across each side of the CCD is determined and an advanced algorithm gives 3D functions for measurements

field-of-view (FoV) and advanced processing, providing a bright, high-quality image. With more details visible, thorough inspections can be carried out at a wide angle with a single screen view, guaranteeing the highest performance for both inspection and measurement – with just a single measurement tip installed.

Most importantly in the ongoing quest for efficiency, the 1.5-times larger FoV and 1.7-times larger depth of field (DoF) of the IPLEX NX finally allow for a four-times wider measurement area compared to conventional scopes, saving time and increasing efficiency by inspecting larger defects with a single image.

PROBABILITY OF DETECTION

Advances in image quality not only support accurate measurements, but they have also led to an increase in the PoD. The 1.7-times increase in DoF allows measurement across a tip-to-target range of 4-60mm, which is a dramatic improvement compared with existing systems which are limited to measuring flaws from greater distances. Such an increase in DoF means flaws can be observed in the most inaccessible areas, such as heat exchanger tubes or turbine blades, without the need to be close to the target object, as demonstrated by the following case study.

CASE STUDY: DISTANCE >200 MM

To achieve the best possible results with the IPLEX NX, a target distance of around 40mm from the target object is recommended, compared to the 20mm required with standard videoscopes. To test the measurement accuracy of the IPLEX NX videoscope against an extreme target distance and under adverse conditions, a measurement was conducted against a known distance of a calibrated rule of 100mm (±0.5mm) length, from a target distance greater than 200mm (192.8-204.8mm). The surface of the rule was highly reflective, in order to place the system under the most adverse conditions possible and to understand the accuracy achievable in the worst case scenario. Although a standard videoscope was unable to achieve any measurement data, the IPLEX NX achieved measurement with 99.79% accuracy.

ADVANCES IN 3D MEASUREMENT

Alongside increased PoD, the accurate measurement of identified flaws is vital for aerospace inspection, providing detailed insights and therefore enabling fully informed decision making. Building on the latest optical and digital technologies, new SWF 3D stereo measurement allows components to be inspected with unprecedented accuracy in less time than previously possible. This is built into videoscopes such as the IPLEX NX, which features new optics and high illumination levels responsible for the 1.5-times increase in the field-of-view. This equates to the measurement area expanded by four, and allows the entire defect to be captured in one attempt, in real time. In addition to saving operators from the time-consuming task of acquiring multiple images and measurements, this is particularly well suited to characterizing larger defects, from a greater target distance. A range of 3D measurement functions are possible using this technique, as sizing and situational information on the x, y and z planes is automatically captured after reference and/or measurement points are plotted. Measurements include the distance between two plotted points or reference line, area/circumference of multiple points, and the depth or height between a point and reference plane.

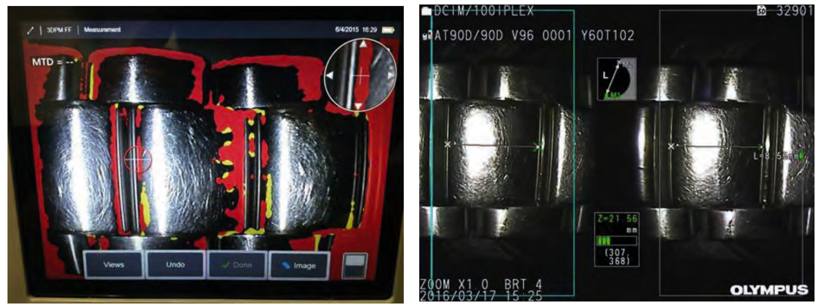
Advances in processor technology and computational algorithms have also underpinned improvements in measurement performance, while introducing valuable new capabilities. For example, displaying data in real time provides a wealth of information, keeping the operator informed of surface shape and distance with no pause or break in the inspection, for a fast and seamless workflow. Distance from the scope tip to multiple points on the inspection surface is provided with multispot ranging, and prior to capturing an image for measurement, its suitability is immediately assessed via pre-measurement surface condition and confidence information. This indicates if the target area can be measured prior to image capture, or if the image must be re-captured under different conditions. Unlike standard videoscopes, which lack such an information feed, SWF 3D stereo measurement displays the cause of error, enabling the user to avoid repeating the same mistake. Greater processing power also allows for maximizing the level of information acquired from a single image through applying multiple measurement modes, with the IPLEX NX performing three types of measurement on the unit itself, and 10 on a compatible PC.

CHALLENGING CONDITIONS

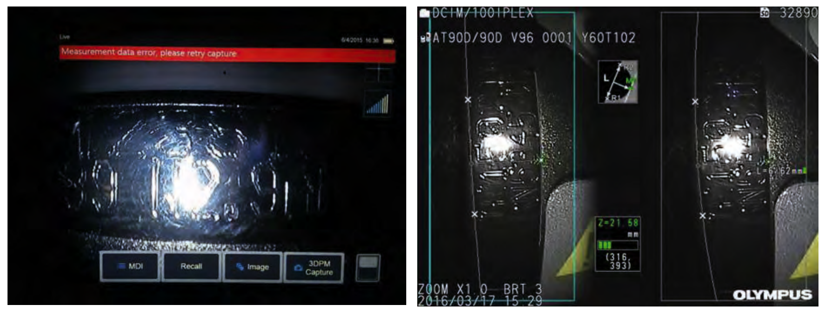
The next generation of videoscope clearly delivers many benefits, as shown by these real-world situations:

Reflective surfaces

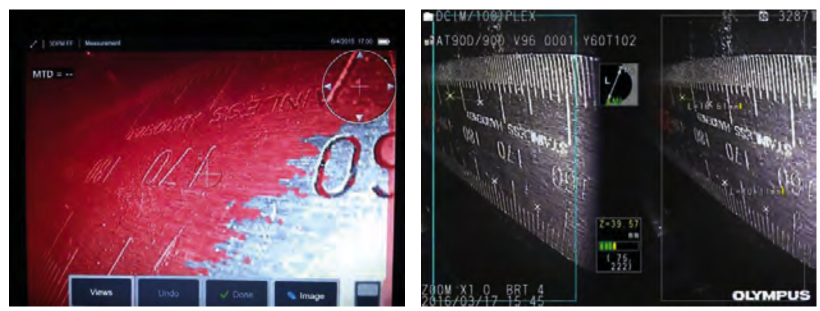
Certain materials, including metals, glass and oily surfaces, are highly reflective. Unfortunately, imaging these samples using a standard videoscope



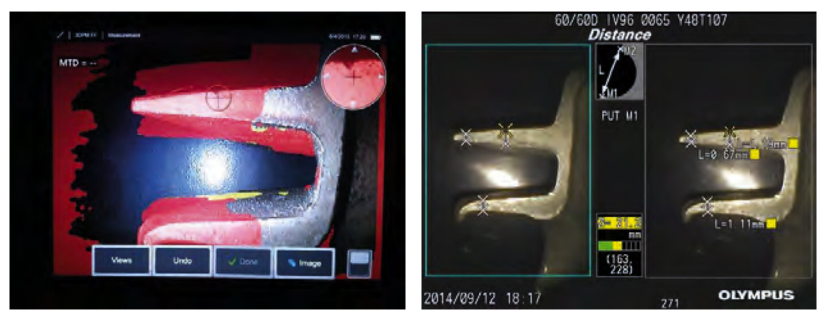
ABOVE: (L) Standard videoscope – red areas cannot be measured. (R) IPLEX NX with super wide field 3D stereo measurement results 10.6mm and 10.1mm for the scale of 10.0mm



ABOVE: (L) Standard videoscope. (R) IPLEX NX super wide field 3D stereo measurements



ABOVE: (L) Standard videoscope – red areas cannot be measured. (R) IPLEX NW with super wide field 3D stereo measurement results 0.6mm and 10.1mm for the scale of 10.0mm



ABOVE: (L) Standard videoscope – red areas cannot be measured. (R) IPLEX NX with super wide field 3D stereo measurement

results in dark areas (shown in red), which cannot be measured. Thus measurement of the object's width cannot be achieved. Under the same conditions, measurement is possible utilizing SWF 3D stereo measurement.

Dark objects

When the object is too dark, many videoscope systems to display the error message "Measurement Error. Please rotate the tip or move closer for better results." Image capturing fails even though the lens is close. This means that components such as large vessels, combustion chambers and highly absorbent materials cannot be accurately inspected. However, the IPLEX NX SWF 3D stereo measurement system achieves accurate results, even at greater distances.

Angled objects

Any object viewed at an angle to the CCD can be challenging to measure. While the image looks fine, the actual measurable area is very small. Standard videoscopes often have inflexible LED illumination for the phase grating pattern projection, which is not adjustable to allow measurement.

With SWF 3D stereo measurement, results can be achieved under the same conditions, and the object is entirely illuminated by brightness control.

Small/narrow surface areas

Components such as gear teeth and front-end blade perspectives have small surface areas, too narrow to project grating patterns, meaning that measurement of the target is not possible with standard videoscopes. Using the IPLEX NX with SWF 3D stereo measurement, the component's distal end can be accurately measured under the same conditions.

SUMMARY

Key factors in improving productivity in aerospace maintenance, reducing inspection time and increasing accuracy have been addressed with the next generation of RVI videoscope, such as the Olympus IPLEX NX.

Integrated into this single-tip system, SWF 3D stereo measurement presents a breakthrough in testing and inspection technology, dramatically increasing PoD and facilitating informed decision making. This is achieved through allowing operators to inspect areas four-times larger than previously possible, thanks to high-quality optics and a wider FoV. In fact, this holds true even when access is severely limited, as increased depth of field enables accurate measurement with a tip-to-target distance of 4-60mm. Through a constant display of real-time information and upgraded computational power, reliable measurements are easily achieved in a variety of test conditions, including low light and reflective surfaces. As has been demonstrated, the IPLEX NX can capture images during test conditions where standard videoscopes fail.

The latest 3D stereo measurement technology increases PoD through high-quality images, allowing operators to quickly uncover and accurately measure flaws that previously remained hidden – thoroughly inspecting components for ultimate confidence in aircraft performance. ▮

Liam G Hanna is a product specialist RVI, VM Maintenance, Scientific Solutions Division of Olympus Europa

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TRACKING MICROVIBRATIONS

Microvibrations can hinder improvements in satellite imaging and measurements – piezoelectric dynamometers can help track down the causes

BY CHRISTOF SONDEREGGER

Recent major advances in terrestrial observations have been accompanied by a dramatic increase in the need to measure Earth's surface and atmosphere with greater precision. Cameras on the latest Earth observation satellites (such as WorldView-3) feature resolution of approximately 0.5m. These are the familiar images seen on Google Earth.

The quality of these pictures would have been unimaginable only a few years ago. A critical step to achieving this has been the reduction of microvibrations onboard satellites. Every satellite requires numerous drives, position controls, actuators, etc. These devices have mechanical components that cause vibrations when they operate. With increased camera resolution, these vibrations cause blurring of the images or 'jitter'. These microvibration problems limit any further improvements to satellite image quality.

There are two solutions: reduce microvibrations at source, or attenuate them. An approach to measuring microvibrations with piezoelectric dynamometers, as well as a novel approach to measuring higher frequency components, is given here.

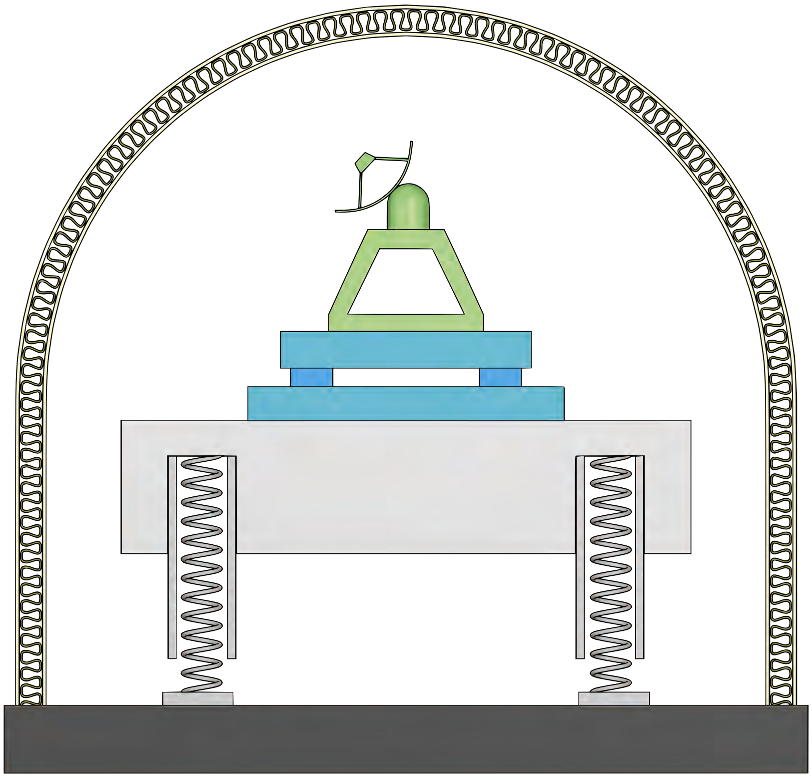


FIGURE 1: Setup to measure microvibrations: payload (green), piezoelectric dynamometer (dark blue), stone table (gray). The outer dome is used for noise protection

MEASURING WITH PIEZOELECTRIC DYNAMOMETERS

Measuring microvibrations is the first step toward improving the situation. These vibrations consist of extremely small accelerations of very low intensity. Measuring them is a challenging task, and methods for doing so have only become known in the past few years. Piezoelectric force sensors and dynamometers are ideally suited to this purpose. A very high span-to-resolution ratio of greater than 100,000 is a particular advantage. This makes it possible to measure dynamic force changes down to 0.01N, even if the object being measured weighs more than 10kg. The static weight can be 'eliminated' by resetting the charge amplifier (like a tare function to re-zero a scale).

Another factor is high rigidity. This permits very high natural frequencies of 1,000Hz or more.

The dynamometer is mounted on a vibration-isolated table to prevent structure-borne sound and external vibrations. These external influences can severely distort measurements because the dynamometer and the mass of the object being measured can generate a large acceleration. With correct setup, the interference signal is in the range of less than 0.01N and 0.003Nm (RMS; 3-350Hz).

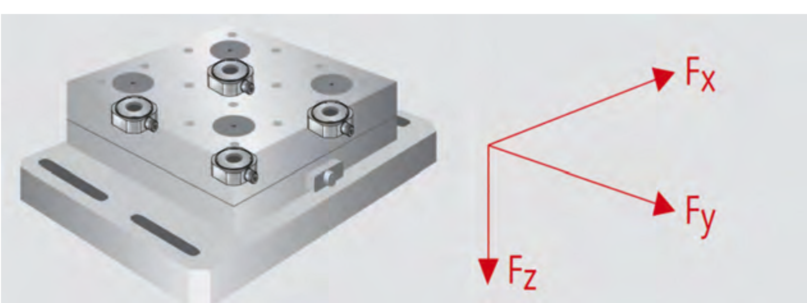


FIGURE 2: Structure of a piezoelectric dynamometer to measure microvibrations with four three-component sensors

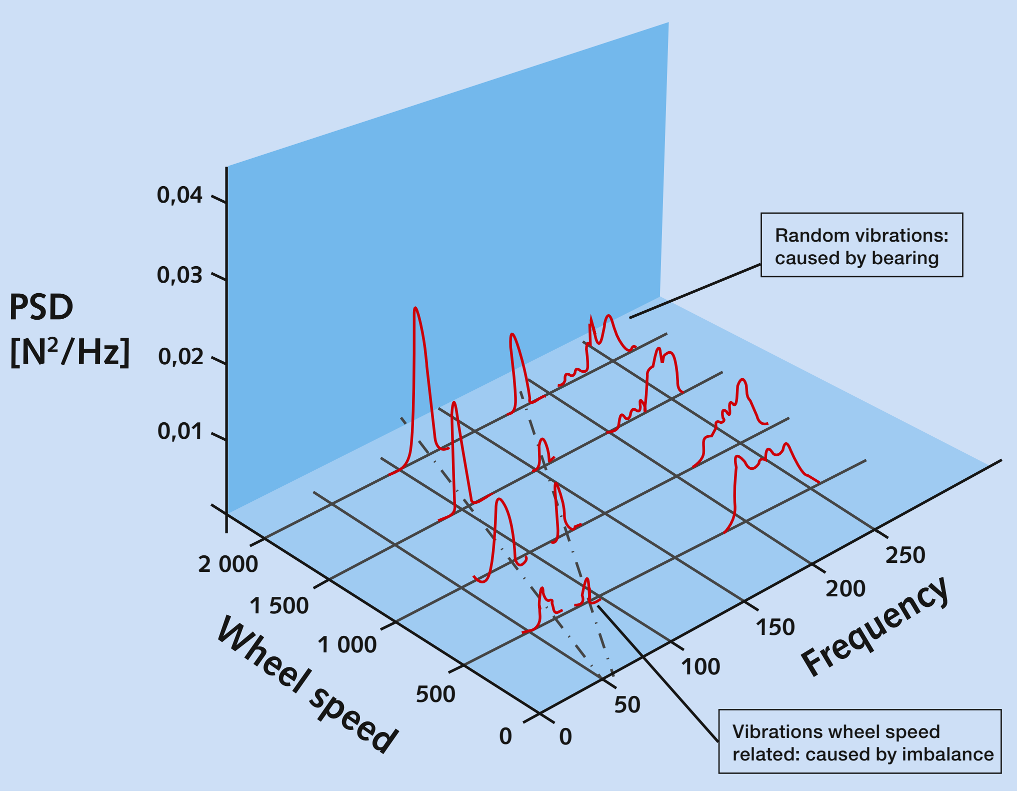


FIGURE 3: Microvibration waterfall chart for a reaction wheel (schematic). The waterfall chart helps to find the root cause of microvibrations. The output signal is shown in relation to frequency as power spectral density (PSD)

The measurable frequency range is typically 1-350Hz. The lower limit is defined by the natural frequency of the vibration-insulated stone table. The upper limit is determined by the natural frequency of the dynamometer together with the mass of the object being measured.

Correct mounting of the measured object and the dynamometer is critical for good measurements. The dynamometer and the measured object must be mounted with plenty of bolts to ensure a clean mechanical coupling. Sound and electromagnetic interference (EMI) should be avoided in or near the measurement setup. The dynamometer is connected to the charge amplifier with a special high-insulation cable. Data recording is handled by a laptop and AD converter.

For visualization of the measured data, a 3D waterfall chart (Figure 3) is typically used to identify microvibrations. The output signal shown is the power spectral density (PSD), a function of the frequency as well as the wheel speed.

Speed-induced vibrations are caused by rotor imbalance and are related to wheel speed. Vibrations that are not speed-related originate from the bearing.

The waterfall chart very clearly shows areas with high microvibrations, so targeted elimination of the causes of disruptive vibrations is possible.

UPPER CUT-OFF FREQUENCY RESTRICTIONS

The maximum measurable frequency for microvibrations is currently in the range of about 350Hz. There has recently been increasing demand for the higher cut-off frequencies needed to measure larger objects.

Modern dynamometers have four three-axis force sensors with a base plate and top plate, each made of steel.

The dynamometer behaves like a second-order spring/mass system with a dominant natural frequency. Measurements must be taken well below the natural frequency.

Additional mass lowers the natural frequency, so a heavy object to be measured can have a major influence if the dynamometer is small.

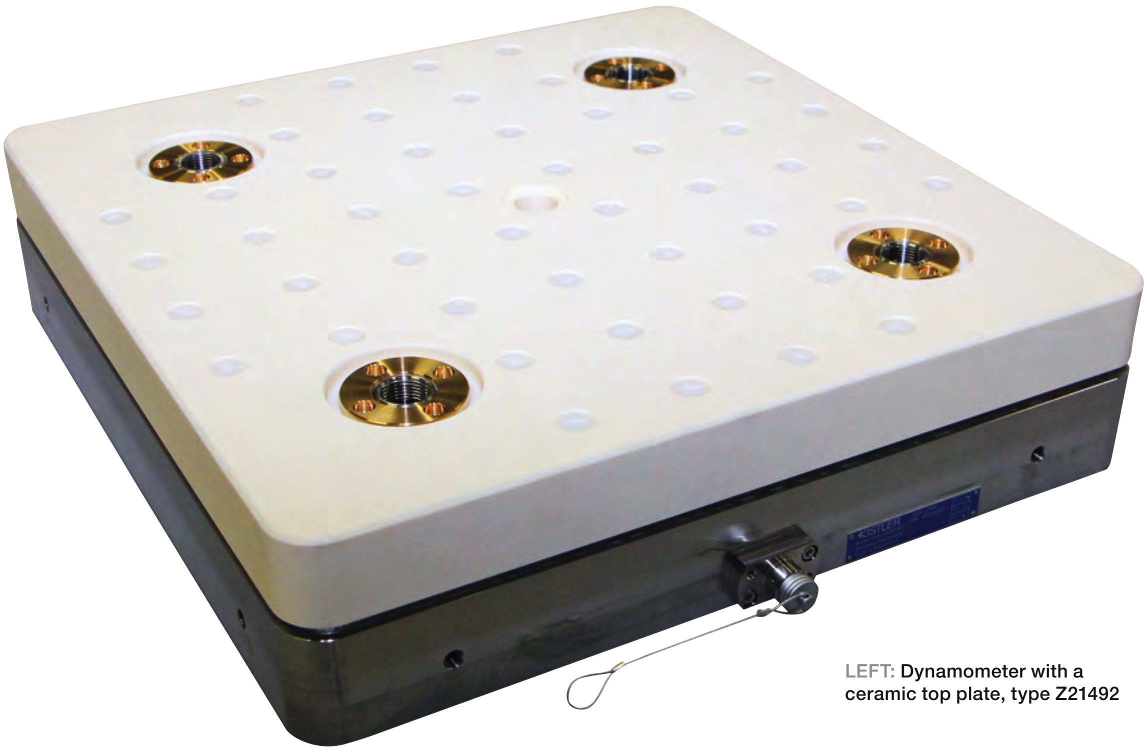
If measurements up to 500Hz are planned, the dynamometer should have a natural frequency greater than 1,500Hz. Otherwise, the resonance will exert too much influence on the measurement signal. Therefore, high natural frequency is advantageous.

The dynamometer's size has a considerable effect on the natural frequency. The larger the dynamometer, the heavier the top plate will be – thereby reducing the natural frequency. This effect cannot be entirely compensated for by using more rigid sensors.

NEW MEASURING TRENDS

One current trend is the use of dynamometers with higher natural frequencies to more easily isolate microvibrations and further reduce their causes.

Another development is the increased size of the dynamometers to test complete subsystems and small



LEFT: Dynamometer with a ceramic top plate, type Z21492

satellites, which require larger physical dimensions. The limits have already been reached with known materials and further improvements can only be incremental, requiring enormous time and cost.

CERAMIC TOP PLATE DYNAMOMETER

Size has a critical impact on the natural frequency of the unit and heavy top plates are especially unfavorable. A search for new materials for the top plate found ceramic offers highly advantageous properties (see table).

Low specific gravity and a high modulus of elasticity for ceramics are benefits, while low tensile strength and thermal expansion are considered drawbacks.

Finite element method (FEM) calculations show that natural frequencies are increased by 40% for ceramic top plates with the same dimensions as steel. Significant improvements in microvibration detection can be achieved.

A lower strength can be accepted because the forces and loads in microvibration measurement are very small. To allow correct mounting of the dynamometer, the steel base plate was retained since it has no effect on the natural frequency of the dynamometer.

Low thermal expansion proved to be a problem: despite the FEM calculation, full validation of this behavior was not possible. An extended investigation with experimental specimens was needed to show that the difference in thermal expansion between the base plate

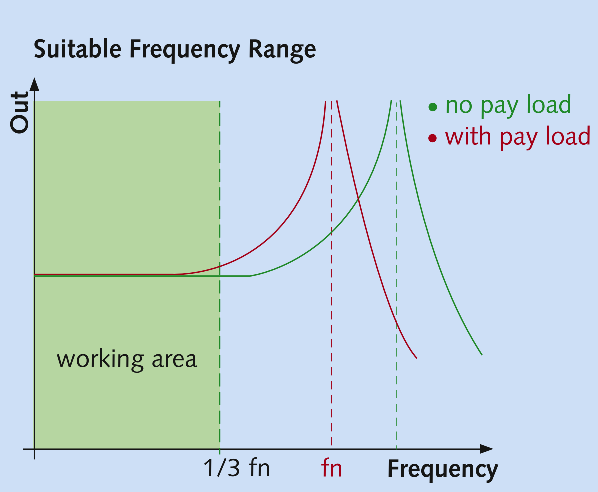
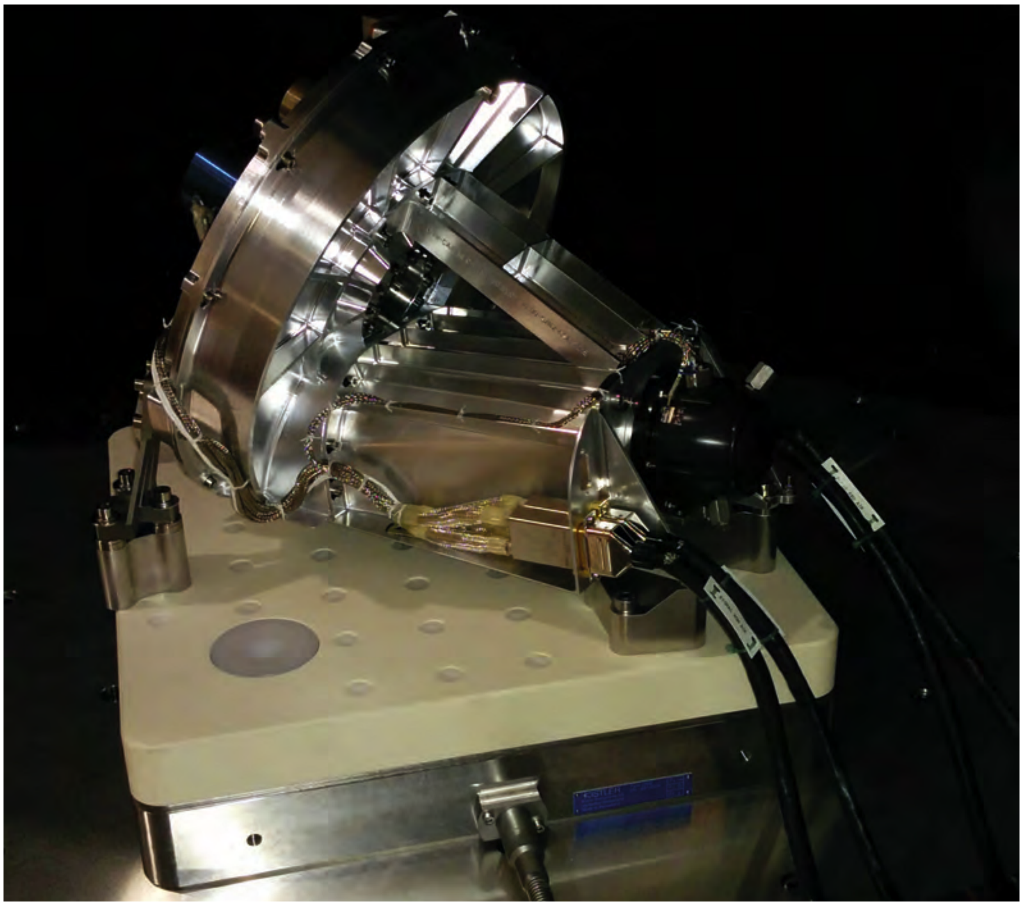


FIGURE 4: Natural frequency of dynamometer with and without additional mass

STEEL AND CERAMIC: MATERIAL PROPERTIES

	Steel 17-4PH	Ceramic (Al_2O_3)
Specific gravity	7.8	3.84
Modulus of elasticity (Young's modulus)	190,000	370,000
Tensile strength	1200	300
Thermal expansion	10.8	5.7



LEFT: Installation of a ceramic-topped dynamometer at the Centre Spatial de Liège

(made of steel) and the top plate (Al_2O_3) does not lead to fractures in the latter because of its special structural design.

MEASUREMENTS FOR NATURAL FREQUENCY

Measurements of the natural frequency in the z-direction show a very well-defined peak at about 2,570Hz (Fig 6). In the shearing direction ($F_{x,y}$), the natural frequency is about 1,950Hz.

Dynamometers with steel top plates reach about 1,400Hz in shear direction.

AN APPLICATION AT THE CSL

The Centre Spatial de Liège (CSL) required a natural frequency greater than 1,500Hz to characterize the optical calibration system of the Sentinel 4 UVN satellite. Kistler's dynamometer type Z21492 with a ceramic top plate was selected due to its large dimensions and high natural resonance frequency.

The dynamometer is set up on an insulated stone table and in a sound-insulated area. The next steps are validation measurements of subassemblies for the Sentinel 4 satellite. After completion of validation, the CSL will offer the space community a superior facility for characterization of microvibration measurements down to a noise floor of 0.01mN (Narrow band noise ΔF=1Hz).

SUMMARY

A ceramic instead of steel top plate has made it possible to manufacture a dynamometer specifically for measuring microvibrations. Benefits are considerably increased rigidity, lower top plate weight, a 40% natural frequency increase, all of which allow measurements at higher frequencies.

In parallel, dynamometer sizes could be increased to accept complete subsystems or small satellites. ∎

Christof Sonderegger is product manager at Kistler Instruments Corporation

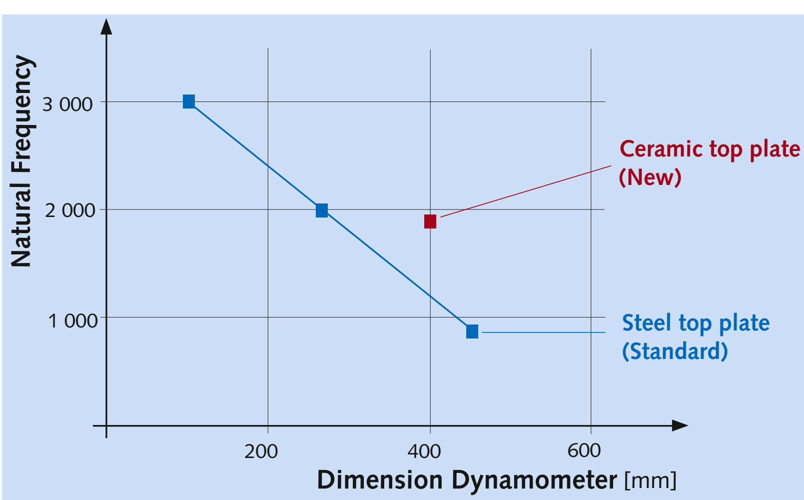


FIGURE 5: Natural frequency Fx,y direction in relation to dynamometer size

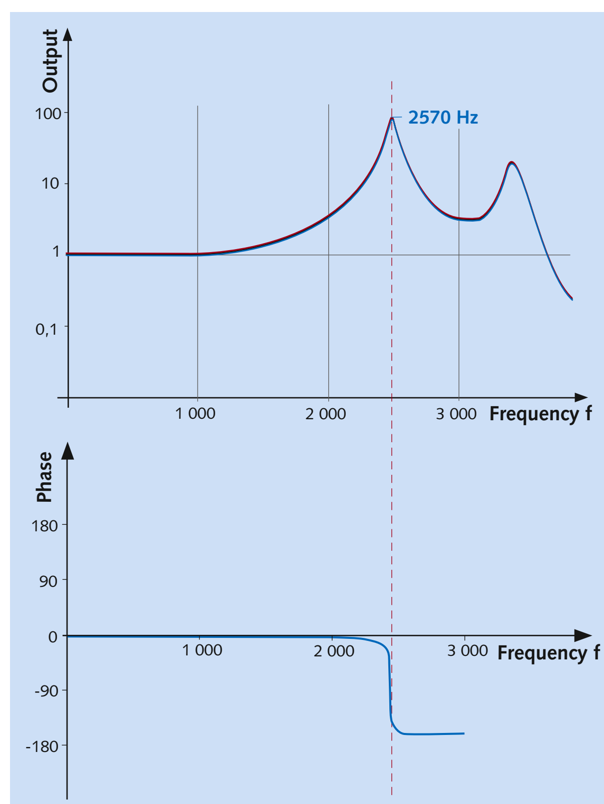


FIGURE 6: Natural frequency in F_z direction, type Z21492

IMPROVING FLIGHT TESTS

Using integrated process management and test planning software tools at the beginning of aircraft development or upgrade programs creates a holistic flight test strategy that saves time and money

BY BERND MATTNER

Flight test engineering is one of the crucial activities in aircraft development. Late developments in the process of flight tests can be the most challenging stage, and dealing with uncertainties thrown up is a major task for the flight test team.

The uncertainty is caused by the cumulative effect of technical difficulties and other unforeseeable events that can result in program delays. The increasing complexity of aircraft, their systems and data acquisition and analysis methods, creates increasing demands for flight testing. Finally there is the pressure to meet time, cost and quality goals.

BOOSTING FLIGHT TESTING

The major opportunity in an aircraft flight test program is the full integration in the overall development process and comprehensive tool support right from the start for optimized and effective concentration of activities and resources. In the same way as the independent verification and validation (IV&V) activities on aircraft system level, the flight test tasks must start in parallel with the gathering of aircraft requirements; and it is essential that flight test engineering maintains the entire development process to achieve a cost-effective, efficient and safe flight test campaign.

Key to achieving this goal are extensive planning and engineering of flight test activities with suitable tools, as well as the use of available or additional test means during the entire development. With the addition of strong database support, these two elements enable the flight test team to oversee and maintain the entire process, improve confidence in the achieved test results, and estimate events and risks for subsequent tasks, especially during flight.

In addition to aircraft-specific flight test requirements, engineers are required to capture the legal, airworthiness and technical requirements for each test in a dedicated flight test management tool chain. This makes it possible to mitigate program risks arising from the uncertainty of flight tests, which are practically the last element in the aircraft development or upgrades.

Integration of flight test equipment and configuration testing in a virtual environment in the early phases of a project and, later, full system hardware-in-the-loop (HIL) testing under operationally representative conditions will speed up the final open air range and flight tests.

Directly linked to the program data bases as main sources of information – e.g. for requirements, test cases, test results and aircraft interfaces – validation and verification capabilities are further enhanced.

The approach described here is based on the well-proven TechSAT ADS2 Technology Platform and the CAM Systems flight test management software (FTMS) extended with additional features to provide a seamlessly integrated tool chain. This allows the flight test team to be involved from the earliest stages and to enhance their understanding of the aircraft or system features and their ability to contribute to the success of the project.

FLIGHT TEST MANAGEMENT

The FTMS from CAM Systems is the central planning and control tool to help flight test engineers do their jobs and improve their productivity. It controls the entire process from requirements engineering to certification. Comprehensive report features provide management visibility on actual program status and help ensure that flight test campaigns stay on schedule and within budget. The tool is used to define the required tests by creating the flight test plan with the appropriate test points including test environment and detailed procedures, configurations and instrumentations as well as dependencies. Management features support the evaluation, approval and version control of flight plans and test cards generation.

is well understood. Problems occur when configuration errors remain undetected. They may become obvious if inexplicable measurement results are found during a flight test campaign, at which point the latest test flight and FTI resources may be lost. This means a waste of money and delays.

To mitigate these risks, customers follow various strategies, from reusing existing lab test setups to specific FTI rigs, for automated verification of their flight test instrumentation in the early project stages when a dedicated flight test aircraft is not available. The purpose of each approach is the verification of configurations for a specific piece of FTI equipment.

The TechSAT ADS2 technology platform provides a test system hardware family that covers both strategies. It supports I/O that fits the FTI equipment interfaces and can provide greater capability to test more FTI input features than a generic test system I/O. The ADS2 architecture and data interface provide all the flexibility needed to integrate customer-specific simulations and run the automatic

ABOVE: As an aircraft idea becomes a completed aircraft, the test flights can throw up the most unpredictable challenges

After flights have been carried out, the testing protocols with test point details, observations, deficiencies and crew remarks are transferred to the FTMS for evaluation by engineers and the generation of reports.

LAB ENVIRONMENT FTI

Flight test instrumentation (FTI) is a complex system of highly variable hardware equipment and rigorous demands in how it is configured. The FTI, such as sensors, data acquisition units (DAUs) and Precision Time Protocol (PTP) network, is usually qualified and well understood.

A typical FTI system employs a number of DAUs, one or more IEEE1588 switches, one datastream merger unit and a transmission unit on the flight test aircraft to collect and transmit the required data. The data receiver is usually the flight test instrumentation ground station.

With the related FTI tools, the creation of the system configuration

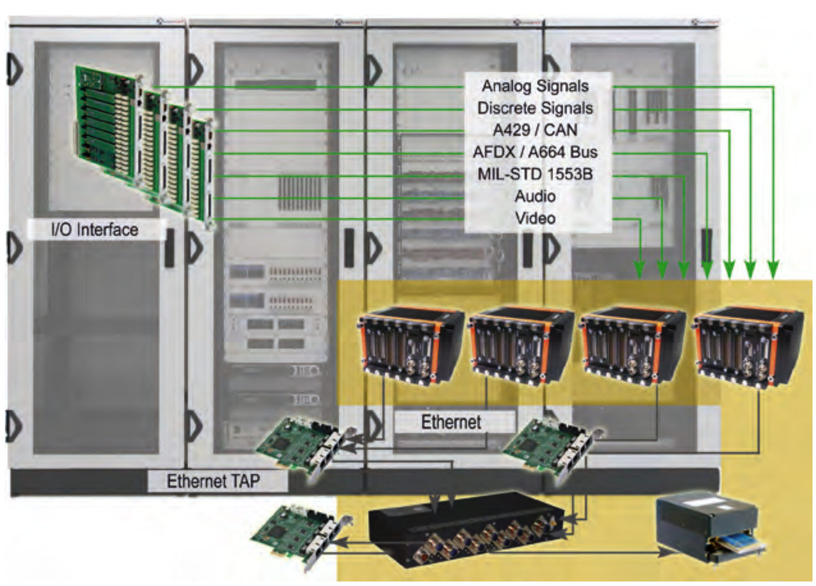


FIGURE 1: FTI Rig with flight test equipment as the system under test (SUT)

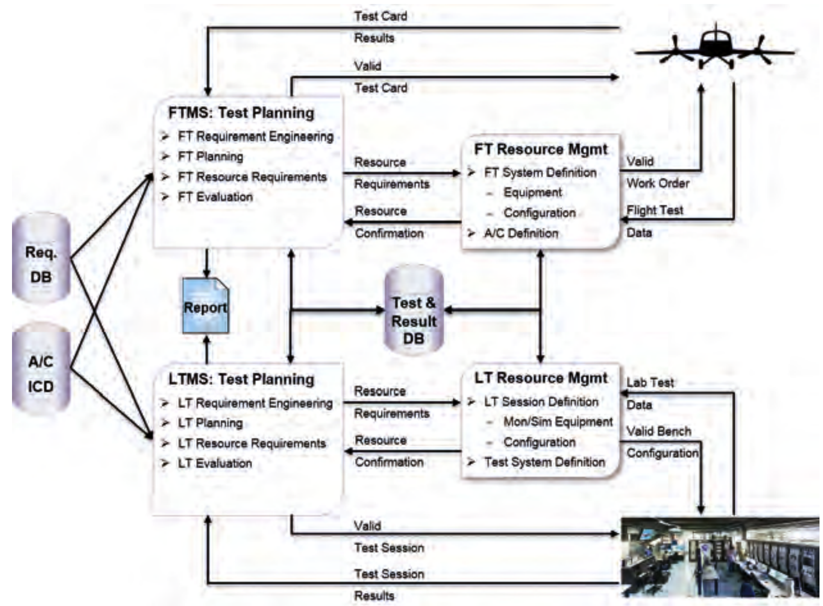


FIGURE 2: **Integrated Test Management for flight and lab testing**

tests. Once created for the ADS2 platform, test cases can be reused over the entire life of the test systems.

A specific FTI rig simulates the required I/O, such as analog and discrete signals, MIL1553B, ARINC-429, CAN and ARINC-664 (AFDX), and passes it as input to the DAU modules. The resulting datastream from the FTI system and its distribution to the receiver is then verified against the earlier simulated input signals.

Functional modules enable future extensions of specific FTI rigs to enhance test capabilities or be adapted to other flight test campaigns. The related test cases can be added to the existing test case library without recompiling them.

Conventional HIL test systems, such as avionic integration rigs or iron birds, can also be used to install prototypes and operate flight test instrumentation in a laboratory environment. The TechSAT approach enables the addition of functional modules that support specific FTI verification capabilities for flight test equipment from various instrument vendors to increase the value of the existing test assets.

DATA-CENTRIC INTEGRATION

The basic principles of integrated test management for flight and lab test, as shown in Figure 2, are very similar, so it seems obvious to implement the tool support and the data flow in an identical way to facilitate information exchange between flight and lab tests.

Both process streams, flight test (FT) and lab test (LT), are linked to the central information databases of an aircraft program, the requirements database and aircraft interface control document database, ensuring unique and valid data. The software tools for flight and lab test planning and resource management are directly linked to a common test and results database to maintain data exchange, storage and version control.

This approach enables the use of a unified data format for data exchange and storage without loss of information. Additionally the same tools for data analysis and reporting can be used for flight and lab test data.

The lab test management software can be implemented based on the same mechanisms applied to the FTMS because the major tasks of both tools are so similar.

The close link to the requirements database enables implementation of test coverage metrics and transparent traceability over the entire project life. This also enables effective allocation of tests to the required means of compliance and helps avoid duplicate testing and untested functions.

The functional verification of flight test instrumentation in the lab environment is seamlessly integrated using the common test database. The FTI configuration files created by the flight test engineers are stored in the database. From there the FTI configuration files are retrieved as input for generating test sessions with lab test rig configurations and test procedures.

The generation and execution of FTI rig configurations and test procedures are realized as automated processes using dedicated tools. Manual data handling in the entire verification process is reduced to a minimum to avoid errors.

BENEFITS

An essential aspect of flight test is to explore the new and unknown by a highly skilled team of test pilots, flight test engineers and supporting staff. In a full-featured scenario the approach described establishes closer collaboration of flight and lab test teams from the very beginning of the aircraft program through to flight testing to avoid unwelcome surprises and costly delays.

For the OEM, this approach opens a chance to meet the requirements in terms of time, cost and quality. ∎

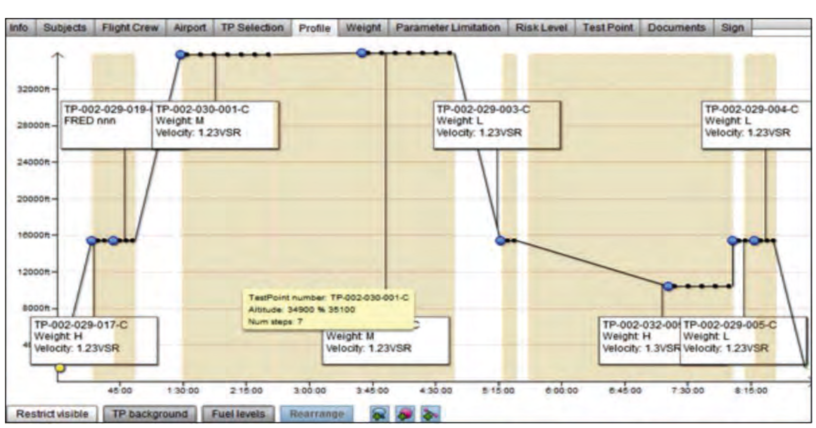


FIGURE 3: **FTMS Flight Profile Editor**

Bernd Mattner is director of business development at TechSAT, Germany

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EASY EXCHANGE STANDARDS

Users can de-couple test automation tools and benches using the generic simulator interface XIL API to better protect their investments and gain independence from tool suppliers

BY DR RAINER RASCHE, DR ANDREAS HIMMLER, MARCO FRANKE

ABOVE: A generic simulator interface will enable exchanging test cases among different test automation tools

Currently, effectively de-coupling test case descriptions from specific tools and benches in order to improve their reuse is a challenging and time-consuming task for testing engineers. The unsuccessful exchange of test cases between different development stages or suppliers complicates the quality assurance process of a unit under test, and sometimes even leads to a complete and costly re-implementation. Side effects are redundant code that is hard to manage and an increase in maintenance costs. Moreover, it is difficult to check the semantic similarity between the two versions of one test case. One way to overcome these problems is standardization.

The Association for Standardisation of Automation and Measuring Systems (ASAM) has developed the XIL API as a 'generic simulator interface' for the communication between test automation tools and test benches. It enables users to choose products freely according to their requirements, independent of the vendor. The notation 'XIL' indicates that the standard is primarily focused on (but not restricted to) 'in-the-loop' systems, most prominently model-in-the-loop (MIL), software-in-the-loop (SIL) and hardware-in-the-loop (HIL). Thus, the standard supports test benches at all stages of the development and testing process. Moreover, knowledge transfer from one stage or tool to another would become much easier, ultimately resulting in lower costs for employee training and system maintenance.

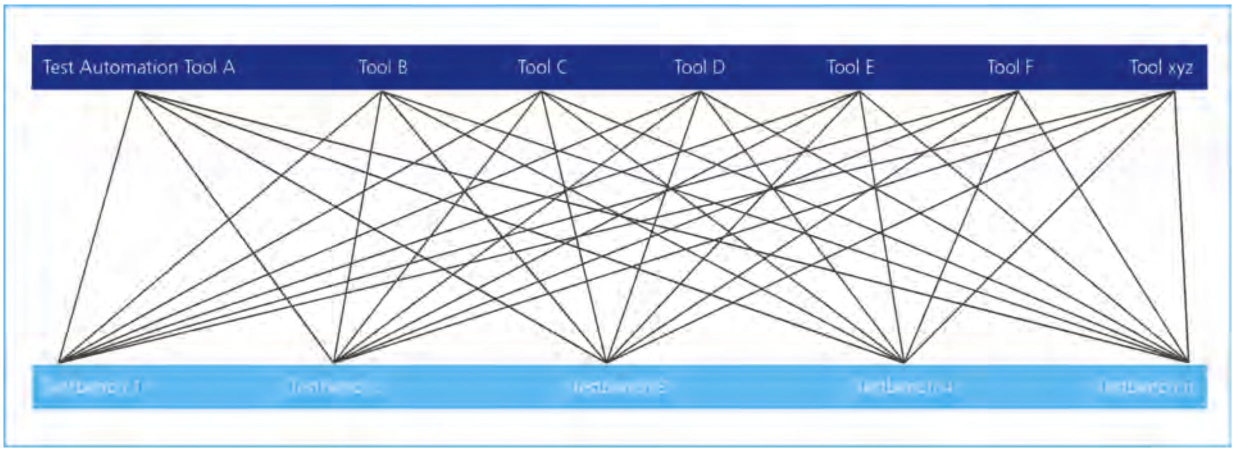
Several implementations based on the latest version of the standard, XIL API 2.0, are currently on the market. Cross tests among the different vendors and their products demonstrate a good interoperability of test benches and test automation tools using the ASAM XIL API. The main focus of the XIL workgroup, until the next release, will be on maintenance, to actively process issues reported by the active user base.

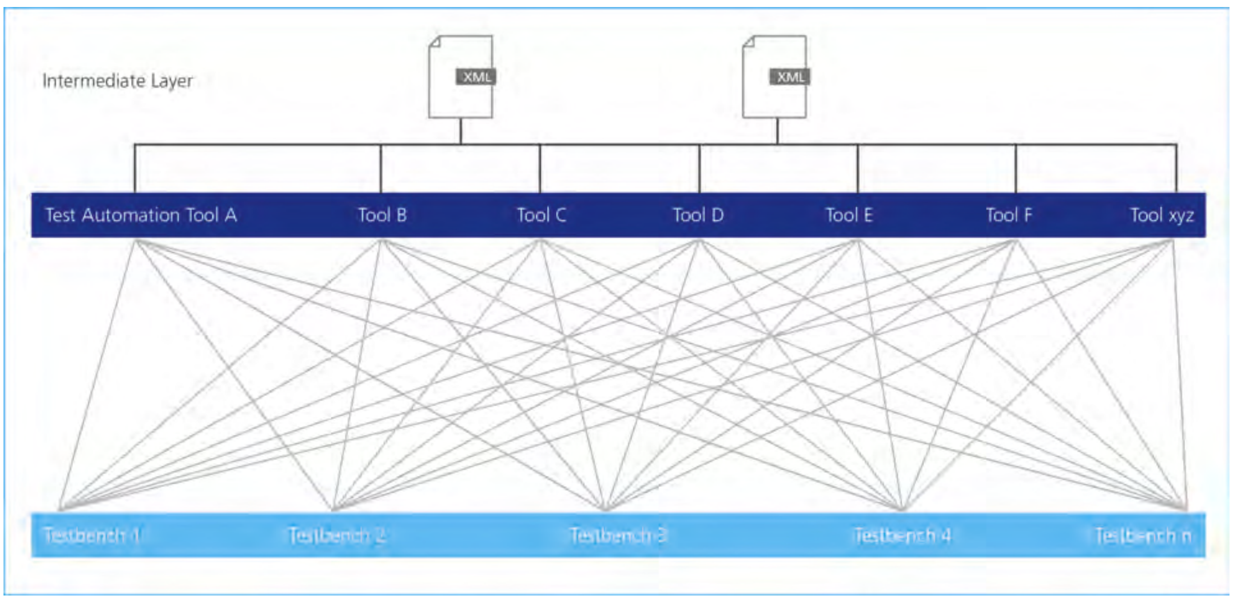
All this gives ASAM XIL API users much more independence from suppliers and more protection of their investments in the purchased sensors. In addition to the pure API functions for accessing test benches, the XIL API has useful and standardized features for defining and exchanging entire test cases or at least essential parts of them. These can be used to exchange test cases easily.

TEST DEVELOPMENT TODAY

Developers of safety-critical systems depend on software tools to achieve their testing goals in many different industries, such as aviation, space and automotive. Test automation tools, used to automate certain development tasks, are designed and used to achieve high levels of productivity required in today's development projects, as they let developers run tests on HIL test systems and in virtual validation environments, and evaluate test results automatically around the clock.

Engineers need tools with interfaces for test authoring and interactive testing during implementation and





ABOVE: **Cross-testing the interoperability between different vendors of test benches and test automation tools**

LEFT: **Exchanging test cases among different test automation tools**

debugging, and when trying processes for the first time. The available tools on the market are created for different test procedure languages such as C/C++, Python, or proprietary test description languages. Each developed test procedure language is fitted to the specific functionality and usability requirements of the application type. A common approach to achieve usability is to reduce the language features, add domain-specific functional extensions, and encapsulate specific language structures to a more abstract but also more convenient and intuitive functionality. These adaption processes have led to a wide range of highly specialized test procedure languages.

It is therefore a challenge for engineers to effectively de-couple the testing case descriptions from the different tools and benches in order to improve reusability for future programs. This means that processes can be reused in various development stages of the unit-under-test and for testing tools from various vendors. Moreover, the different languages complicate the exchange of test cases between companies, for example, between the system integrator and a supplier of the same product. It might even make it impossible, in a worst case scenario, if the system integrator detects a failure and the supplier cannot reproduce the failure or find the cause, the supplier has to re-implement the test case of the system integrator in their own test procedure language.

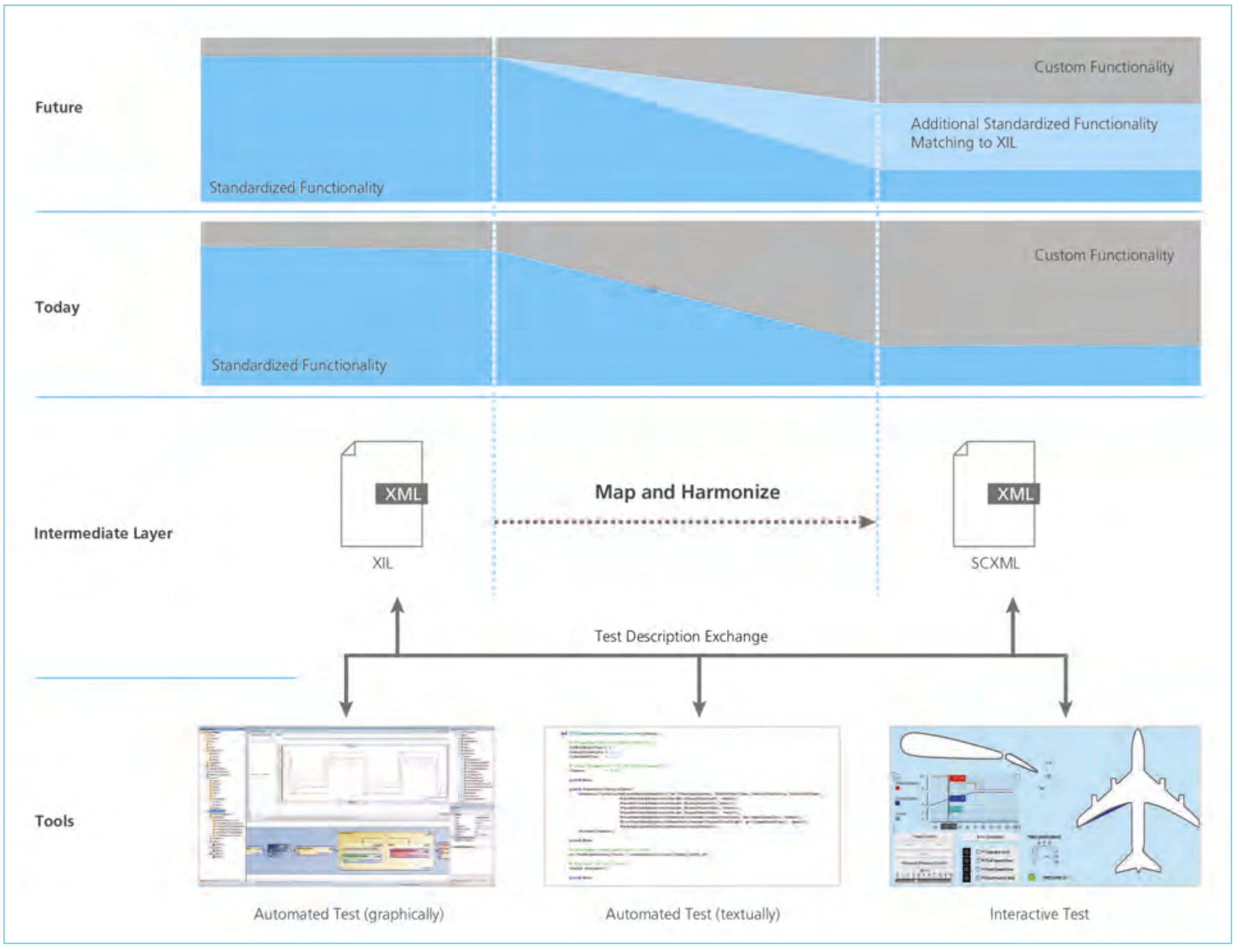
TEST CASE STANDARDIZATION: A SMOOTH TRANSITION SCENARIO

Interoperability can be achieved by developing and using an intermediate layer that represents the common content of different test procedure languages. Once a standard (such as for test case exchange) is established, the communication between tools of different vendors and between different development stages would improve significantly. Again, transferring knowledge from one test stage or tool to another becomes a lot easier, and ultimately results in reduced costs for employee trainings and system maintenance requirements.

In the aviation industry, the W3C State Chart XML (SCXML) standard is established and recent research activities lead to the conclusion that the application is a test exchange format. It gives high flexibility in introducing specific custom functions but does not fully cover the functionality of specific domains (such as mechatronic systems testing) and test languages.

To allow a smooth transition scenario to add additional functionality to SCXML, the current SCXML command set and each extension must be mapped to the ASAM XIL API command set to have an overview of how the ASAM command set complies with the aviation area's needs. Domain specific features of XIL API for testing mechatronic systems can then be used to complement the SCXML standard.

The following example provides insight into some details: XIL signal description sets as a subset of the XIL API standard are designed to intuitively define signal-based tests (for example, representing physical values within a simulation model, an



ABOVE: Test automation tools and test definitions which could be implemented by an intermediate layer

TEST AUTOMATION TOOLS

The figure above shows various test automation tools and their respective application focus and convenience aspects (automated tests defined graphically, or textually, interactive tests). All test automation tools require the exchange of test definitions which could be implemented by using an intermediate layer (XIL or SCXML) in the future. The current starting point is that only a common standardized command set can be exchanged. Custom functionality cannot be exchanged since it is proprietary. One of the current research questions that arises is whether the custom functionality could be developed through the combination of the provided common and standardized command set.

The goal is to map and harmonize missing standardized features in the SCXML to XIL, because XIL provides a specialized command set for tests (as described above) in order to increase the exchangeable volume of test functionality.

electronic control unit, or bus signals) for stimulation, recording and reference data. These signals can be defined either synthetically (using generator functions such as constant, ramp, sine) or by taking recorded data from standardized measurement file formats. For each monitored signal, an evaluation rule (e.g. as a parameterized tolerance tube) can be defined to generate a verdict during test execution. More sophisticated evaluations allow spliting a signal into segments. The transition from one segment to the other can be triggered either duration-based (for example, after three seconds) or condition-based (e.g., if FlapsAngle exceeds 20°). For example, start and stop segments can suppress evaluation during initialization and shutdown phases, or a segment can have its own evaluation rule or individual tolerance tube, resulting in a passed or failed verdict, depending on whether the defined evaluation criterion matches.

In summary, the generic simulator interface XIL API lets users de-couple test automation tools and test benches. This leads to independence of tool suppliers and development process stages and thus, ultimately better protects customer investments. To some extent, the XIL API even provides standardized description means (e.g., signal descriptions and electrical error patterns). Mapping the current SCXML command set and each extension to the corresponding XIL API command set provides a smooth transition towards a new standard of a test exchange format. ∎

ACKNOWLEDGEMENTS

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MULTICHANNEL MONITORING

Independent vibration monitoring system enables full protection of the test article and shaker

BY JIM CHURCHILL AND GUIDO BOSSAERT

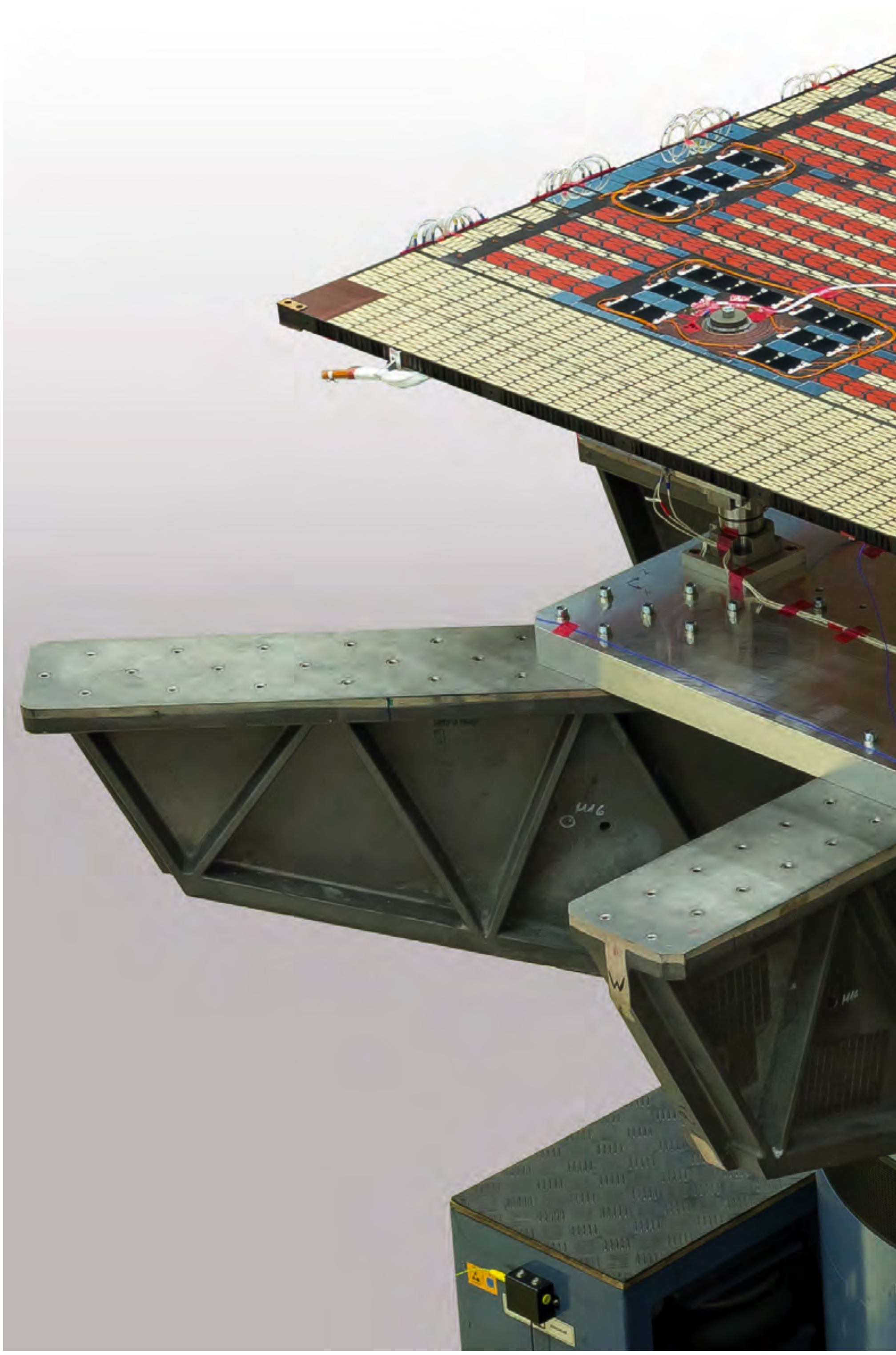
During vibration and acoustic testing of spacecraft, there is a need to monitor more and more signals that are independent from feedback measured for control purposes. Redundancy is key to guaranteeing a safe testing environment without influencing the vibration or acoustic control task and system performance.

Historically, independent specimen protection systems have been limited to a single channel of acceleration, velocity or displacement data. While the intent to provide an independent monitor was met, it also introduced a single point of failure. Additionally, the cost-per-channel for these systems made multiple measurement points cost-prohibitive.

A Southern California aerospace facility was looking for a replacement for an obsolete analog system. The original installation enabled multiple channels of both acceleration and strain sensors to be monitored. They needed a modern replacement that provided similar capabilities of multiple channels with support for mixed signal types.

A monitoring system based on the m+p Coda software package was installed. The system can be used to monitor multiple response data channels in real time, independent of the control system, prior to, during and after the vibration test. The monitoring channels can be of any type, but in this case acceleration and strain was measured to ensure no over-test occurred at any time. A total of 48 channels were measuring and monitoring the feedback signals and comparing them versus user-defined thresholds to not exceed alarm and abort limits. The measurement of the signals is independent of the control system as they can be started any time, and acquire data with independent user-selectable sampling rates.

Once an alarm criterion is exceeded, the operator will be warned on the screen or by audio/visual signals. If an abort criteria is exceeded, different actions can be taken. Typically, in the case of this installation, it was decided to trigger

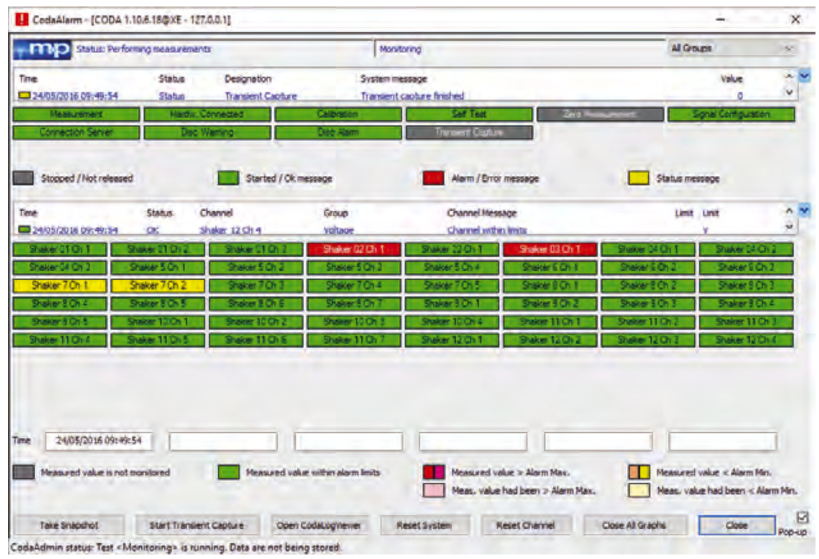


"ANY KIND OF SENSOR WHATSOEVER MAY BE MONITORED TO GUARANTEE THE SAFETY OF THE TEST ARTICLE OR THE TEST EQUIPMENT"

Shaker with m+p Coda monitoring software installed a relay to stop the vibration test. Other relays, triggered by various events, could have a different influence on the course of the test. Also, different abort situations in general can trigger a user-defined action, such as sending messages to the control system, allowing that system to take appropriate action based on the feedback received from m+p international's Coda system.

SIGNAL TYPES

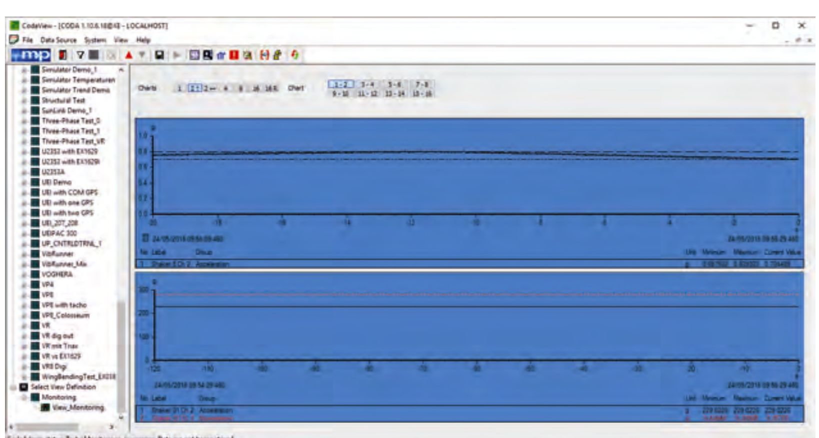
As mentioned, the signals acquired and monitored can be of any type and types can be mixed using one of the different types of measurement hardware. Also, sampling rates may be user-defined and can vary per channel. The available signal types are: acceleration, displacement, pressure, temperature, DC values, strain, force, current, gas flow and electrostatic radiation. Any electrical signal, from any kind of sensor whatsoever, may be monitored to guarantee the safety of the test article or the test equipment performing the vibration test. The SQL database structure of the m+p Coda software allows for this mixing of signals as well as the ability to create groups of data. This grouping function also allows for filtering by measurement type or measurement hardware, making data management for mixed signals simple and easy. The unique feature of m+p Coda is this capability of monitoring and triggering alarms/aborts based on a mixture of fast (i.e. acceleration) and slow sampling channels (i.e. temperature) and the user-defined actions which are triggered by alarm/abort detection on each channel.



ABOVE: **Full-featured limit checking and alarm monitoring**

If continuous throughput is not needed, a transient capture mode is available. This mode is triggered when an event such as an alarm/abort condition is met which will start storing recording data from all or a selection of channels. A pre-trigger event time and post-trigger event time can be selected so that data, prior to and after the alarm/abort condition is met, will be stored for post-test review. It is important that all channel data in this transient capture mode is synchronized so influences from different feedback channels monitored by the m+p Coda system can be visualized and can lead to a better understanding of the event that triggered the capture. Acceleration changes, both in amplitude and frequency, in one location could lead to a change in behavior of other response channels on the structure or the test equipment resulting in triggering the alarm/abort condition.

m+p Coda also supports different measurement hardware platforms from several manufacturers. It also allows for combinations of different hardware platforms, so the ideal platform can be selected per type of signal to be acquired and monitored. This guarantees a maximum of flexibility by making sure the right signal conditioning is in place for each type of signal. ∎



ABOVE: **History of the measured acceleration with alarm limits**

Jim Churchill is area sales manager and Guido Bossaert is senior VP with m+p international

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Multi-channel dynamic testing solutions


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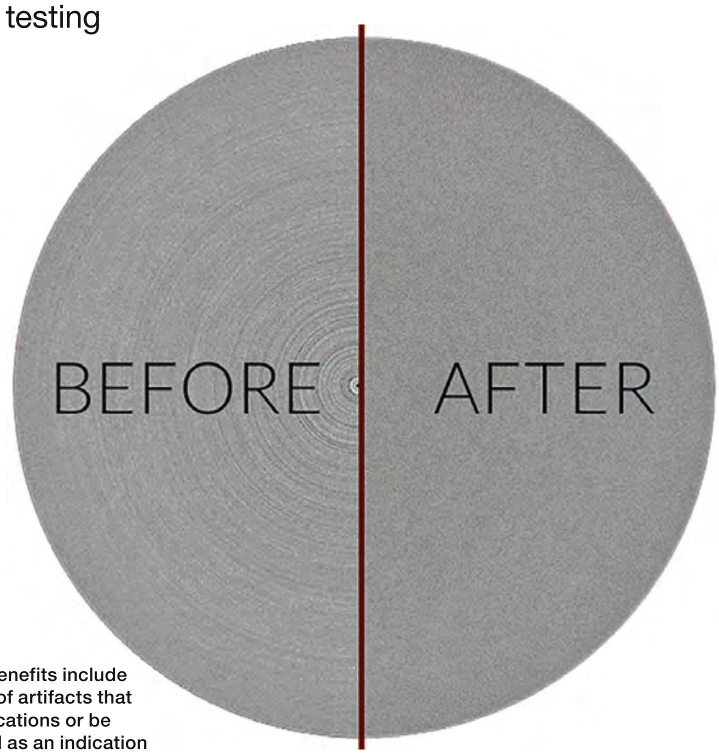
LORD OF THE RINGS

Nick Brinkhoff, product manager at North Star Imaging, explains how a new software module enhances computerized tomography scans for non-destructive testing

BY ANTHONY JAMES



RIGHT: RAR benefits include the reduction of artifacts that can mask indications or be misinterpreted as an indication

PLEASE COULD YOU TELL US MORE ABOUT THE NEW RING ARTIFACT REDUCTION (RAR) SOFTWARE MODULE?

Ring Artifact Reduction (RAR) uses a combination of hardware and software to eliminate rings caused by inconsistent pixel responses from a digital flat-panel detector during a CT scan. These inconsistent responses can be caused by various things such as dead pixels, and over- and under-responding pixels. In a flat image this is typically corrected by gain and offset corrections, but during a CT scan the variation in pixel response becomes more evident.

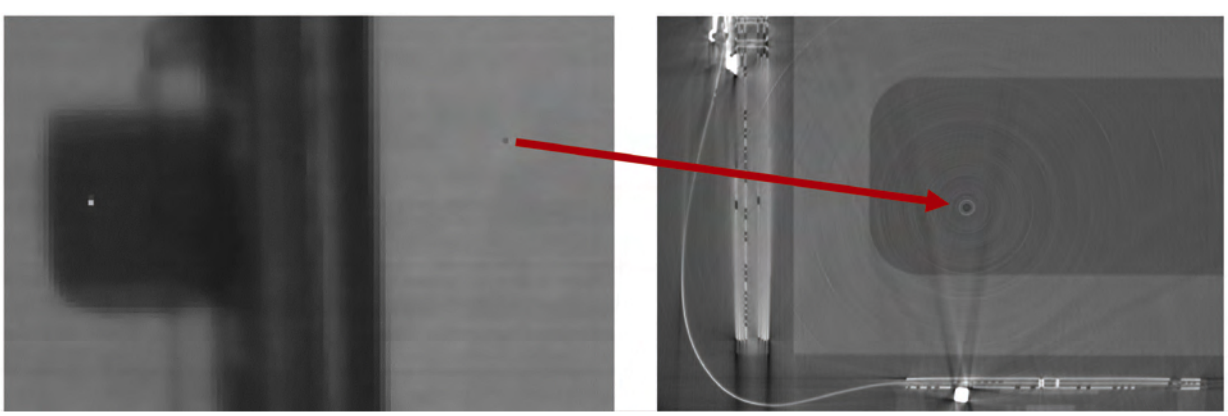
WHAT ARE SOME OF THE KEY ADVANTAGES IT OFFERS CT SCAN OPERATORS?

Cone beam CT will produce 'rings' that are not only annoying, but they can also impair one's ability to properly interpret the data. Depending on the severity and location of the rings, there is a potential for an incorrect disposition by an operator. There is also a potential for problems when using software for inspection and disposition of the data. The software could potentially see a change in contrast and disposition as a void or defect, when in reality it is just an irrelevant artifact caused by the scanning method. The flip-side could also be true where an actual void or defect could be masked by the ring and could potentially be missed by the person or the software interpreting the data. One common application where ring artifacts have been a problem in the past is aerospace castings, while composites and electronics could also benefit from the greater clarity provided by the RAR module.

WHAT CUSTOMER FEEDBACK HAVE YOU HAD TO DATE?

When some of our prime customers came to us and requested a way to eliminate this artifact, we put a plan into place to research and develop a solution that would provide the customer not only effective, but also efficient results.

One of the customers' requests was to be able to use this tool without an increase in scan time. In response, we were not only able to come up with a solution that eliminated the ring, but did so without any increase in scan time.



ABOVE: Pixel response differences cause tracks along scan trajectories in reconstruction

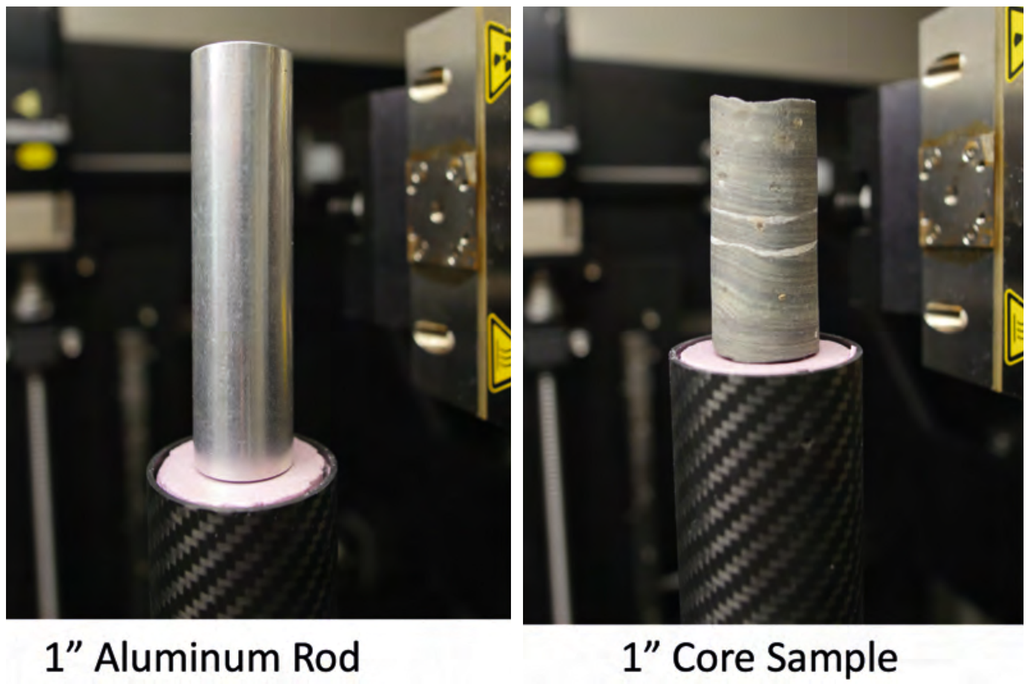
BEYOND THE NEW MODULE, WHAT ELSE HAS THE COMPANY RECENTLY LAUNCHED?

North Star Imaging has launched several new innovations in the past couple of years – the most prominent being mosaiX, subpiX, vorteX, and 4D CT. The first, mosaiX, uses hardware and a proprietary software algorithm to stitch multiple images to form one seamless image covering a much larger field of view than a system would typically be capable of. With mosaiX the effective imaging field of view is no longer limited by the detector size.

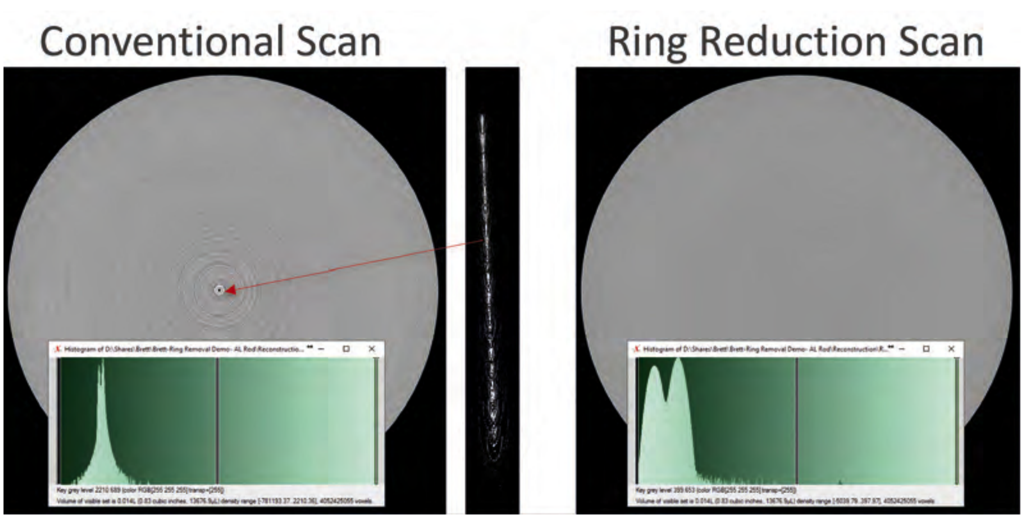
The second, subpiX, also utilizes hardware and a proprietary software algorithm to generate images with improved resolution that is typically double of what the detector alone is capable of achieving.

Meanwhile, vorteX is an automated single-pass CT scanning technique utilizing spiral acquisition and reconstruction with a digital flat-panel detector. This technique allows for the scanning of elongated objects that traditionally cannot fit onto the detector.

Finally, 4D CT is a technique that combines time and motion with traditional 3D CT volumes. The resulting dynamic data set allows for the study of form, structure and function. It is an ideal application for failure analysis, reverse engineering and quality assurance.



ABOVE: Scan samples: a 1in aluminum rod (left); and a 1in core sample (right)



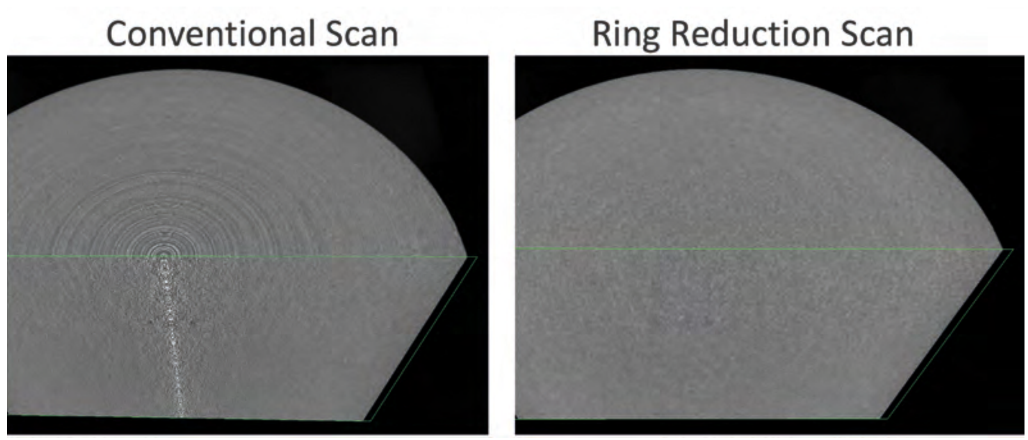
BELOW: Aluminum rod scan comparisions

WHAT ARE SOME OF THE KEY NDT TRENDS MOST RELEVANT TO AEROSPACE?

A trend that is gaining more and more traction is the conversion from film to digital radiography. While there is still a strong presence of film in the industry, the number of companies making the conversion has steadily increased over time. The conversion process started a few years ago, but took some time for buy-in from some of the primes or major aerospace manufacturing companies. As soon as these primes buy in, the flow down to their suppliers takes place and that is what we are seeing more than ever right now.

WHAT ADVICE WOULD YOU GIVE TO A TEST ENGINEER LOOKING TO BUY THE LATEST DIGITAL IMAGING EQUIPMENT?

Do your homework. There are a lot of companies out there that offer CT equipment, but your experience will go well beyond the system itself, from the initial contact with the sales representative to the installation, training, service and support. You



RIGHT: Further aluminum rod scan comparisons

“WITH DIGITAL IMAGING YOU CAN PUT SEVERAL PARTS INTO A FIXTURE AND SET UP A MOTION PROGRAM TO IMAGE SEVERAL CRITICAL AREAS OF THE PART AUTOMATICALLY”

want a system that you can rely on, and a team that will support that system. You should also be sure to visit each company to get a true understanding of what they stand for and meet the people you will be working with. A system like this is an investment and is well worth the few-hundred-dollar air fare and hotel room.

WHAT ARE SOME OF THE COMMON INDUSTRY MISCONCEPTIONS REGARDING DIGITAL IMAGING?

One common misconception is that digital imaging doesn’t have the resolution required to image the parts as film would. While film does have better basic spatial resolution, you would typically use magnification with digital imaging to produce results better than film.

Another common misconception is that digital imaging is slower with batches of parts. In reality, it is actually faster if properly employed. With digital imaging you can put several parts into a fixture and set up a motion program to image several critical areas of the part automatically.

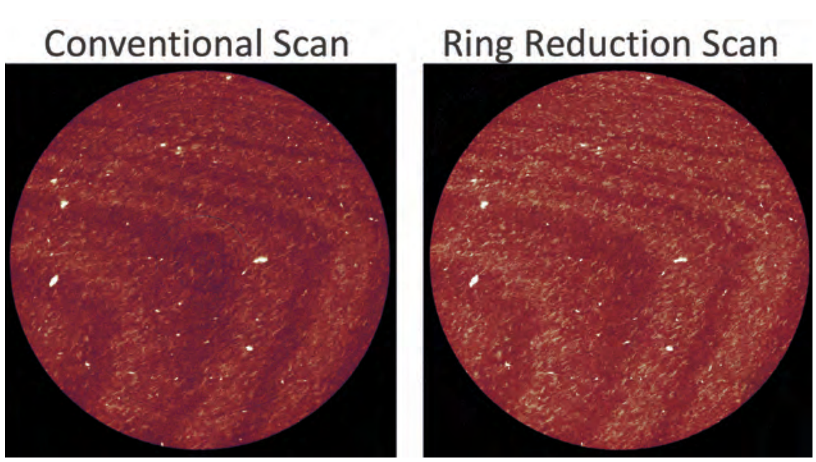
WHERE DO YOU SEE THE GREATEST OPPORTUNITY FOR GROWTH IN THE NEXT DECADE?

The greatest opportunity for growth for North Star Imaging over the next decade will be through constant innovation. We are continually innovating based on feedback received from customers and employees.

This drive to innovate has kept the company on the cutting edge of digital imaging for the past decade. The customers are our core and will continue to be well into the future.

Anthony James is editorial director at UKIP Media & Events, the publisher of Aerospace Testing International *magazine*

BELOW: Core sample scan comparisons

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LOW PRESSURE, HIGH HEAT

Modifying an existing data acquisition front-end product in a short timescale to operate in low pressures and high heat was accomplished by making use of in-house capabilities

BY JIM HONE

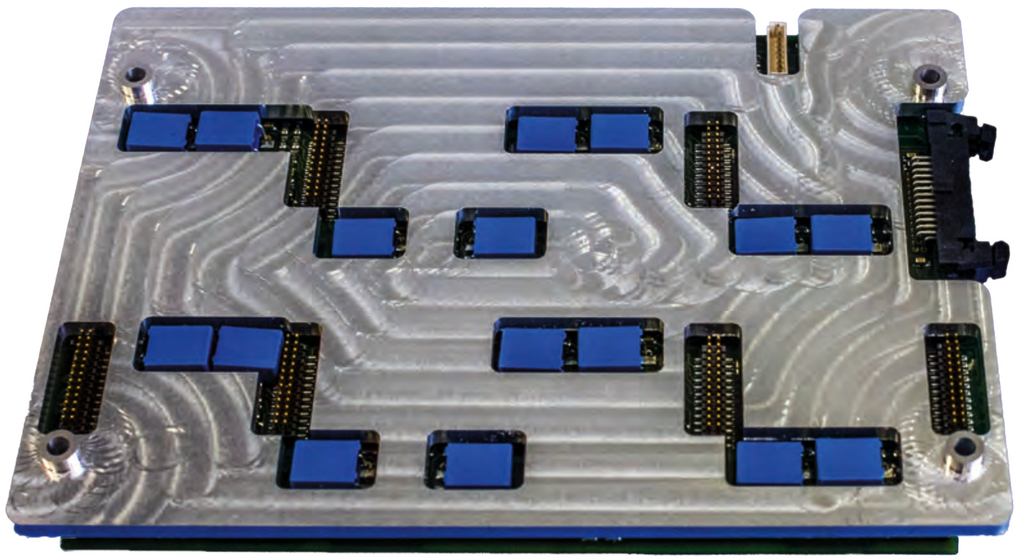

FIGURE 1: Conduction cooling plate for signal conditioning card

The challenge faced by HGL Dynamics in April 2016 was to provide, within 90 days of contract award, three 256-channel data acquisition front-end systems with full conditioning to operate continuously at 0.7psi in ambient temperatures of 55°C for a major US altitude test facility. The task required speedily modifying existing products designed to perform in sea-level environments (-25°C to +40°C) while ensuring that investment in design enhancements would also provide benefits for clients operating under less rigorous conditions.

The short lead time ruled out the design and build of new electronics – an inherently risky and time-hungry process. Long supplier lead times also ruled out the outsourcing of manufacturing tasks. Fortunately the contract was awarded following major infrastructure investment by HGL Dynamics, which included bringing outsourced assembly and manufacturing in-house.

REQUIREMENT

To expand its altitude test facility, the client required three 256-channel systems operating at 80kHz bandwidth for extended hours, with the conditioning and digitization front end close to the test vehicle. This positioning provides benefits to the client, cable costs are reduced and signal quality improved. However, it presents the challenge of operating the front-end electronics in a space-restricted, low-pressure, high-temperature (55°C) environment.

The associated computing elements (monitoring, data storage and analysis) were to be located outside the low-pressure environment. A single 10Gb fiber link would facilitate the flow of control and data, meaning power supplies and network switches capable of operating in the low-pressure environment were also required.

SOLUTION

HGL's proposal was to provide a modified version of its existing Hummingbird rugged chassis fitted with 32 channels of acquisition (HGL Dragonfly cards), 32 channels of universal conditioning (voltage, IEPE, 1/4 bridge, 1/2 bridge, full bridge, dynamic strain, single ended and differential charge), an internal IRIG B synchronization card, internal calibration card and all power and gigabit networking electronics. The total power consumption was measured at 54W (1.7W per channel).

The standard Hummingbird uses a combination of forced air and conduction cooling. This provides effective cooling at sea level, with the internal electronics temperatures being within 5°C of ambient.

During initial tests at 0.7psi, the unmodified Hummingbird unit failed within 20-30 minutes, giving high temperature readings via the onboard temperature sensors. HGL engineers quickly needed to know why.

THE PROBLEM OF HEAT

All electronic circuits generate heat; the amount depends a variety of factors including device capabilities, circuit design and board layout. Circuit designers work hard to reduce the power consumption and heat generation of their designs, without compromising the capabilities of the circuits and fulfilling the market desire for miniaturization.

The task is made more difficult in dynamics systems because heat adversely affects measurement accuracy. Designers must also factor in the need to excite dynamics sensors with constant voltage/current sources which themselves generate heat. In this particular case study, the signal conditioning (particularly the excitation) accounted for 60% of the total power budget.

There are three methods by which heat can be extracted from a body.

Convection is heat transfer by mass motion of a fluid or gas, which when

FIGURE 2: The Hummingbird 32

heated by a component or surface, moves away, carrying the trapped energy. For sea level applications, convection cooling has traditionally proved popular. It is inexpensive and easy to design though inefficient; a high volume of air is required to effectively cool even moderately heat-generating circuits.

In low-pressure environments, convection is contraindicated. There are very few air particles present to capture the energy, and forced movement of the low pressure air is almost impossible to achieve.

Conduction is heat transfer through a solid. It is a mechanism often used to remove heat from a semiconductor device quickly to a thermal mass such as a heatsink, from which convection or radiation is used to extract the heat into the environment.

Heat conductivity varies greatly between materials. Copper is a highly efficient conductive material but is not ideal for chassis manufacture, being both expensive and difficult to mill. Aluminum, however, still provides half the thermal conductivity of copper and is a very obliging metal to work with.

Radiation transfers heat from a body to its environment through electromagnetic waves. It requires no particle movement and is the only viable method to effectively remove heat from a body in a (near) vacuum.

Not only is the choice of metal important, but the finish and color of the material is a crucial factor in the efficiency of heat emission. Although shiny aluminum finishes are more aesthetically appealing, the anodized black aluminum used in HGL chassis has far greater emissivity.

HUMMINGBIRD MODIFICATIONS

The standard Hummingbird relies predominantly on convection cooling. In a low-pressure environment, however, it is necessary to conduct heat from the smallest component to the chassis.

In an ideal world, with a generous delivery lead time, HGL would have relaid the electronics, placing all the hot components on one side of the board and reducing mounting complexities. But with a 90-day window, efforts were focused on mechanical solutions. Recent investment in a PCB assembly plant and a three-axis high-speed milling machine for component and chassis manufacture proved worthwhile.

Modifications to the exterior of the Hummingbird were minimal; HGL's black anodized aluminum chassis already represented the best choice of material. The design was enhanced to provide a greater number of thinner, deeper fins on the rear surface to increase the radiating surface area.

The interior modifications were much more important. A number of complex heat conduction plates were designed to fit between neighboring boards and/or the chassis. To produce 3D models of the HGL cards, the conditioning cards supplied by Fylde Electronic Laboratories were modeled using a Faro measurement arm. These SolidWorks models were then transformed into machining instructions using a CAM package and produced on the milling machine within minutes (Figure 1).

Each heat plate was designed to conduct the heat from a board through the mounting posts to the next plate and onward to the chassis, where it would be radiated to the environment (Figure 3). These plates did add substantial weight to the finished unit, but included the benefit of further strengthening the finished machine.

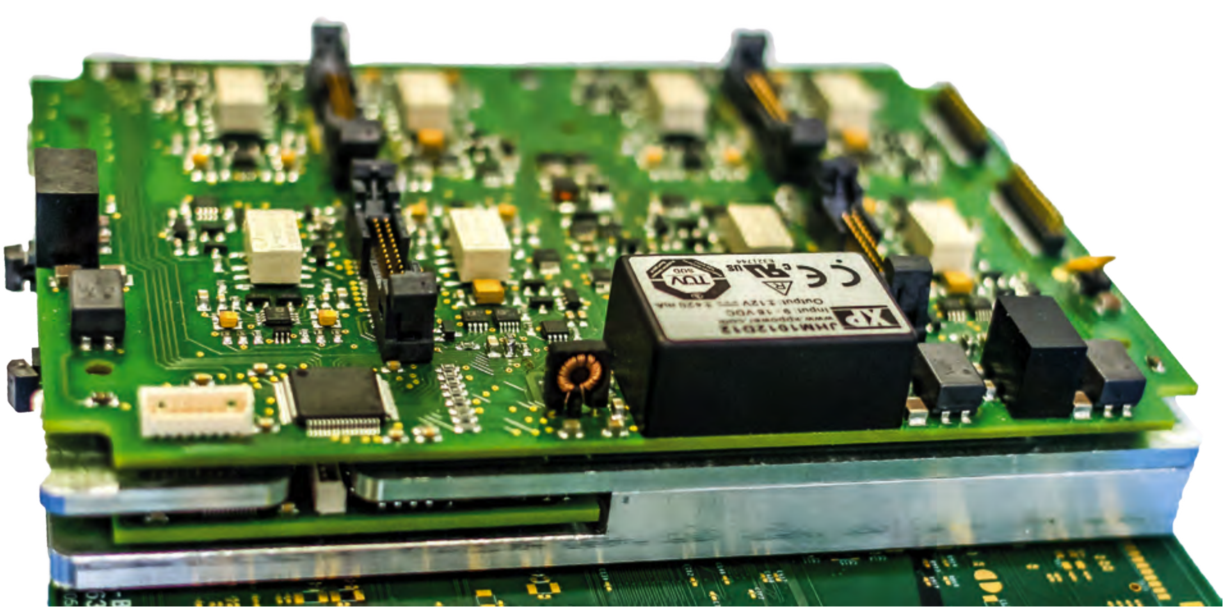

FIGURE 3: Conduction cooled acquisition and conditioning card stack

Unit	Unmodified Hummingbird @ 0.7psi	Modified Hummingbird @ 0.7psi	Unmodified Hummingbird @ 14.7psi	Modified Hummingbird @ 14.7psi	Modified Hummingbird @ 14.7psi
Duration	20 minutes	18 hours	18 hours	18 hours	18 hours
Condition	Failed	Operating	Operating	Operating	Operating
Time to reach stable temperature	Not reached	8 hours	1 hour	8 hours	8 hours
Internal temperature	80°C	65°C	70°C	33°C	78°C
Chassis Temperature	Not measured	55°C	65°C	28°C	73°C
Estimated Ambient Temperature	<40°C	50°C	25°C	25°C	70°C

FIGURE 4: Temperature test results

DID THE MODIFICATIONS WORK?

The modified Hummingbird (Figure 2) closely resembles a standard unit; the major differences being the absence of fans and venting holes, and an increase in weight of approximately 2kg. But the key question of whether the modifications would meet the requirements remained.

Testing was undertaken with both unmodified and modified units, at atmospheric pressure (14.7psi) and at the required 0.7psi. Once again, in-house design and manufacturing were employed to build a vacuum chamber that could accommodate the unit for testing. The chamber enabled pressures to 0.2psi to be achieved and maintained indefinitely.

The temperature of the electronics was measured by the Dragonfly card's own temperature sensor, the chassis' external temperature was monitored at the end of each 18-hour test period after repressurization, and the ambient temperature within the vacuum was estimated based on the vacuum chamber's external shell temperature readings.

Pre-modification testing established that network communications failed when the devices reached 80°C.

The results in Figure 4 clearly demonstrate that the modified unit operates at low pressures and high temperatures indefinitely, with a 15°C difference between the electronics and ambient temperatures.

The measurements at standard atmospheric pressure, where the modified Hummingbird provides exceptional performance with a temperature difference of only 8°C between the electronics and ambient temperatures due to the combined effect of radiation and convection, proved extremely interesting.

PRODUCTION

The modifications to the Hummingbird resulted in a unit that satisfied the client's exacting requirements, but the investigation and design effort had used over 60% of the project time.

The remaining challenge was to build, test, integrate and deliver 24 front-end units, together with their respective computing resources, power supplies and network switches, to the client via HGL Dynamics (Indianapolis). At this point in the project, access to in-house manufacturing resources paid dividends. The capability of the high-speed milling machine and the commitment of the engineers resulted in the completion of the chassis and internal components in less than two weeks. External suppliers had quoted lead times of up to 30 weeks. Additionally the cost of manufacture in-house was less than 20% of that quoted externally, even when manpower costs were considered.

The front ends were shipped to the USA and integrated with the waiting machines, leading to a complete system in Indianapolis 95 days after the contract start date (Figure 5). The system has since been installed and commissioned and is awaiting its first vehicle test later this year

CONCLUSION

The science and techniques discussed are not revolutionary, but it is true that few data acquisition vendors routinely use conduction and radiation for module cooling. And even if these are used, the chassis metal and finish is often not the best for the maximum cooling capability.

The major conclusion that HGL draws from the delivery of this 256-channel system is that a return to in-house design and manufacture is extremely beneficial when undertaking short timescale, technically challenging projects. Delivery of this system simply would not have been possible without these capabilities being available within the company.

The techniques gleaned from the project will, in due course, be implemented throughout the HGL product portfolio, with fanless, conduction-cooled systems becoming available across the range. The one downside of this development, increased module weight, will be more than offset by the many benefits, including extended environmental operating conditions, improved reliability through the reduction in moving parts and the increased module ruggedness.

Dr Jim Hone is managing director of HGL Dynamics Ltd with offices in the UK and globally

FIGURE 5: 768-channel system front-end units

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NEW PSD ESTIMATION METHOD

New software can provide a power spectral density estimation in a fraction of the time of traditional methods

BY JACOB MAATMAN

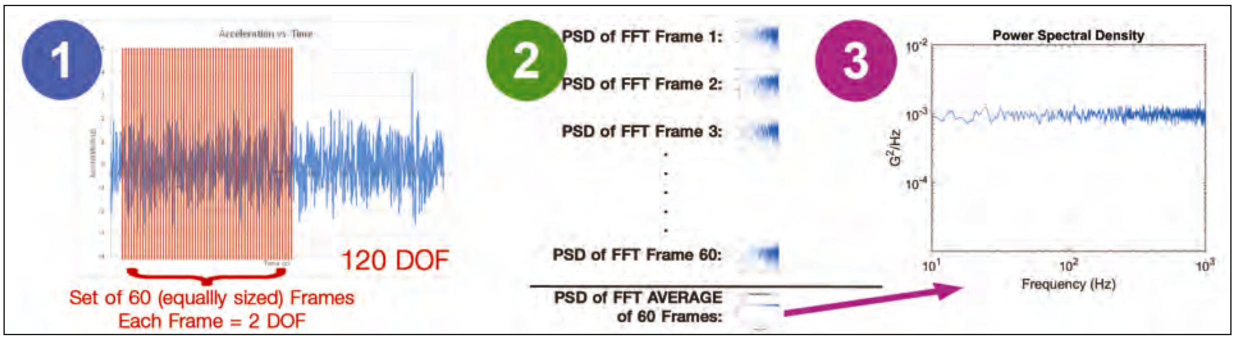

FIGURE 1: Frames of data are (1) collected, (2) transformed, calculated, and averaged, and then (3) displayed in the PSD estimate

It is vital that a random test consistently meets power spectral density (PSD) requirements throughout. By its nature, random averaging requires time to present in-tolerance and smooth spectral lines. Vibration Research has a newly developed method of PSD estimation, Instant Degrees of Freedom (iDoF), which provides an accurate and smooth PSD estimate without requiring traditional averaging time. This is the best method available to ensure that a random vibration test meets PSD requirements throughout.

RANDOM AVERAGING SURVEY

During a random test, control systems collect time-domain data and divide it into equally sized periods (frames). The data from each frame is transformed using the fast Fourier transform (FFT), and the power density is computed at each frequency to get a PSD estimate. Multiple frames of data are processed and averaged to get a better PSD estimate for the signal. As more frames are included, the estimate improves.

This discussion is limited to linear averaging without overlap processing and windowing. The characteristics of simple linear averaging also hold when windowing, overlap processing and exponential averaging are included.

VARIANCE

Because the test is random and Gaussian, the raggedness or variance of the PSD estimate can be quantified statistically according to the chi-squared distribution. The statistical degrees of freedom (DoF) of the chi-squared distribution is twice the number of frames included in the average. DoF and variance are inversely proportional. The greater the DoF, the more data included in the average and the smoother the estimate.

On the other hand, the lower the DoF, the higher the variance and the more ragged the PSD estimate. This explains why, early in the test with low DoF, the PSD plot is ragged and lines are out of tolerance. According to chi-squared statistics, this is to be the expected result.

Attempts to circumvent the variance by including scaled, low-level data in the high-level PSD estimate generate inaccuracies.[2] Because product response does not change linearly with a change in level, this method can mask potentially damaging resonances. Averaging must be reset at changes in level.

INSTANT DEGREES OF FREEDOM

There is a need to see product response as soon as possible and to verify that test requirements are being met throughout the test. This goal is confronted with the time requirement of traditional averaging – the time needed to collect, process and average data to reduce the variance of the PSD estimate. New method iDoF is a patent-pending algorithm that answers the need for an accurate, low-variance PSD estimate that can be quickly obtained in a manner that does not require the time necessary for traditional PSD averaging methods.

iDoF does this by recognizing the difference between estimation error and control error. Estimation error in a PSD trace is an undesired characteristic of the algorithm. It is the variance in the PSD estimate that is reduced through averaging to achieve a smoother plot. The control error is the true difference between the PSD of the signal and the demand PSD required by the test specification. It is the control error which the test engineer is most concerned, because it indicates how accurately the product is actually being tested. Removing estimation error provides a clear view of the control errors and iDoF enables engineers to make appropriate and informed decisions on how the test is affecting the product. Details previously obscured, either by averaging with low-level data or by estimation error, are now clear.

Figure 3, comparing results using the three averaging methods, shows how iDoF reveals details in the response that are obscured by the other methods. With a method that scales low-level data, the high-level resonance is suppressed in the estimate. Using a method that resets the averaging at a change in level, estimation error clouds the plot. With iDoF, estimation error is removed and the resonance clearly displayed.

Control errors become visible much sooner with iDoF than with traditional averaging. For example, 10 frames of

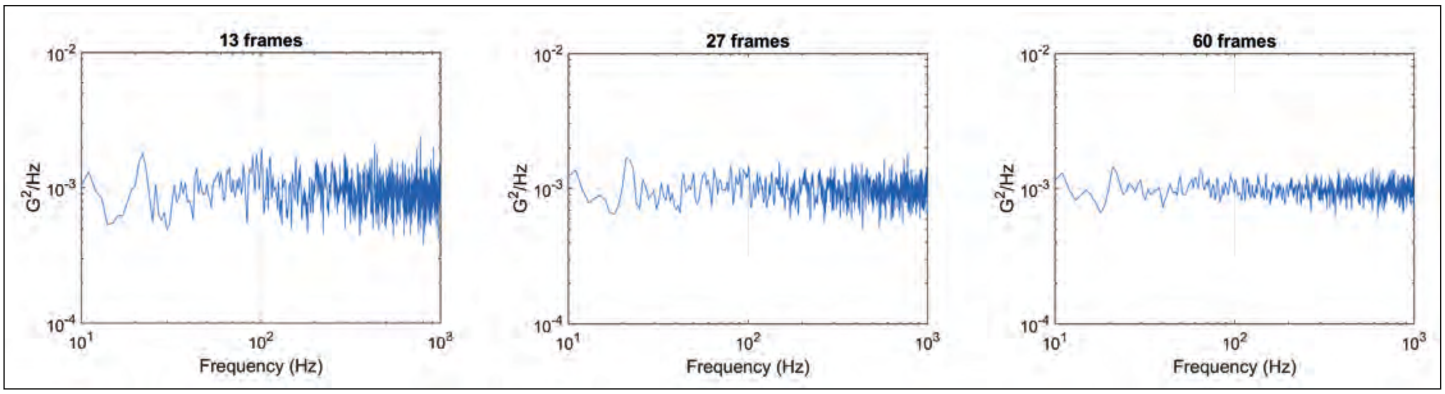

FIGURE 2: As more frames are averaged, variance decreases, and the PSD estimate improves

data can be processed with the iDoF algorithm to produce a PSD estimate for which traditional averaging would require 500 frames. This can be valuable in quickly detecting changing responses such as shifting resonances (e.g. due to a product beginning to fatigue) without the long averaging times associated with high DoF.

After a change in level, iDoF quickly reduces the variance of the PSD estimate without including low-level data. iDoF does so in a way that keeps control error visible. Thus iDoF quickly exposes any lines out of tolerance without masking resonances and without requiring the time necessary for traditional averaging.

GRAPHICAL RESPONSIVENESS

Another advantage of iDoF is that it can provide a responsive PSD estimate throughout the test. With traditional averaging, as more are acquired to reduce the variance of the PSD estimate, the estimate becomes less responsive. This is because so much data is included in the average that a change in the signal, when sampled, processed and averaged, takes longer to significantly affect the average. The other data in the average dilutes the data that first captures the signal change, and potentially damaging changes in the vibration of the product become less obvious.

iDOF can give the same variance as a high-DoF PSD estimate – a small amount – but with much lower DoF, in much less time. So, by setting low DoF, iDoF will still function, but the DoF in the average of the PSD estimate throughout the test will be low, which makes for a responsive PSD estimate throughout the test. Should there be a change in the signal (e.g., due to part of the product breaking), since the PSD estimate contains many fewer DoF (although the variance of the PSD estimate is still that of a high-DoF estimate averaged traditionally), the data that first captures the change in the signal would make much more of an impact on the PSD plot. iDoF updates test responses with much less data than with traditional averaging. This fast update throughout the test enables the test engineer to verify that not only the average of the test over the test time, but also the test at every point in its duration, is in tolerance.

This is shown in Figures 4 and 5. While the controller ran a random test, a crescent wrench was placed on the fixture to simulate a break in the product. The PSD estimate averaged traditionally with 200 DoF did not capture this signal change quickly, as is evident from Figure 4, which

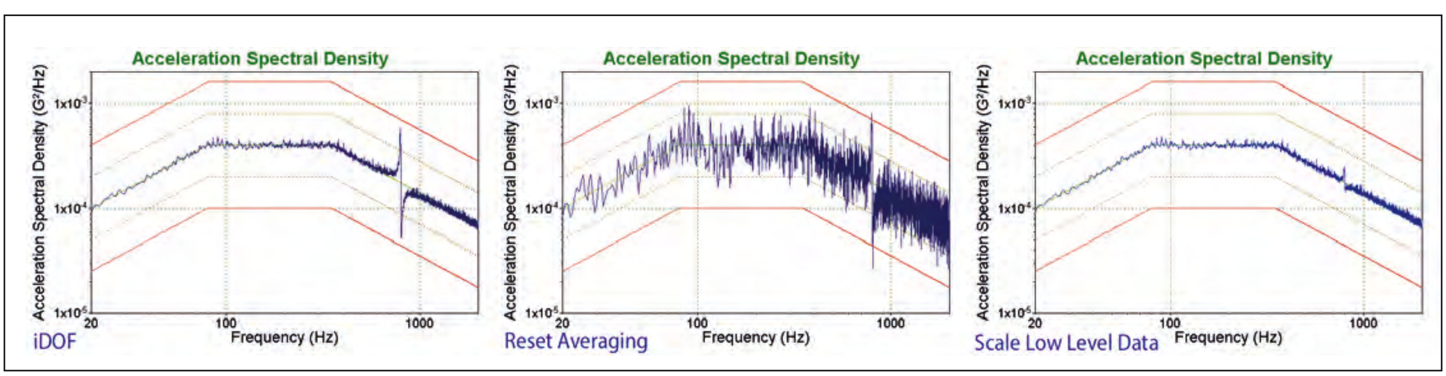

FIGURE 3: Comparison of PSD estimates after switching from low level to full level (top) using scaled low-level data, (middle) resetting the averaging when the level changes, (bottom) using the iDoF algorithm. The estimation error is removed and the resonance clearly displayed

displays the PSD estimate five seconds after the wrench was placed. However, when the averaging amount was set to 10 DoF (to make the response of the PSD estimate faster) and iDoF was enabled and set to 200 DoF (so that the variance of the PSD estimate might be equal to a 200 DoF PSD estimate averaged traditionally), the PSD estimate did capture the change in the signal quickly, as is evident from Figure 5, which displays the PSD estimate five seconds after the wrench was placed.

CONCLUSION

The early test variance and loss of responsiveness inherent in traditional averaging are both negated by iDoF. As a result, the test engineer is given a PSD estimate that quickly and accurately displays control error and product response, allowing him to verify that response is in tolerance throughout the test and not only at the end. This is something every test engineer wants, especially those running a short-duration, high-level test on an expensive product. ∎

Jacob Maatman is a product software engineer with Vibration Research

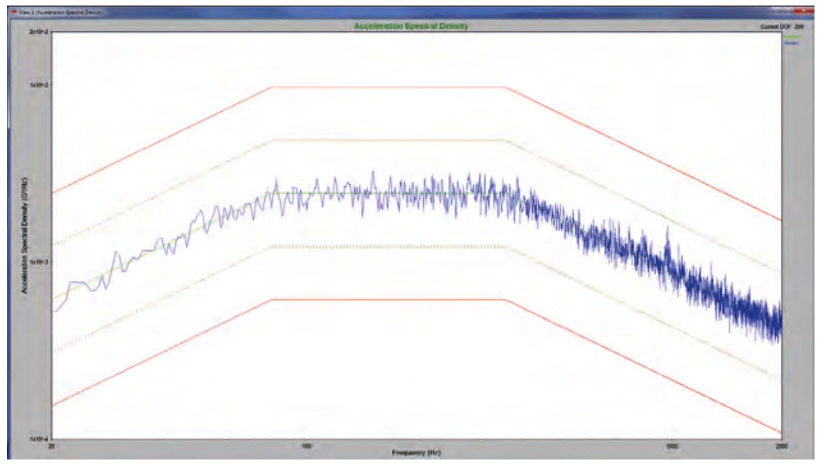

FIGURE 4: **PSD estimate with 200 DoF, averaged traditionally**

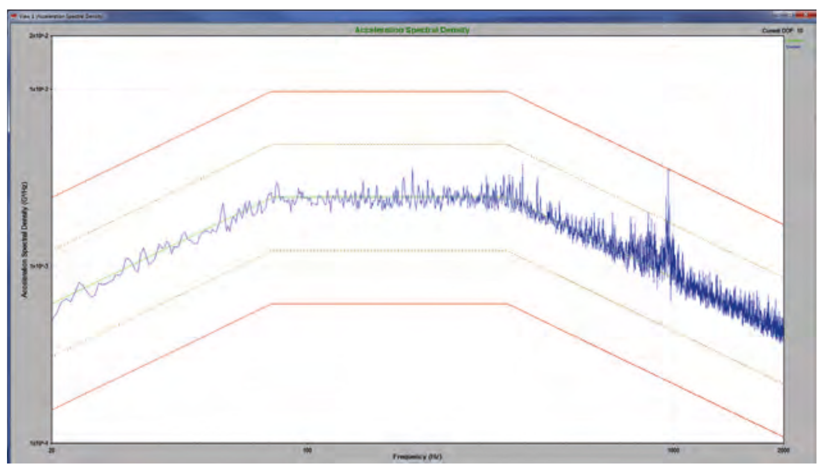

FIGURE 5: **10 DoF PSD estimate with iDoF enabled at 200 DoF**

EXPECTED PERCENTAGE OF LINES OUTSIDE FOR GIVEN TOLERANCE AND DOF

DOF	80	100	120	140	160	180	200
+3 dB	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
+2 dB	0.068%	0.018%	0.005%	0.001%	0.000%	0.000%	0.000%
+1.5 dB	0.892%	0.418%	0.199%	0.095%	0.046%	0.022%	0.011%
+1 dB	5.867%	4.099%	2.892%	2.056%	1.470%	1.055%	0.761%
+0.5 dB	21.342%	19.032%	17.058%	15.350%	13.856%	12.541%	11.375%
-0.5 dB	25.424%	22.628%	20.283%	18.276%	16.534%	15.006%	13.655%
-1 dB	8.870%	6.426%	4.708%	3.478%	2.586%	1.932%	1.450%
-1.5 dB	2.214%	1.188%	0.670%	0.356%	0.197%	0.110%	0.062%
-2 dB	0.402%	0.146%	0.054%	0.020%	0.008%	0.003%	0.001%
-3 dB	0.006%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%

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SPECIALIST INTERIOR TESTING

Teamwork and specialist collaboration can yield some unexpectedly eye-opening results for a wide range of aircraft interiors needs

BY SEBASTIAN BEERMANN AND HANS-JÖRG DAU

Visualizing pictures of 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?

In northern Germany there is a specialist team that focuses on this area. It comprises Stükerjürgen Aerospace Composites (SAC) – well known for high-quality and flexible cabin interiors, design, manufacture and repair in plastics; InteriorsDIRECT – SAC's partner and solution provider for the aftermarket as airlines, maintenance repair organizations and completion centers for spares and customized cabin interiors; and DAUtec – experts in qualification and certification of aircraft parts. Together these three companies have a shared objective – to fulfill customers' needs for cabin interiors, from idea to qualified product, ready for installation on aircraft.

COORDINATED TESTING

DAUtec has established a name for itself in the aviation design and manufacturing community as specialists in aerospace testing and qualification, technical documentation and flight accident investigation.

Its collaboration with SAC began in 2013 and in 2015 it formed a framework agreement to ensure closer consultation on future projects. It has already completed over 20 tests and documentation with SAC, covering a range of its products, including Boeing cargo door studs, Sukhoi Superjet 100 (SSJ100) windows, raceway profiles for the Mitsubishi Regional Jet (MRJ 22/300), panels, seals and covers. Another DAUtec specialty is toilet seat component tests.

The advantage of the collaboration with SAC is that only one partner is required for all testing projects. DAUtec has a large network of partner laboratories and a long history of aerospace know-how going way beyond laboratory practice.

Aircraft bidets during manufacturing and inspection

"Stükerjürgen is one of our biggest clients," says Hans-Jörg Dau, CEO of DAUtec, "and we are working with it to increase the capacity of the existing lab and add even more test facilities for future projects. The advantage of this collaboration for all of us is a close connection to the customer and standardized test procedures. Our cooperation means that we can look forward to working together on the many new and exciting projects that are in the pipeline."

SAC has over 30 years of experience working with authorized aviation thermoplastic materials and various manufacturing processes, and together with DAUtec's expertise in aerospace testing and quality service can now offer many tried-and-tested solutions.

PROJECT SCOPE

One of interiorDIRECT's main customers is one of the world's leading completion centers. Here all the incredibly stylish VIP aircraft cabins are designed and put into shape, step by step. A complete cabin project is structured down to sections and finally single parts and components. A huge organization is needed for such a complex job to conform to schedule. As a consequence several work packages are sourced out to trusted suppliers. This is where InteriorsDIRECT comes into the picture. Totally understanding the customer's requirements, setting up a project to deliver a work package to spec and within time/cost, and providing a final complete solution to the customer is our main business focus. InteriorsDIRECT, SAC and DAUtec can now offer a complete solution from one source, making it easy for the customer to outsource a complete package for execution.

SPECIAL REQUESTS

A project that required a high degree of collaboration was a request for a bidet in the bathroom of an A330 VIP aircraft. The completion center defined an outer shape in 3D data with the final VIP aircraft owner and an area defined for system integration as water/waste. Technical and qualification requirements including weight limits, abuse and *g*-loads, common flammability, smoke density and toxicity requirements were set up.

Naturally the whole project had a challenging lead time for the part to be installed. InteriorsDIRECT was able to establish the complete project planning and was the interface to the customer's engineers, procurement managers and heads of communication during the entire project. Finally the customer received fully qualified parts to install in the aircraft within the allotted time.

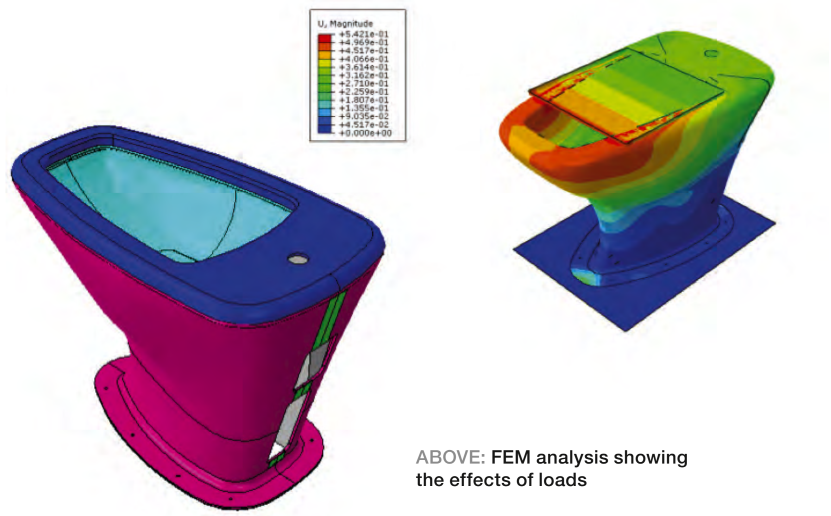
DESIGN AND PRODUCTION

To manufacture the parts and fulfill requirements, an assessment was done to define the best production technologies before production. SAC's more than 30 years of production experience were used, supported by an in-house tooling manufacturing division that had an incredible effect on the short lead time.

The unit was divided into several parts. Two side shells and a top shell were manufactured by vacuum forming, the bowl was completed by 3D printing (FDM) and a CNC-produced foam core in the inside increased the stiffness of the assembly. All parts were glued and finished with a specific primer and a topcoat. The various manufacturing technologies enabled the production of the parts within eight weeks with very competitive pricing. After production of the test part and preparation of the Qualification Test Procedure (QTP), definition began at DAUtec.

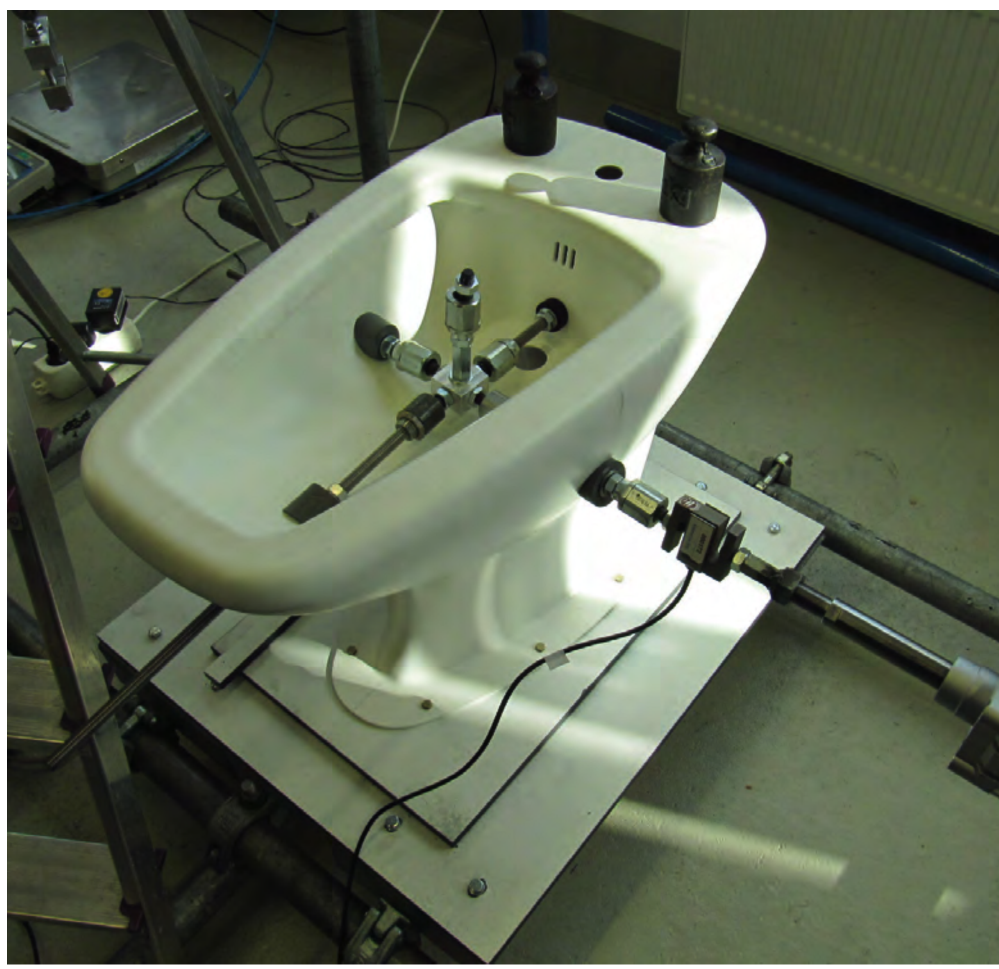
PRODUCTION TO CERTIFICATION

DAUtec's expertise in the testing and qualification fields of avionics includes the carrying out of Acceptance Test Procedures (ATPs), creation of test reports and other documents up to the Declaration of Design and Performance (DPP) necessary and Certification Consulting including Luftfahrt Bundesamt (LBA/EASA) for civil and military aircraft systems and equipment. DAUtec, so far, has qualified equipment and components for cabin interiors, galleys, fuel systems, avionics, power plants,



ABOVE: FEM analysis showing the effects of loads

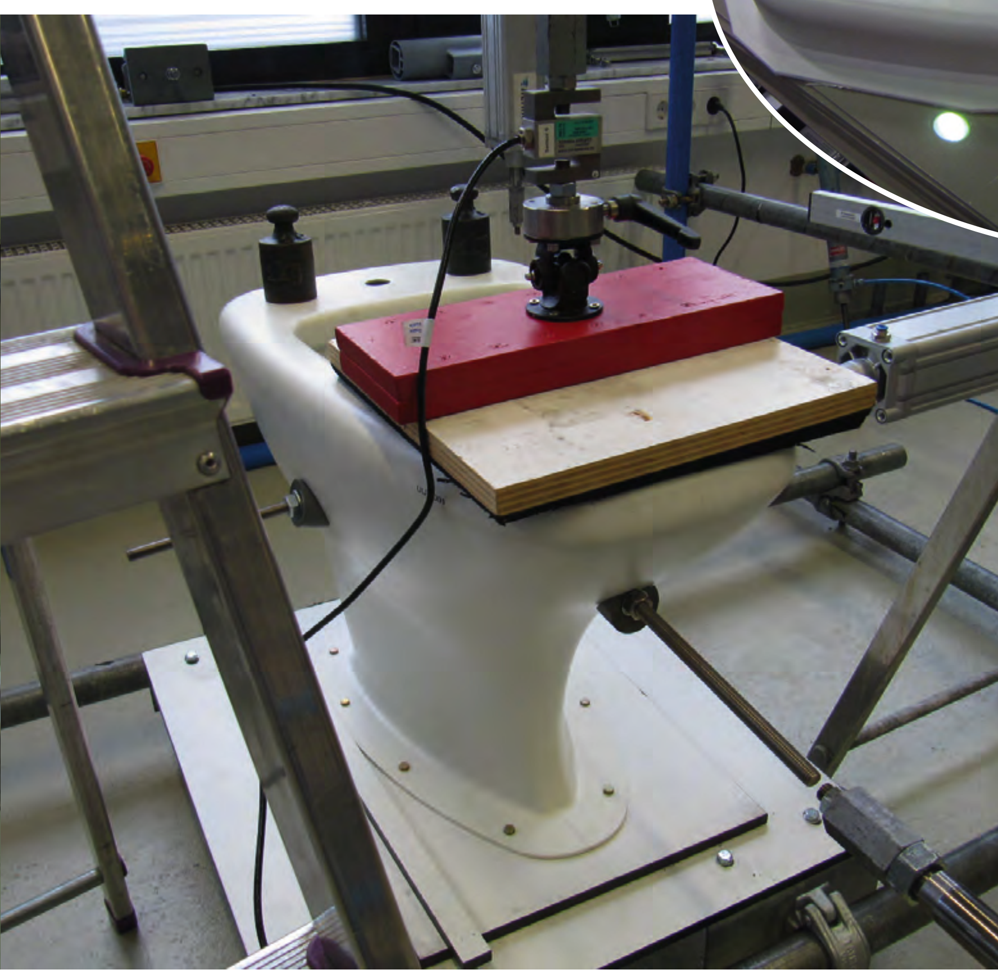
BELOW: Bidet *g*-load test simulating centrifugal forces



LEFT: Tooling for molding the upper panel of the unit

BELOW: Upper panel made from the tooling, shown before trimming

BELOW: The abuse load test on a bidet in a test laboratory



in-flight entertainment systems, tie-rods and shock mounts.

All results from testing are available as photos, diagrams or test curves. Validation is by airworthiness qualification engineers and all results are summarized in the qualification test report and then evaluated. Among our many challenges is the diversity of testing units under deadline pressures, recognition of even the smallest of deviations in the unit under test during testing, and determining the resulting effects regarding safety, quality and convenience. Another side to our testing service is the expertise and experience of airworthiness qualification and test engineers.

DAUtec can develop individual test plans or assist in coordinating entire test programs for any company or aircraft type. ∎

Sebastion Beermann is CEO of InteriorsDIRECT and Hans-Jörg Dau is CEO of DAUtec

SOLID SHAKERS

The problems of conventional shaker tables have been overcome by Unholtz-Dickie with its unique solid armature design

BY MICHAEL GAROFALO

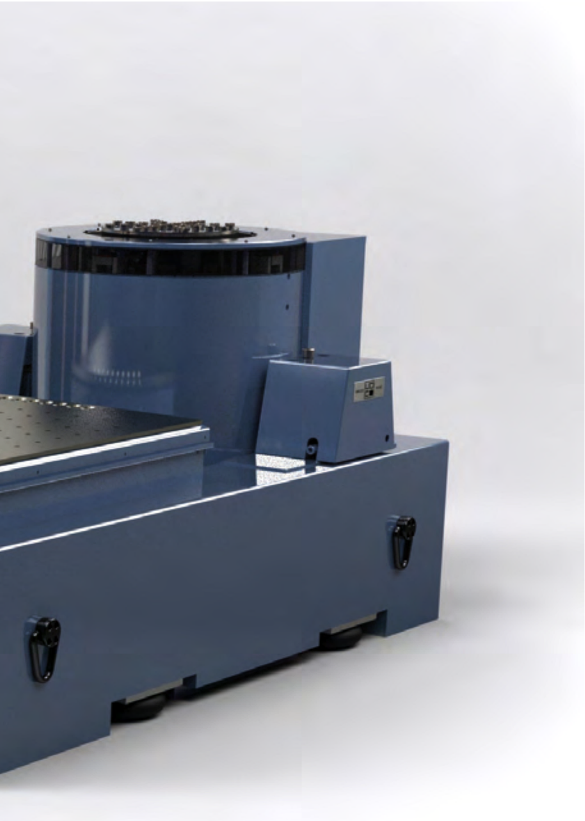
ABOVE: Unholtz-Dickie Model T2000-3 Induct-a-Ring shaker driven by massive 720 KVA air cooled power amplifier

For high-level vibration and shock testing capabilities, Unholtz-Dickie (UD) offers its Model T2000 shaker with 3in peak-peak stroke (76mm), a specification that moves the unit into an unmatched specification and performance level. In combination with available power amplifiers rated up to 720KVA output, the 3in-stroke machine produces staggeringly high acceleration and velocity output. Specific breakthrough performance examples include: 154g RMS random on a 16 lb (7kg) load; 100g peak sine on a 140 lb (64kg) load; 500g peak/4ms half-sine shock pulse on a 50 lb load; and up to 295in/sec (7.4m/sec) intermittent velocity.

Why haven't numbers like these been available before? What improved technical design component has made this radical increase in vibration and shock ratings possible? The answer can be found by understanding the construction of the T2000's armature. This design is called 'Induct-a-Ring' and was put into production by UD in the early 1970s.

HISTORY

Conventional electrodynamic (ED) shakers use the same basic design configuration as a loud speaker – an AC voice coil suspended in a DC magnetic field that is driven by an audio amplifier to produce vibration (sound). All conventional ED shaker designs have used this basic design configuration – just beefed up to industrial strength proportions. Therefore, most of today's conventional shakers use a multi-turn wound



BELOW: UD Model T2000-3 featuring a heavy-duty pedestal base and externally guided head expander

BELOW RIGHT: UD T2000 Induct-a-Ring armature with solid metal coil

armature coil (air- or sometimes water-cooled), which interacts with a fixed DC magnetic field (produced by field coils) to develop output force when the driven armature coil receives AC current from a power amplifier. This 'moving driver coil' design philosophy completely dominated ED shaker development up until about 1970, when two important things happened.

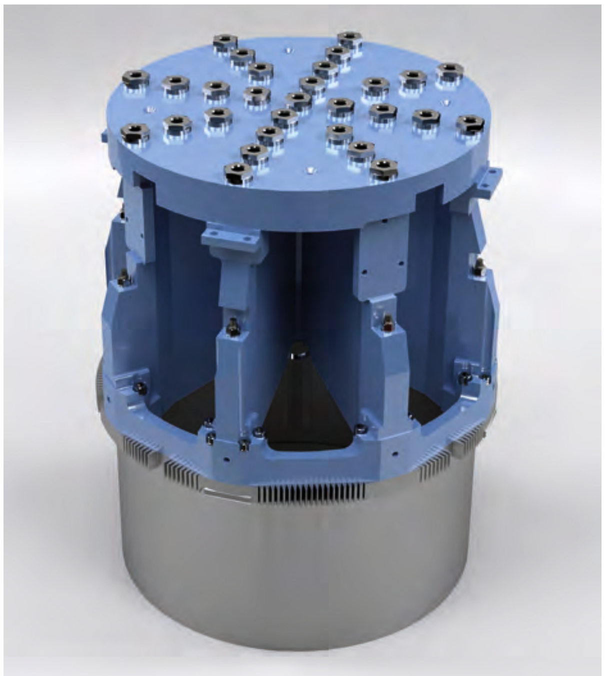
First, Unholtz-Dickie engineers developed a line of solid state (low-voltage/high-current) power amplifiers that soon replaced the earlier high-voltage/ low-current vacuum tube amplifier designs. Second, in concert with the new power amplifier development, UD engineers developed the breakthrough design of the Induct-a-Ring shaker.

PUTTING INDUCTION TO WORK

In the UD Induct-a-Ring, the driven AC coil is moved from its original position on the moving armature frame to a stationary location within the ED shaker iron structure, but closely surrounding the bottom half of the moving armature. The lower section of the armature was changed to a solid metal, single-turn coil made from an aluminum forging. Stationary AC coils, rigidly mounted within the massive iron structure of the T2000 shaker body, are direct-coupled to the power amplifier output. Amplifier output power is transferred to the actual moving armature through highly efficient inductive coupling between the fixed AC stator coils and the single-turn driver coil on the armature frame. Electrically, the internal coil configuration of the T2000 behaves like a transformer with a single-turn secondary winding. There is an enormous advantage to delivering hundreds of KVA of power amplifier output to the moving armature's driver coil without the need for a flexing current lead. Taking this current lead out of the picture creates a step-change in armature reliability.

INDUCT-A-RING ADVANTAGES

The Induct-a-Ring design eliminates the three soft spots in conventional 'wound coil' armature designs: an epoxied multi-turn (water cooled) driver coil; a flexing AC current lead that has to carry 1,000A or more; and



flexing water hoses that deliver critical coolant to the driver coil – all three being asked to operate reliably in a high-displacement, high-acceleration vibration environment.

AIR COOLING THE ARMATURE

Another inherent benefit of the Induct-a-Ring design is the ability to air-cool the driver coil, thus eliminating the flexing water hoses required by conventional, high-force armature designs. AC currents that flow in the Induct-a-Ring single-turn coil travel primarily along its outer surface due to the well-known 'skin effect' that applies to AC current conductors. Since the resulting heat resides on the surface of the solid driver coil, forced air-cooling using a remote blower is practical. Elimination of the closed-loop water-cooling hardware (especially the flexing water hoses) used in conventional armature designs again scores a major breakthrough in reliable operation under extreme vibration conditions.

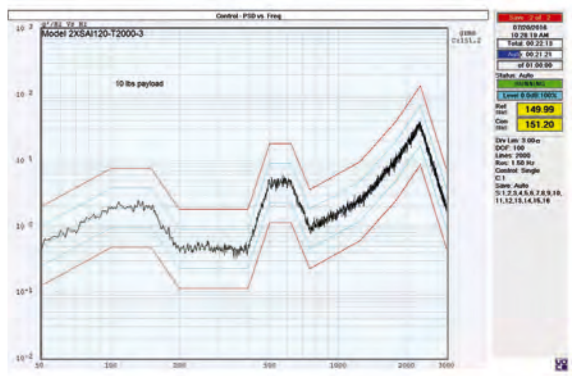
THE 'SLINKY' EFFECT

One of the best-known bits of folklore in the vibration testing industry is one failure mode of wound coil armatures known as the 'slinky' or accordion effect. When the generated force acting on the wound driver coil of a conventional armature exceeds a critical point, the coil separates from the armature frame; the fractured epoxy joints fail further until the coil may then break free from the armature frame completely, resulting in a catastrophic shaker failure. When the operator later attempts to remove the armature by pulling the frame vertically out of the shaker, the no longer attached driver coil often reveals itself as an elongating helix dangling from the armature frame – thus the name 'slinky effect'. The T2000 Induct-a-Ring armature is immune to this condition by virtue of its solid metal construction with no windings or epoxy joints employed in the force-generating driver coil. ∎

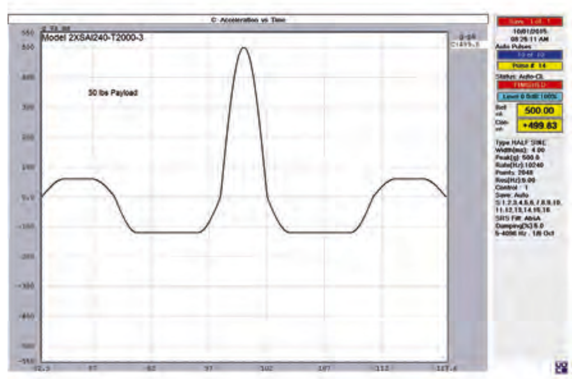
Michael Garofalo is an applications engineer at Unholtz-Dickie

UD INDUCT-A-RING TEST RESULTS

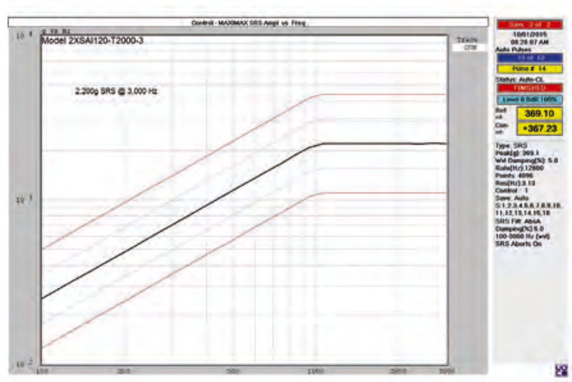
The examples shown are representative of the extreme testing conditions that can be performed by Induct-a-Ring shakers. If these had been conventional wound driver-coil shakers, these tests would be put into the category of 'armature breakers'– but UD's technology has changed that.



TEST A1: Random vibration. (150*g* random with 10 lb payload)



TEST A2: Classical shock pulse. (500*g* peak, 4ms half-sine pulse with a 50 lb payload)



TEST A3: Shock response spectrum (SRS) -2,200*g* SRS at 3,000Hz)

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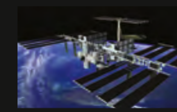
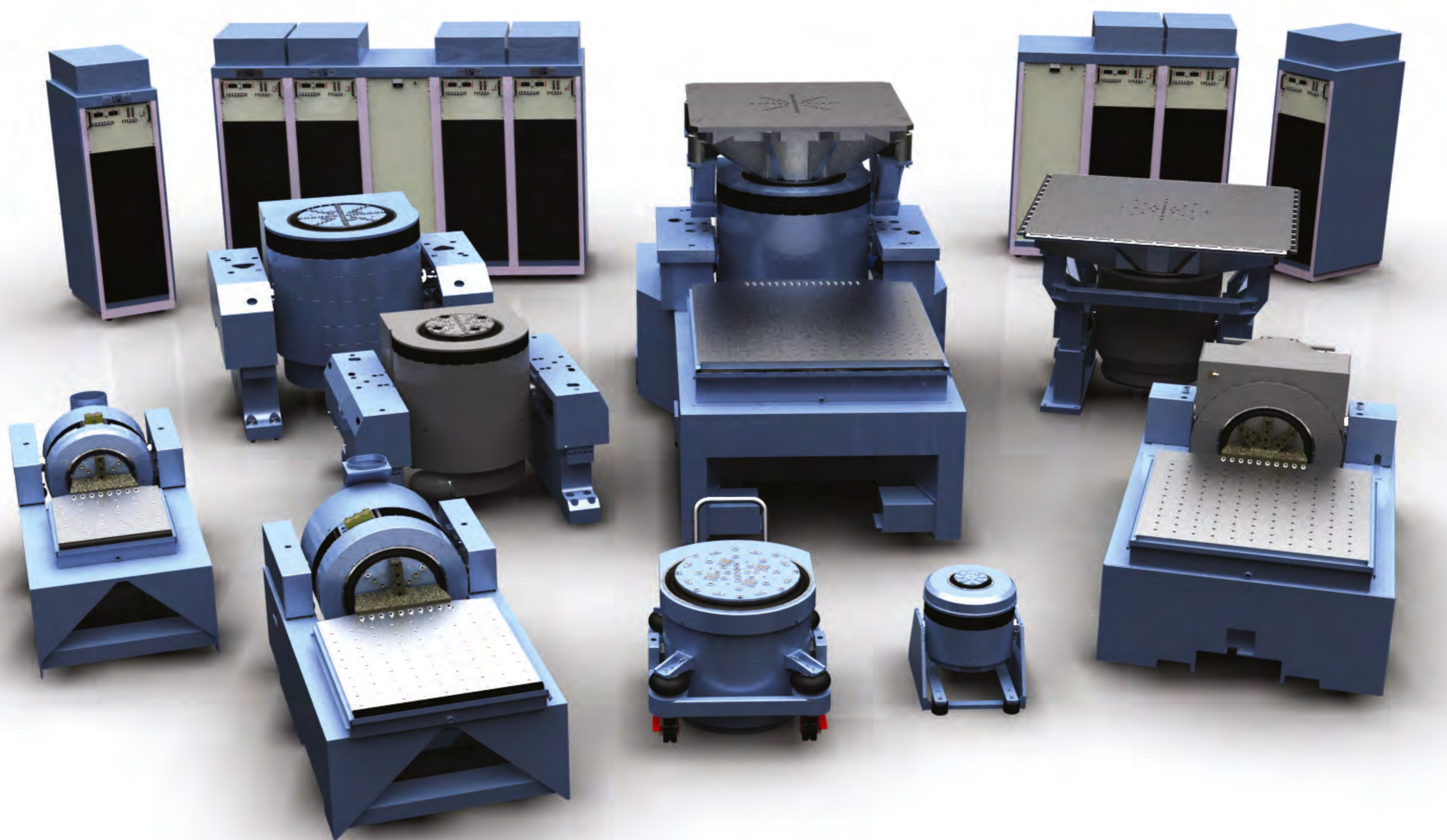


Vibration Test Solutions...



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TESTING THE UNIQUE

Developing the systems of a hybrid aircraft requires configurable and versatile test software and hardware so systems can be fully examined in imaginative ways before the first flight

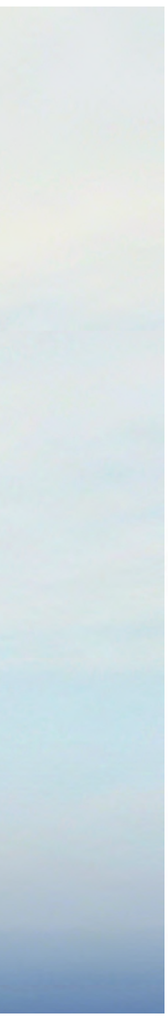
BY ARNE BREHMER AND JÖRN HAASE

The CANoe from Vector Informatik is a software tool for development, test and analysis of entire networks and individual line replaceable units (LRUs), and it supports engineers throughout the entire development process. Its versatile functions optimize troubleshooting, communication analysis, stimulation of bus communication, and manual as well as automated testing. Furthermore, it offers universal support for bus networks used in the aerospace industry, among them AFDX, ARINC 664, ARINC 429 and ARINC 825.

To test LRUs thoroughly, it is not only necessary to connect the communication networks to the test system, it is also necessary to connect the I/O interfaces. This task is handled by the Vector VT System. It simplifies enormously the setup of test benches and HIL test systems, because it integrates all circuit components needed to connect an I/O channel in one module.

CASE STUDY: AIRLANDER 10

The engineers at Hybrid Air Vehicles (HAV), builders of the Airlander 10 hybrid aircraft, decided to run complete test scenarios with the help of the Vector systems. The Airlander 10, the world's longest aircraft, embodies a new type of hybrid concept, combining the best of aircraft and helicopters with lighter-than-air technology to bring brand-new capabilities to aircraft. In a pioneering project of this magnitude, meticulous testing of the control and communication systems is critical and plays an important role both before and during test flights. In the CANoe (CAN open environment) testing and simulation system, and in the VT System test hardware, developers have found the optimal tool combination for handling hardware-in-the-loop (HIL) testing of individual control units, one that provides testing capability ranges from extensive monitoring tasks to full verification of entire sub-networks – before the first flight.



LEFT: The Airlander 10 successfully completed its first flight

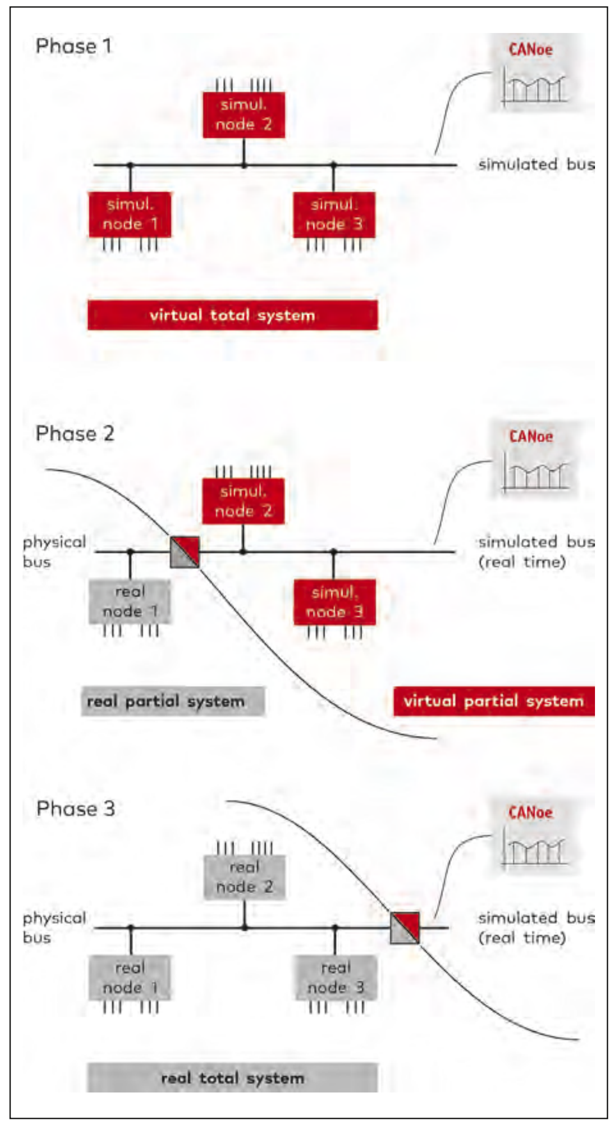
BELOW: The Vector VT System simplifies the setup of test benches

For this project, CANoe and the VT System are handling the current RS422 and RS485 communication systems of the Airlander 10 and they can also support CAN bus systems. If HAV later on decides to switch over to a bus system such as ARINC 825 in the next hybrid airship generation or in series production, it will only be necessary to swap out the physical layers of the CANoe interfaces; no additional changes will be required.

To obtain a defined starting point, HAV began by fully mapping the network communication in CANoe, so that it could be simulated completely by the test software. Together with the VT System, a realistic HIL environment could be generated for each control unit (LRU), and the devices could be tested individually. Among other things, developers used MATLAB/Simulink to design an aerodynamic model of the Airlander 10, and then linked it to CANoe. Furthermore, the software was used to generate a virtual mapping of the Airlander cockpit to test and control the MATLAB/Simulink model in CANoe. This has been utilized to develop the Vector Airlander Flight Trainer. CANoe offers the ability to create user-defined panels with individual layouts of graphic controls such as switches, sliders, pointer instruments, and so on. After a control is linked to the desired signal or variable, the relevant value is then modified or shown in real time.

TESTING, TESTING & MORE TESTING

Important preparatory steps before the test flight in August this year included extensive testing of the control and communications systems such as the flight control network, power distribution controller and flight test equipment. The flight control network is used to directly control the aerodynamic behavior of the hybrid aircraft, and it sends commands from the cockpit or flight control station to the electric actuators. Managers were acutely aware that the upcoming tests would be a challenging undertaking. There were no proven concepts or models that could be accessed, and a lot had to be developed from scratch.



ABOVE: CANoe offers the ability to simulate missing modules and later replace them with real units

The prototype still had a very experimental character. Since many details of the onboard electronics could still change before an optimal solution for the production version could be found, a test system was needed that could meet changing constraints and rise to the challenges with a high degree of flexibility.

The sought-after test system was not to be designed for a special use – what was desired by Hybrid Air Vehicles, instead, was a general tool suitable for many different tasks related to

RIGHT: The panels and bus communication of the Vector Airlander Flight Trainer are both based on CANoe

BELOW: During the testing phase, the Airlander is controlled by panels that are created individually using CANoe

electrical/electronic development subprojects concerning the Airlander.

Hybrid Air Vehicles became aware of CANoe software and the VT System. Vector, headquartered in Stuttgart, Germany, has made its name providing a professional and open development platform of tools, software components and services for creating embedded systems. These give engineers a crucial advantage in making a challenging and highly complex subject matter as simple and understandable as possible. Vector systems are in use across the globe, in the automotive, aerospace, heavy-duty vehicle, rail transportation and maritime industries, as well as in numerous other automation projects.

100% TESTING BY AUTOMATION

HAV uses the switches and controls of the virtual cockpit to simulate the typical actions of a pilot and thereby stimulate the device under test. At the same time, employees can observe how the control unit reacts in different situations. The great advantage of such simulations is that subnetworks can already be started up and tested during development even if some components are not yet available. The missing modules can be simulated and later replaced by real units in a step-by-step process in development until the total system is implemented. In this way, HAV was able to test the flight control network entirely on the ground and to start it up virtually.

An important task during flight operation is assigned to the power distribution controller, which ensures that sufficient energy reserves are available at all times. The system monitors all components that contribute to the energy supply – such as batteries and their charge state, generators, the emergency power system, diesel fuel supply, and much more. In case of problems or in emergency situations, for instance if a generator fails, the power distribution controller must initiate the right actions at lightning speed and switch over to emergency mode. Several hundred test cases are run to verify that functionality is assured in all conceivable situations.

With the help of CANoe, the VT System and vTESTstudio by Vector, HAV not only rapidly created the test configurations, but also attained 100% test coverage with automated test sequences. The vTESTstudio software tool provides different methods for conveniently generating automatic configurations. These sequences may be defined in table format, in the CAPL script language, by C# programming, or modeled in a graphic notation. Excel tables can be imported, and the user simply links the input/output variables.

TESTING THE TEST EQUIPMENT

Last but not least, the Vector test tools were used to verify the flight test

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BLIMP, AIRCRAFT AND HELICOPTER

Based in Bedfordshire in the UK, Hybrid Air Vehicles (HAV) is the owner, designer and assembler of the Airlander 10. It is the only company in the world to have designed and built a full-sized hybrid aircraft, with 21 current worldwide patents.

With 40 years of lighter-than-air expertise in the UK, Hybrid Air Vehicles was formed as a new entity in 2007 and won a US government contract in 2010, which brought US$300m into the project, leading to a successful 90-minute first test flight. Following the US Army's closing down of the LEMV (Long Endurance Multi-Intelligence Vehicle) project, Hybrid Air Vehicles acquired the aircraft and transported the Airlander back to Bedfordshire. Here it was tested in readiness for its first flight, which took place in August.

Today, HAV is considered the world's leading manufacturer of hybrid air vehicles with lighter-than-air technology, and the Airlander is distinguished by a whole series of extraordinary properties. Of particular note is its combination of blimp, aircraft and helicopter traits.

The helium fill with its static lift contributes around 60% of the lift, while the rest comes from its aerodynamic shape and propulsion system. Its four rotor drives, each powered by a 4-liter V8 turbodiesel engine with 325hp of output power, can be swiveled, and generate ±25% of propulsive force in a directed upward or downward direction as necessary. Finally, the aerodynamic shape, similar to the airfoil of a conventional airplane, can contribute up to 40% of lift in response to forward movement. The exterior skin or hull is made of an extremely inelastic liquid crystal polymer fiber that exhibits high tensile strength. All it takes to maintain its form is a slight overpressure of the helium. Based on this concept, its operation is 10 times more cost-effective than that of a helicopter.

This next-generation aircraft is primarily expected to offer cost efficiency and low fuel consumption. Also desirable are the longest possible flight range and duration, high payload capacity and flexibility with regard to take-off and landing requirements. In these and other disciplines, the Airlander 10 sets new standards and is essentially assuming a pioneering role. It has an exemplary CO_2 footprint and low noise emissions, it can stay in the air for up to five days manned and can take off and land vertically on grass, desert, ice, snow and water. Meanwhile, the hybrid aircraft is capable of transporting loads of up to 10 metric tons and up to 60 passengers point-to-point at a velocity of approximately 150km/h. The applications of the Airlander 10 include transport, delivery and crane functions for heavy loads to difficult to access locations – such as wind generator components, oil, gas or pipeline equipment. Uses include tourist excursions and luxury safaris, telecommunications and long-term monitoring missions.

equipment (FTE) in depth before its installation in the airship. The test equipment monitors the onboard electronics during test flights and records important events. Before installation and startup of the FTE, verification must be provided that the system itself is operating correctly and reliably. The network and hardware simulations of the Vector tools were used as a foundation for verification of the FTE. Interesting in this context is CANoe's ability to deliberately feed errors into the communication and, for example, block or falsify messages, or manipulate checksums. Comparably on the hardware side, the VT System can be used to simulate line breaks and short circuits of I/O lines. When such faults occur, it must be possible to find errors in the log data of the FTE.

SUMMARY AND OUTLOOK

Vector's CANoe and VT System have significantly simplified development and testing processes for the control units and communication networks of the Airlander 10. An important requirement for HAV is the ability to simulate the hardware and software and to initially implement their functions using model-based methods. This was already possible in project phases before real components were available. The developers stated frankly that they never reached tool limits with CANoe and VT System and could implement any sort of 'crazy idea' they likes using this combination. The manager of the testing unit was grateful that for many tasks, he now only had to perform them once, and could always reuse the test cases, such as for the next planned project of the type-certified Airlander 10 and ultimately for the much larger Airlander 50. HAV is especially pleased with the reliability and reproducibility of the simulations and tests. Everything is traceable, and the results were obtained from a reliable foundation upon which more advanced developments can be based. The systems installed in the hybrid airship can be controlled from the virtual cockpit, and a lot can be done from the central control station during ground testing, saving a lot of time and walking, given the impressive dimensions of the Airlander 10. ∎

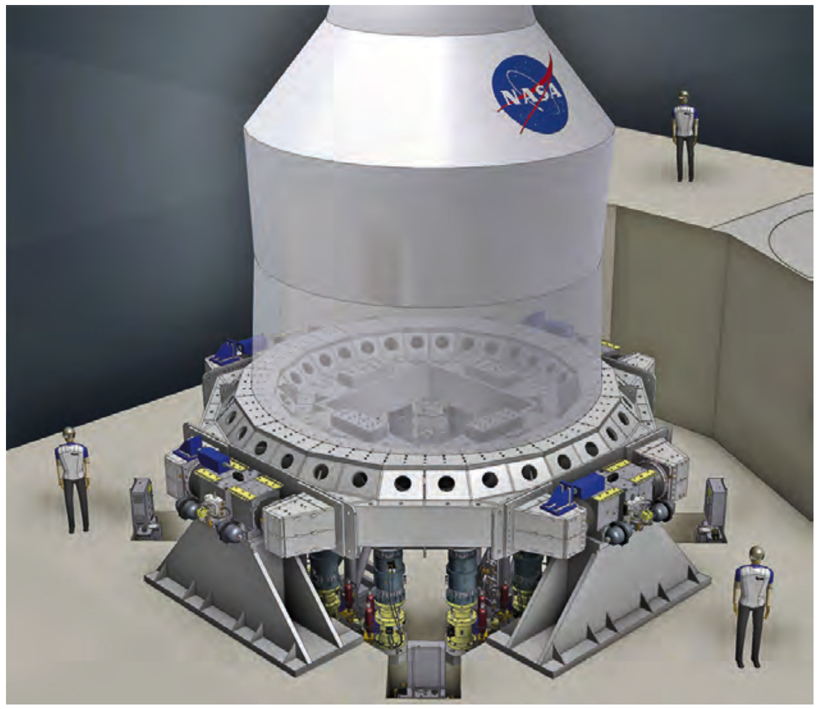
Dr Arne Brehmer is manager aerospace, and Dipl. Ing. Jörn Haase is senior expert aerospace at Vector Informatik

THE SPACE POWER FACILITY

Strong vibroacoustic characteristics are needed for testing space systems for vibration and noise, and NASA's facilities have impressive capabilities

BY ERIC JONESON

The Space Power Facility (SPF) located in NASA Glenn Research Center's Plum Brook facility outside Sandusky, Ohio, houses the world's largest and most powerful space environment simulation facilities. The Mechanical Vibration Facility (MVF) is the world's highest capacity and most powerful spacecraft shaker system and the Reverberant Acoustic Test Facility (RATF) is the world's most powerful spacecraft acoustic test chamber. The SPF was originally constructed in 1969 to perform testing of large space systems needed for advanced missions beyond low Earth orbit. In 2008, in support of the Constellation Program, NASA embarked upon an effort to expand the original SPF facilities to permit acoustic and vibration testing of large spacecraft. A partnership of SAIC and NVT Group members, Team Corporation and Data Physics were awarded the contract to provide the needed equipment.



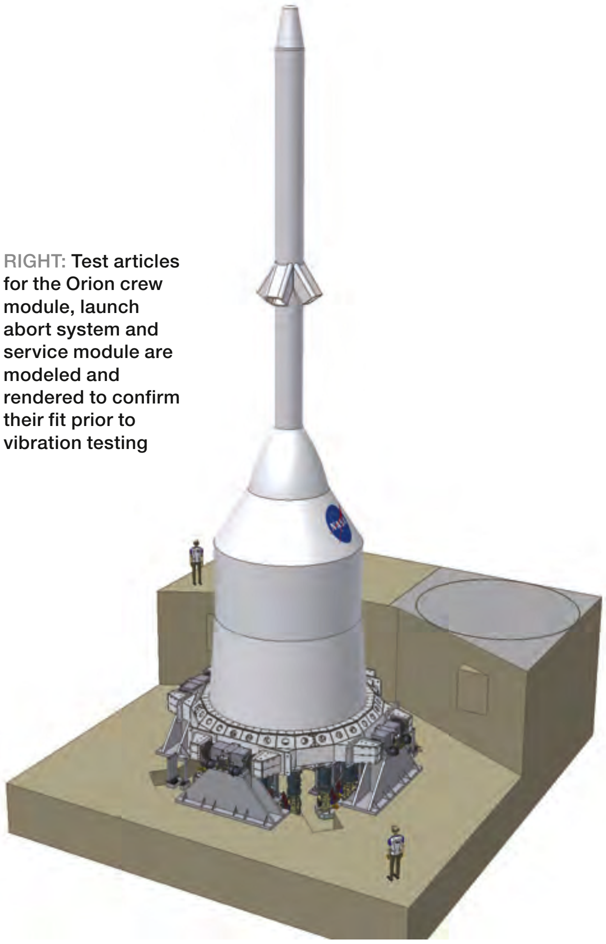
ABOVE: Rendering of the Orion Test Article mounted on the MVF

RIGHT: Photograph of the RATF horn wall and a test article being prepared for testing

VIBRATION AT THE SPF

The MVF is located in the Vibroacoustic Highbay and consists of a three-axis, 6DOF, servohydraulic vibration system. The application requirements for the Constellation Program were limited to single-axis base excitation; however the MVF is capable of simultaneous excitation of all three axes as well as controlling the three axial rotations, establishing a path for future growth in vibratory testing. The MVF system consists of a reaction mass on which are mounted four horizontal servohydraulic actuators and 16 vertical servo-hydraulic actuators. All the actuators interface to the aluminum table via hydrostatic spherical couplings. The 2,100,000kg (4,700,000 lb) reaction mass is used to resist undesired rotations of the test article inherent in vibration testing and transfers the vibratory energy into the shale bedrock foundation. The reaction mass has been sized such that it has sufficient inertial mass and stiffness to react against the forces applied by the actuator/couplings during sine vibration testing. The existing actuator and table design is for sine sweep capability of 0-1.25g (peak), from 5-150Hz in the vertical axis, and 0-1g from 5-150Hz in each horizontal axis for a test article mass of 34,000kg (75,000 lb) with a center of gravity elevation of 7m.

The MVF system design uses a large aluminum table approximately 6.7m (22ft) diameter with a 0.6m (2ft) wide annular mounting surface centered around a 5.5m (18ft) nominal diameter. Table weight is partially offloaded from the system via four inflatable airbags. The vertical actuator assemblies provide the controlled vertical sine vibration and provide overturning constraints during horizontal vibration. The double-spherical



RIGHT: Test articles for the Orion crew module, launch abort system and service module are modeled and rendered to confirm their fit prior to vibration testing

couplings provide high axial stiffness to deliver the vertical vibratory force during vertical excitation. When locked into the fully retracted position, they also permit horizontal translations of the table and test object during lateral and longitudinal excitation. Each double-spherical coupling has internal pressure sensors to enable the vibe controller to limit forces. Four horizontal actuators provide the controlled horizontal sine vibration. The horizontal actuator assemblies restrain off-axis motions during vertical actuation. The system is designed to permit testing in three independent axes without removing or lifting the test article from the table.

MVF CONTROL SYSTEMS

Several independent but communicating control systems provide the operator interface and safety interlocks to the MVF as well as the various facility supplies such as hydraulics and compressed air. The Facility Control System (FCS) and the Table Control System (TCON) communicate with the table actuator servo-valve drivers, initiate the table to a lifted, centered, ready position, and verify all servo drivers are started and ready. Operators then initiate the Vibration Control System (VCON) to generate the sine wave inputs to the servo-valve controllers, establishing vibration. The VCON controller generates drive voltage waveforms for each servo-valve driver to satisfy the control and limit channel constraints from the test article (outer-loop control), and each servo-valve driver maintains a closed-loop control to each actuator (inner-loop control). The VCON has 64 analog input channels, which can be assigned to control, limit or response channels, where the control and limit channels can be set to alarm and/or abort a test. Up to 44 of the analog inputs can be available for test article limit channels. Data is acquired at the MVF via the Facility Data Acquisition System (FDAS), a 1,024-channel high-speed digital system.

ACOUSTIC TEST CAPABILITIES

The RATF chamber is located within the Vibroacoustic Highbay, taking advantage of the 1.8m (6ft) thick surrounding concrete walls to help attenuate sound migration through the SPF. The RATF is a 2,860m^3 (101,189ft^3) acoustic chamber capable of achieving an empty-chamber acoustic overall sound pressure level (OASPL) of 163dB. The facility structure is designed for a future upgrade to 166dB OASPL, including areas in the horn room wall that have been left blank for future installation of additional modulators/horns. The RATF includes various supporting subsystems including gaseous nitrogen generation system, horn room with acoustic modulators and horns, acoustic control system, and hydraulic supply system.

Test articles are mounted onto elevated customer-provided mounting fixtures for testing. The chamber has been constructed with load-bearing wall attachments for future installation of a 5-ton interior bridge crane. The chamber can be operated as a Class 100,000 clean room once the access doors are closed and the facility is cleaned. The combinations of servohydraulic and electropneumatic noise modulators utilize gaseous nitrogen capable of producing a tailored wide-range of acoustic spectrums in the frequency range from 25-10,000Hz. The RATF chamber internal dimensions are 11.4m (37.5ft) wide by 14.5m (47.5ft) deep by 17.4m (57ft) high.

A maximum of 19 control microphones can be placed around

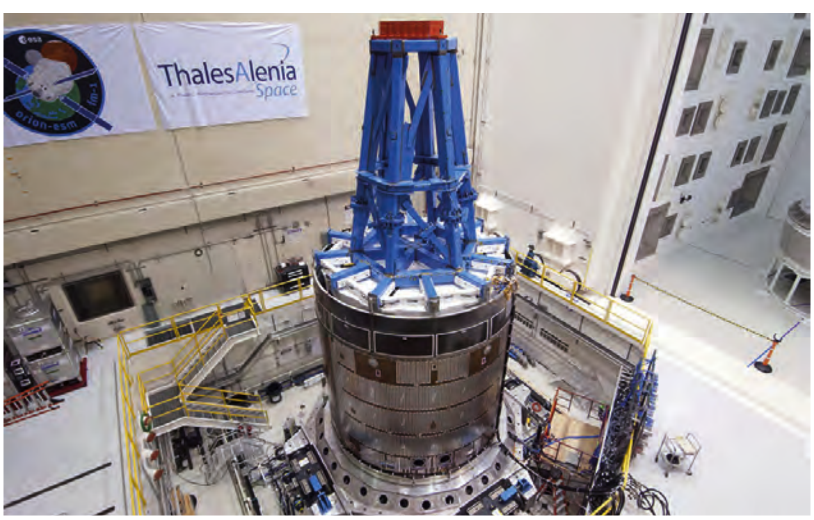
RATF BASIC SPECIFICATIONS

Parameters	
Team Mk VI modulators	12
Team Mk VII modulators	11
Wyle WAS5000 modulators	13
Horns	36
Max. empty-chamber SPL	163dB OASPL
Frequency range	25Hz to 10kHz
Physical characteristics	
Chamber dimensions	14.5 x 11.4 x 17.4m (47.5 x 37.5 x 57ft H)
Chamber volume	2,860m^3 (101,189ft^3)
Crane capacity	18,143kg (40,000 lb)
Floor loading	54,422kg (120,000 lb)
Blank penetrations	25 at 0.15m (6in) dia., 2 at 0.20m (8in.) dia.

BASIC MVF SPECIFICATIONS

Parameters	
Max. test article mass	34,000kg (75,000 lb)
Max. Cg above table	7.2m (23.6ft)
Seismic mass	2,100,000kg (4,650,000 lb)
Max. vertical static force	3,203kN (720,000 lb)
Max. vertical dynamic displacement (Pk-Pk)	3.18cm (1.25in)
Max. vertical velocity	41.7cm/s (16.4in/s)
Max. lateral static force	1,139kN (256,200 lb)
Max. lateral dynamic displacement (Pk-Pk)	3.048cm (1.2in)
Max. lateral velocity	33.8cm/s (13.3in/s)
Frequency range	5-150Hz
Sine sweep rate	Dwell to 4 octave/min
Physical Characteristics	
Table mounting bolt-circle diameter	518.16, 538.48, 558.8, and 579.12cm
Max. test article height	23.5m (77ft)
Max. test article height below crane bridge	20.4m (67ft)
Sine sweep rate	Dwell to 4 octave/min

BELOW: The MVF with a test object

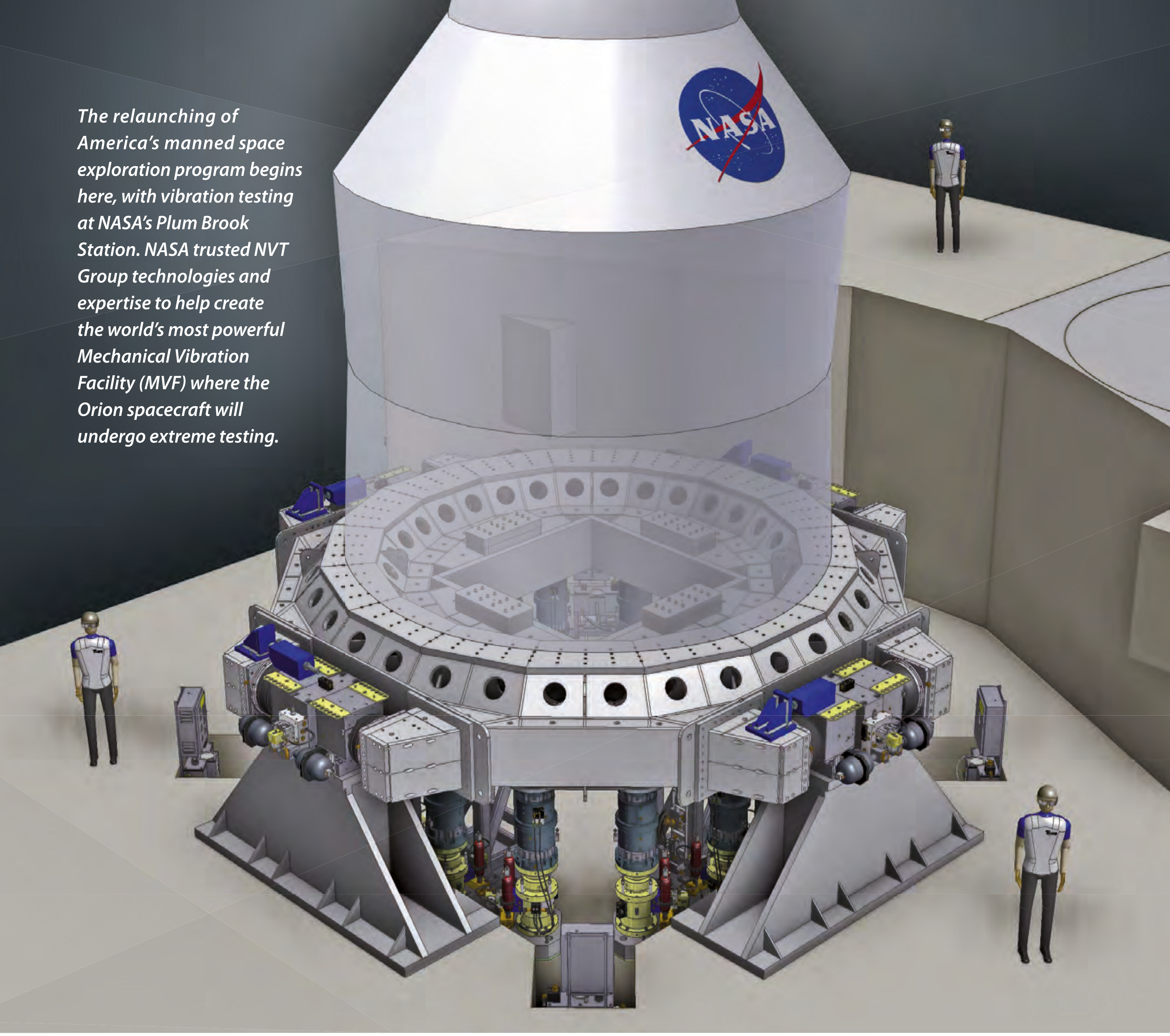


the test article for closed-loop control using the Acoustic Control System (ACS). The ACS, control microphones, or other response instrumentation (accelerometers, microphones) may be input into the Analog Abort System (AAS) to provide automatic shutdown capability. Each of 23 servohydraulic acoustic modulators is coupled with individual horns of six different cut-off frequencies. Each of the 13 electropneumatic acoustic modulators is coupled with individual horns of one cut-off frequency. This combination of modulators and horns provides for an extremely variable and tailored acoustic spectrum. Threaded inserts are located in the floor for attachment of test article mounting fixtures.

Data is acquired at the RATF via the same FDAS as used by the MVF. In addition, the hydraulic power supply is shared between the MVF and RATF.

The combined efforts and technology of NVT Group partner companies Team Corporation and Data Physics has played a key role in supporting NASA's effort to upgrade the SPF at NASA Glenn Research Center's Plum Brook facility in order to permit acoustic and vibration testing of larger spacecraft. This operational technology is currently being used to test NASA's Orion Spacecraft, in an effort to prepare the hardware for launch into deep space, and its eventual mission to Mars. ∎

Eric Joneson is vice president of marketing for the NVT Group



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MARCHING TO C-BAND

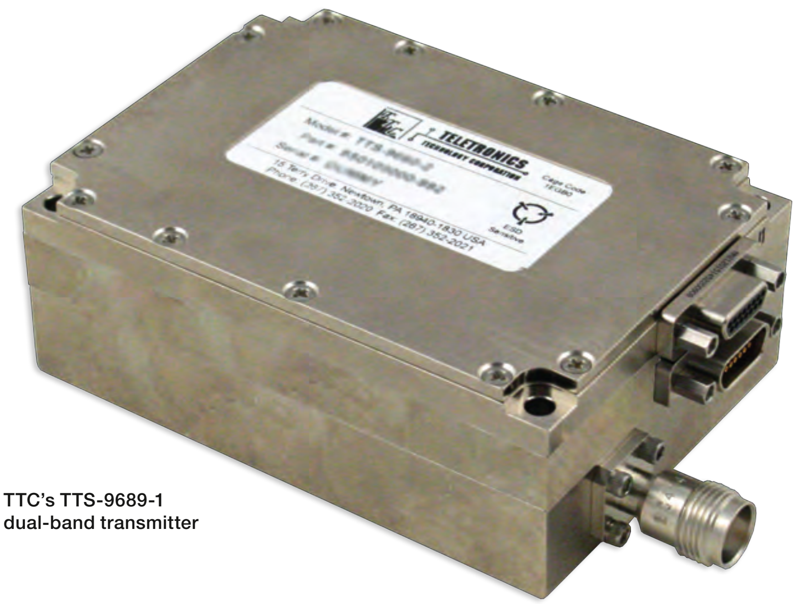
The transition to C-band telemetry has been marked by experiments as new hardware is developed for the testing community

BY PAUL COOK

The auction of airwaves for use in mobile broadband held in November 2014 was done to support the demand for internet access by smartphones and tablets.

Frequencies that were sold included two blocks in the 1,695-1,710MHz band, and four paired sets of frequencies at 1,755-1,780MHz and 2,155-2,180MHz that were traditionally used for telemetry applications both in aircraft flight and missile tests, and on launch platforms.

New C-band frequencies were established in the 4,400-4,940MHz, 5,090-5,150MHz and the 5,925-6,700MHz for telemetry usage.



TTC's TTS-9689-1 dual-band transmitter

THE SELL-OFF EFFECTS

With the governmental auctions and sell-off of the telemetry frequency bands, the everyday operation of the flight test community is drastically affected, with reduced operational availability due to increased frequency crowding.

The US government responded with new standards for bandwidth-efficient modulation schemes to 'pack' more data bandwidth in the remaining telemetry workspace, allowing the private sector to develop hardware in the new C-band allocations for telemetry. The current transition status to C-band is that a dual-band operation is needed for telemetry that must still operate for a short time while the systems are upgraded to C-band.

VENDOR RESPONSE

The telemetry supplier community responded first with spectrum-efficient hardware for both air and ground applications, while the requirements for C-band applications evolved from initial experiments to products actually meeting testing requirements.

The landscape for the transition to C-band has changed recently with the increased government spending as the result of the sell-off. Range operations now have the funding for full-range upgrades. The upgrades will support the transition to C-band over the next five years at least.

The TTS-9670-1 C-band transmitter

C-BAND HARDWARE DISCOVERIES

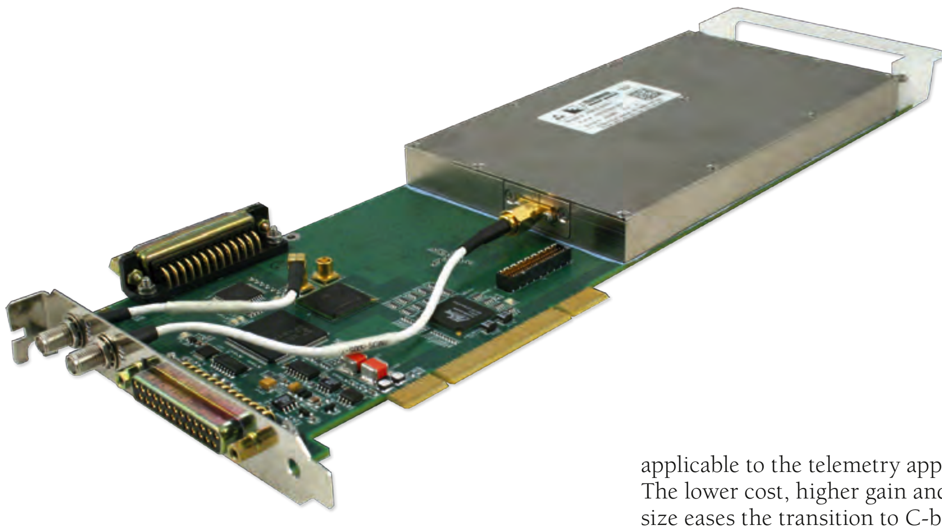
Testing of the initial C-band hardware demonstrated the impact on link margin caused primarily by cable and connector losses. Increasing the RF power to compensate for the loss also increases the current draw by 20% on average comparing S-band to a C-band 5W transmitter. The aircraft platforms are implementing 20W C-band transmitters in instances that previously flew 10W variants.

Tracking accuracies and water vapor effects on the link margins are still being evaluated for C-band, but are viewed as problem areas requiring additional RF power or enhanced performance to obtain good data download reception.

TECHNOLOGY ROAD MAPS

The transition to C-band requires not only multiband operation, but higher RF power as well on the new frequencies. Once the grace period is over, all telemetry will reside in C-band in the continental USA.

Higher gain coding schemes have been introduced to the telemetry market to obtain additional link margin. These coding schemes have been used for many years in the launch and space industry segments and may have a new home in flight test.



ABOVE: The RMDS-500S-8 C-band PCI receiver

Commercial RF devices are leading the RF efficiency challenge as the cell industry has increased its frequency dependency. The desire for broadband access fuels the spectrum sell-off both in funding and in the development of RF devices that operate in higher frequency bands with greater efficiency, allowing entry into the telemetry market with increased RF power efficiency and better performance in C-band.

The trend of the past 20 years continues as the commercial market develops better devices that are applicable to the telemetry application. The lower cost, higher gain and smaller size eases the transition to C-band.

TRANSITIONAL SOLUTIONS

Suppliers such as TTC are supporting the transition with singleband and multiband to allow the dual-band usage as long as the grace period continues. This allows the end user to gracefully enter into the C-band, and to evaluate the system performance in both bands. TTC also offers the TTS-9689 dual-band transmitter that is programmable in lower L-band (1,435-1,534MHz) upper L-band (1,700-1,850MHz), lower C-band (4,400-4,940MHz) and middle C-band (5,090-5,150MHz).

The TTS-9689 provides an RS-232 programming port and a parallel interface port to select the frequency of interest along with modulation type and RF output level.

TTC also offers singleband C-band transmitters when the dual-band operation is no longer necessary.

A full range of ground receiver equipment is available from lab use to full-range operation. Receivers in both PCI and rack-mounted form factors support all aspects for system testing and support. ∎

Paul Cook is director, missile systems with Teletronics Technology Corporation

TELETRONICS TECHNOLOGY CORPORATION

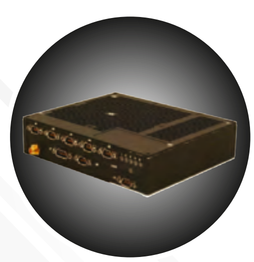
AIRBORNE SWITCHES

TTC Ethernet switches provide flexible multicast packet routing and robust time gateway capabilities that allow for implementation of advanced avionic networked data acquisition systems. System time distribution is supported using either 1588 V1 or V2 on a port -by-port basis, with a global clock sourced from either GPS, IRIG AC/DC, or battery-backed real-time clock and is distributable to all interfaces. TTC switches support managed operation, allowing for dynamic configuration, statistics gathering and health monitoring using Simple Network Management Protocol (SNMP).

sales@ttcdas.com
www.ttcdas.com
267.352.2098

16-Port 10G/1G Airborne Ethernet Switch
NSW-16GT

12-Port Gigabit Airborne Ethernet Switch
NSW-12GT



5-Port Gigabit Airborne Ethernet Switch
NSW-5GT-TGE-2

3-Port 100BASE-T Airborne Ethernet Switch
MNSW-503-1

ADAPTABLE TESTERS

A quiet corner of the world is offering an innovative, flexible approach to vibration and fire testing for aerospace uses

BY MICHAEL THOMPSON

The rolling countryside of County Down in Northern Ireland may seem an unlikely setting for one of the world's newest aerospace propulsion fire test facilities. Tucked away almost within sight of the Irish border, Resonate Testing's new purpose-built facilities are home to a hive of engineering development.

Of course, Northern Ireland is no stranger to aircraft development, with Short Brothers, now part of Bombardier, just 40 miles north and claiming to be one of the earliest commercial aircraft manufacturers having undertaken an order for six Wright Flyers. It is this engineering heritage, which includes a centuries-old shipbuilding industry, from which Resonate draws its strength. With a team of experienced nacelle/propulsion system engineers, recent diversification has led the company into the aerospace testing field and the creation of a new business focused initially on vibration and fire testing.

TESTING GOALS

Early in the planning stage, the staff and management identified two key tasks. First, the company recognized the importance of their testing by gaining accreditation to ISO 17025. The pursuit of this has driven the company from its earliest planning stages.

Vibration testing is possibly better understood and the Japanese manufactured IMV Shaker table was selected due to an extended stroke length, and matched with slip tables using an oil film. Avoidance of conventional bearings and careful selection of test setups enable Resonate Testing to offer higher g levels, over extended periods, in response to trends in the industry, which drives increased reliability enhancement testing.

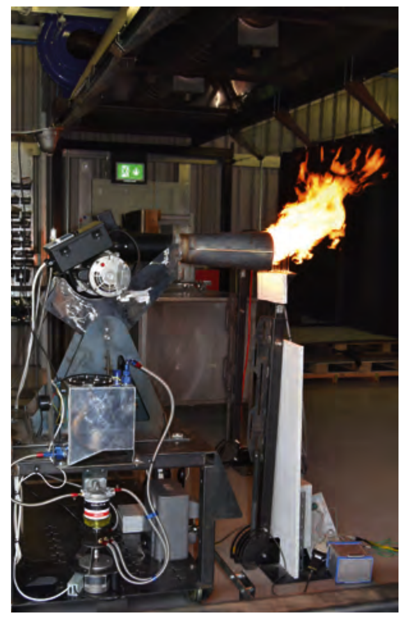
While focused on aerospace, the lab accommodates automotive, energy, medical technology and a range of other industry sectors. Having researched the requirements, targeted the market needs and listened to customers, installation and configuration was a straightforward exercise.

FIRE TESTING LAB

This same approach was taken for the flammability testing, which is undertaken in compliance with mandated horizontal, vertical and 45° burn tests. However, setting up a new fire testing facility, to FAA and EASA propulsion systems standards (both FAR 25 and FAR 33), has provided a much greater challenge to the team. In addition to building a bespoke infrastructure and purchasing the FAA-mandated burner types, the team set about automating key stages of the testing processes and procedures, in compliance with the latest health and safety standards.

From a purpose-built control room, the team remotely controls all aspects of the testing. This includes the key flame calibration sequences mandated by both FAA and EASA. Aerospace should never be a 'trust me' industry.

Resonate Testing can repeatedly demonstrate a stable reliable flame at 2,000°F and 4,500Btu/h (9.3Btu/ft^2/s) across the flame profile, which can be



ABOVE: **Kerosene-based FAA Carlin Burner allows testing within FAR25 and FAR33**

FAA NexGen Burner

proved both pre- and post-test. The preliminary challenge was to work with an array of supply chain partners to identify reliable equipment such as thermocouples for temperature monitoring, a copper calorimeter and Gardon gauge systems to measure BTU, as well as a data acquisition system for data recording and creation of key certification requirements such as a flame map. This equipment is all complemented by multiple high-definition cameras to record progress of every stage of the test. The team has also adopted an approach of adapting what is to hand including a ventilation system recycled (and much improved) from a closed-down restaurant kitchen.

FLEXIBLE AND INNOVATIVE TESTING

The organization's second goal is to be recognized for innovation. Indeed the team's ability to adapt to find solutions was key to successfully completing some early customer challenges when it soon became clear that clients rarely want a standard test. While the steps through calibration must always be accommodated, the actual test conditions vary widely as the UUT is subjected to some of the simulated conditions it could face in operation. So the engineering team at Resonate set about creating a range of innovative fixtures and infrastructure that could be adapted as required to operational parameters. Key among these were rigs, to simulate regulatory vibration inputs, the ability to create, apply and monitor loads, and to simulate required bulkhead pressure differentials and airflows.

ADAPTIVE ENGINEERING

Possibly the most creative solution was found when challenged to simulate an airflow of 300ft/s while maintaining a pressure differential of 8psi, as per the in-flight parameters experienced around the aircraft engines. The first challenge was how to generate the mass flow and pressure. While a compressed air solution was considered to address the need to deliver a specific pressure, the difficulty in realizing the mass flow for an extended period meant that the solution devised by the Resonate team warranted a different approach. So applying some lateral engineering thinking, they bought a 1999 Jaguar Sovereign along with a challenger tank supercharger and set about creating a rig to mount the stripped out 3.2-liter V8 engine plus transmission before connecting it to the supercharger. Arguably it may not be the most elegant-looking solution, however for those who have seen it, the universal response is "cool". Demonstrating the solution is something Resonate takes great pleasure in doing and everybody leaves with a smile on their face. It also proved remarkably effective and reliable in creating the test conditions required.

ABOVE: The custom-built V8/supercharger airflow rig

This adaptable engineering experience is not just applied internally at Resonate as the team has also been working with FAA working groups and other test houses worldwide in the development and improvement of the mandated infrastructures. R&D activities through the latter half of 2016 included bringing forward a paper to the FAA Triennial on *The development of FAA copper tube heat flux calorimeter for parametric study of heat flux calibration*, including comparison of the results for the standard Carlin Gun Burner and proposed NexGen burner. The company will continue to focus on innovation and R&D.

SUMMARY

It has been a important year for Resonate Testing, not least because the new facility only obtained a roof in February 2016. As aircraft development continues apace with the use of new materials and manufacturing techniques, it is critically important that the industry maintains both capacity and engineering flexibility to test new developments, and ensure continued safety in certification for airworthiness. In a quiet part of the Irish countryside, the engineers at Resonate will ensure that these challenges continue to be met. ∎

Michael Thompson is general manager of the Nacelle Group, which incorporates Resonate Testing

HOW TIGHT?

Ultrasonic testing is taking off and special techniques are needed to ensure that maximum advantage is being made of fastener material

BY RON BAKER

Ultrasonic technology to measure load in critical fasteners is accelerating through a period of rapid development based on miniaturization and new software. Composite development and special new fastener designs with rapid tightening machines have spurred interest in the accurate measurement of load and the consequent saving in weight, reliability and cost.

Engineers need to know the lo ad in a bolt as part of the design, a testing program, or as an investigation into why fasteners are loosening. This can be critical in complex assemblies and fatigue analysis. Detailed studies of bolted connections in laminated composite structures have been made using the latest developments in ultrasonic measurement technology.

ABOVE: **Standard measuring box – Intellifast LPTouch – weight 4kg**

LOADING VARIABLES

Time-dependent cyclic loads accentuated by temperature changes and intense vibration require a thoughtful approach to load. Current progress in ultrasonic measurement technology enables more advantage to be taken of the spring effect in a fastener under tension as it clamps the joint members together.

The latest developments in bolt tightening stem from the availability of lighter measuring equipment working at far higher speeds. Measurement speeds of actual loads in a group of 30 fasteners can be simultaneously documented well above 10Hz using the latest multichannel technology. If post-measurement analysis is acceptable, the measurement rate can be increased to 1kHz. Measurement devices weighing only 0.75kg are being used on flight tests. A measurement box weighing 4kg processes, transmits and documents all data, and controls tightening wrenches and tensioners.

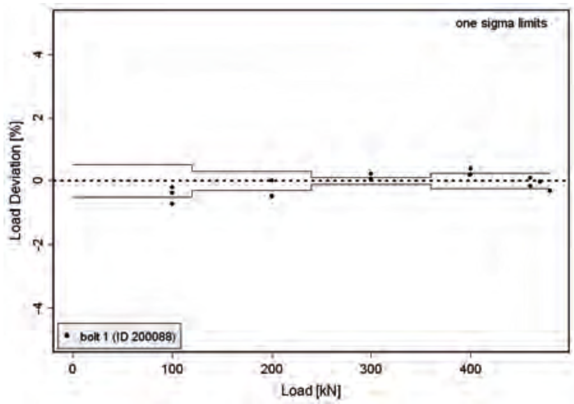
ABOVE: **Assembly of components for space satellite using Intellifast sensors**

A history of pre-loads gives the designer confidence. For many years, trays of fasteners fitted with sensors have equipped companies with basic data on pre-load. Bolt manufacturing and drilling tolerances change with different suppliers and new plating requirements have resulted in greater attention being paid to the joint. Anodizing and similar processes can change the critical coefficient of friction and the tightening procedure.

If searching for the maximum use of the spring characteristic within the shank of the bolt, then ductility and the stiffness of the bolted joint have to be considered. Low stiffness usually means a more resilient spring with better energy storage. A longer bolt will also help. Testing that provides the optimum characteristic requires accurate measurement of bolt load.

TRANSDUCERS AND TESTING

The multichannel system is based on a pack of standard circuit boards each incorporating an FPGA chip mounted in a 19in standard rack with an external switch driven off a laptop and integrated into a datalogger. This arrangement has worked well in the airframe and automotive fields. External loads are applied using hydraulic rams. The resultant documented data can be compared



ABOVE: Wrench displaying load, torque and angle on the handle

ABOVE LEFT: Achieved preload bolt accuracy using Intellifast technology

and important points such as initiation of microcracking investigated.

Experience has been gained in testing systems to failure. Ultrasonic systems have collected data from assemblies under the most arduous conditions of heat, vibration, high gravity accelerations and rapidly changing load. Exposure to salt, sand, grime and engine deposits have not interfered with the ability to take readings. The sensors perform well in engines with coatings of hot oil.

An important benefit of the permanently mounted transducer system is a usual accuracy of ±3%, irrespective of who took the readings. Data is enhanced by using special wrenches displaying the actual load as the torque is applied. They document the tightening process, continuously recording load, torque and angle.

The sensors are normally suitable for use at up to 180°C. For special applications, sensors suitable for temperatures up to 320°C are widely used. The smallest bolt to have sensors fitted was 2.5mm diameter.

Special circuits have been used which will trigger suspension of a test as a bolt is failing. This can have significant savings in both cost and production time as it may make it unnecessary to remove a broken bolt.

Permanently mounted transducer systems overcome the variation in load when a coupling fluid is used between the transducer and the piezo. Different operators can obtain varying loads owing to the way the measuring device is held relative to the piezo.

It is now possible to recognize bolts using laser-readable barcodes and data-matrices which have calibration data to facilitate the measurement of loaded fasteners.

The pace of change in ultrasonics will see new techniques, such as slip rings for measuring rotating parts, move into production and new software availability will improve customer satisfaction. ∎

Ron Baker is a consultant with Intellifast

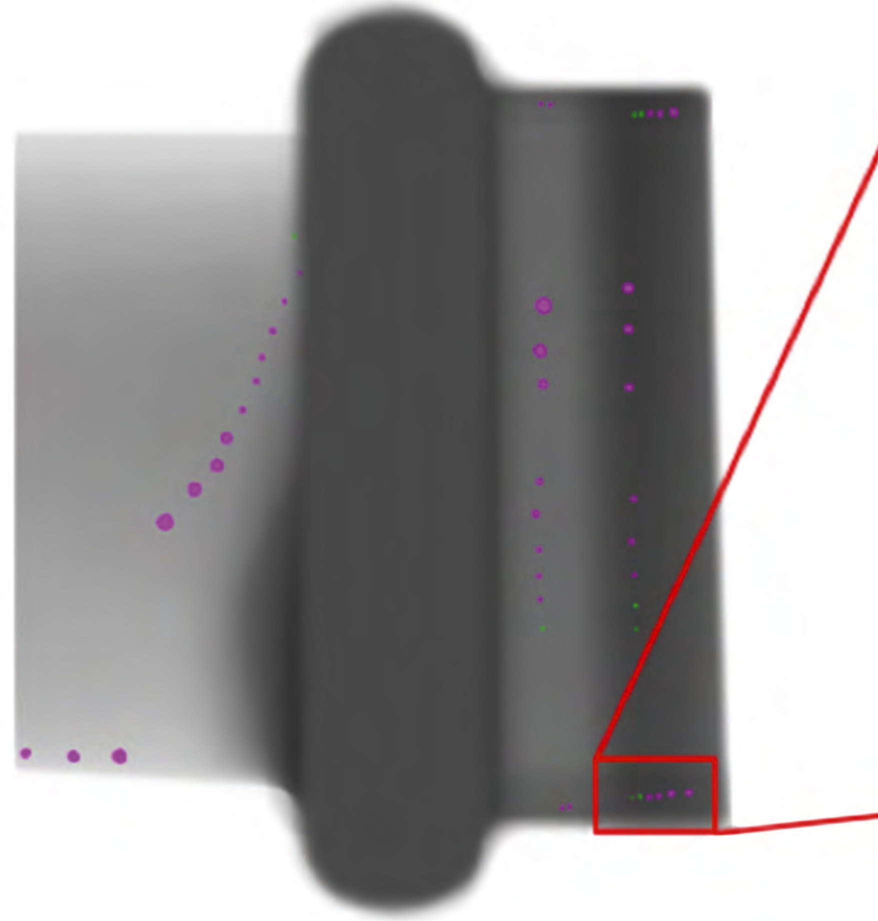
FINDING FLAWS

The aerospace industry can benefit from automatic systems part inspections used in other industries if software and imaging tools are improved

BY JASON ROBBINS AND GINA NAUJOKAT

The US Air Force-sponsored Metals Affordability Initiative (MAI) group is in the midst of implementing automatic or assisted defect recognition (ADR) into the aerospace industry. The goal is to increase the efficiency and reliability of x-ray inspection using automatic software – initially in an assisted mode. Many major aerospace companies are already far along in the evaluation process of ADR technology. Some of them have already begun production implementation. Although the change may be a tough process, the aerospace industry has now realized the immense advantages of ADR in x-ray inspection and has started the implementation.

ADR technology has been used in industrial x-ray inspection for decades in many industries. The first in-line ADR systems for automotive castings were installed over 20 years ago, and this technology is used today – for inspection of wheels, tires, cast parts, raw material, electronics, etc. These systems typically make an 'accept' or 'reject' decision based on the parameters supplied by a quality engineer, and are designed to enable repeatable, reliable, documented results independent of human inspection error. Due to part complexity and more stringent safety requirements, the migration into the aerospace market has been much slower. Now, advanced software and imaging tools provide new opportunities for this industry too.



ABOVE: **A test piece, designed and constructed by Yxlon, has a range of small drilled holes. The inspection criterion was defects of 0.1mm must be detected with a decision threshold of 0.2mm. Magenta spots identify holes detected at 0.2mm and above the required size. These defects could either be rejected automatically or flagged for review in the assisted mode. Green spots are holes detected below the 0.2mm threshold down to the required size**

TRANSITIONING TO ADR

Transition to digital imaging and automation tools is realized over several phases. The process starts with manual inspection where the system stops at every position and the operator evaluates the image and makes a decision, as before. In some cases, the images are automatically acquired and stored for future evaluation. Once the digital imaging and automation has been accepted, and everyone is comfortable with the results, a common next step is semi-automatic or assisted inspection where the system stops at every position, the software marks anomalies based on parameter settings for each view, and an operator makes a decision using this additional information. During this stage, the organization typically uses the data to correlate results with the manual inspection to gain confidence that the software tools are successfully helping operators make better and faster inspection decisions.

The next step is to start operating a supervised automatic inspection. This system typically uses human intervention only if the part has any perceived defects. When the software detects something suspicious, the areas are marked automatically, the operator reviews the images and either confirms the software decision or reclassifies and overrides it. The software can be fine-tuned to the point where an inspector may not be required for a majority of the inspection task. In

many cases this is enough because the ADR software has met the goals of more reliable evaluations, reduced inspection times, and reduced workload for inspectors.

FULL ADR

At this point it also becomes evident if the application is now suitable for fully automatic ADR, where the system is making both the accept and reject decisions automatically without any operator intervention. This mode is a balance between the risk of the system missing an indication and the number of falsely rejected parts. False rejects cost a lot of money, but acceptance of defective parts is not an option, either. To address this, some utilize a remote operator who eliminates false rejects by reviewing all suspect images from a networked PC – especially effective if they supervise several systems.

ACCEPT OR REJECT RATES

Once the automatic inspections have proven equivalence to the approved methods for never accepting a bad part in the first step, it can be fine-tuned to keep the false rejects at a minimum or even zero in some cases in the second step. Current ADR systems can typically detect flaws down to 0.1mm with a minimal depth of approximately 3% of the material thickness with an average 2-5% false reject rate. These values are strongly dependent on the application.

A common defect specification for aluminum automotive parts is 0.5mm at a false reject rate of maximum 4%. The image acquisition and evaluation software is optimized for a very high throughput and low false reject rates and is capable of recognizing, within a certain tolerance, regular structures defined as a reproducible geometric structure. These structures are taught to be accepted by the ADR software. After image optimization and teaching regions of interest with appropriate filters, a false reject rate of even 2% is achievable in many applications. ▮

Jason Robbins is senior product manager aerospace; Gina Naujokat is marketing communication manager for Yxlon International

IMAGE PROCESSING FOR ADR

Acquiring the image is the first and most important step. Selecting the correct imaging chain, with the right calibration and spatial resolution is critical. Choosing the correct magnification and integration time will define the detectability of the smallest defects. All of the details regarding focal spot size, energy, detector type, pixel pitch, scintillator material, geometry, integration time, etc, must be optimized for these types of critical inspections.

Filtering the images allows the software to take advantage of the 16bit images and find the smallest details. The filters are specific to the inspection tasks, and are designed to detect specific features. Many defects that are difficult or even unable to be seen by the human eye can be automatically identified.

After filtering, the images are further processed for visualization and classification purposes with the help of intelligent binarization. Filtering and processing also includes eliminating edge artifacts and pseudo-defects not inherent to the image that cause false rejects.

In addition to detecting defects or anomalies, the ADR software must also classify the flaws. There are many different categories and types of flaws, and each application has different requirements for accepting or rejecting the parts. Examples for classification criteria are porosities, inclusions, flaw density and flaw distances.

MORE RESULTS WITH LESS

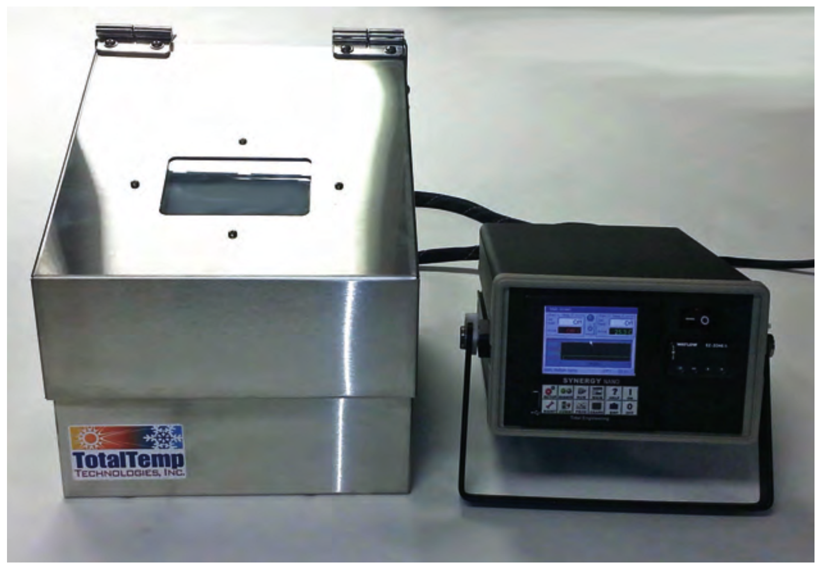
A unique range of thermal test equipment increases accuracy and efficiency across several requirements

BY JOHN A BOOHER

Thermal environmental testing has been a big concern in electronics since the early days and, like most processes, it must evolve to become cheaper, more effective, take less precious time and lab space, and be more resource efficient in general. Testing began with large and expensive temperature chambers that, for many reasons, often failed to produce effective results. Users complained that primitive controls did not provide easy programmability or good verification results. The first chambers used were sometimes too large for the specific application or the space available, or too slow, or the airflow they provided was either too much or not enough. Finally, there was often no understanding of what the utility, manpower or maintenance costs might run to.

Controllers have developed to become more sophisticated. Advanced temperature control algorithms that monitor device temperature and air temperature have evolved, as has the ability to easily automate the process with optimum ramp rates, provide notifications of exceptions and test status, and log results to a printed file. All of these processes are now easily accomplished. Automation saves tremendous amounts of time and can offer automated reports showing consistent results.

There are now many kinds of temperature chambers and many sizes, including those cooled with closed cycle refrigeration systems and those with expendable cryogenic refrigerants such as liquid nitrogen. With a better understanding, it is now not difficult to select an appropriate chamber or thermal platform with the right size and cooling method, and generally at a more affordable price.



ABOVE: Hybrid benchtop chambers combine the benefits of a thermal platform with those of a small benchtop unit

THERMAL PLATFORMS

Many devices to be tested have a flat thermally conductive surface that often makes them more suitable for testing on a thermal platform. Due to their speed, benchtop accessibility and efficiency, thermal platforms have gained considerable acceptance in testing microwave and other electronic and power modules.

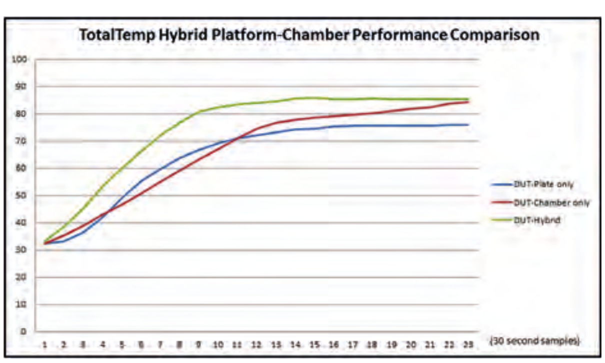
A limitation of thermal platforms is the ability to control thermal gradients that exist from the platform to the top of a relatively tall device under test. For smaller modules this problem is not important, but for larger – and particularly taller – devices, gradients can be an issue. Platform covers and thermally conditioned purge systems are effective and are often used to reduce the gradients when tested with thermal platforms.

The best way to gain the speed and efficiency of a thermal platform while achieving reduced thermal gradients is to combine a thermal platform and a temperature chamber into one system.

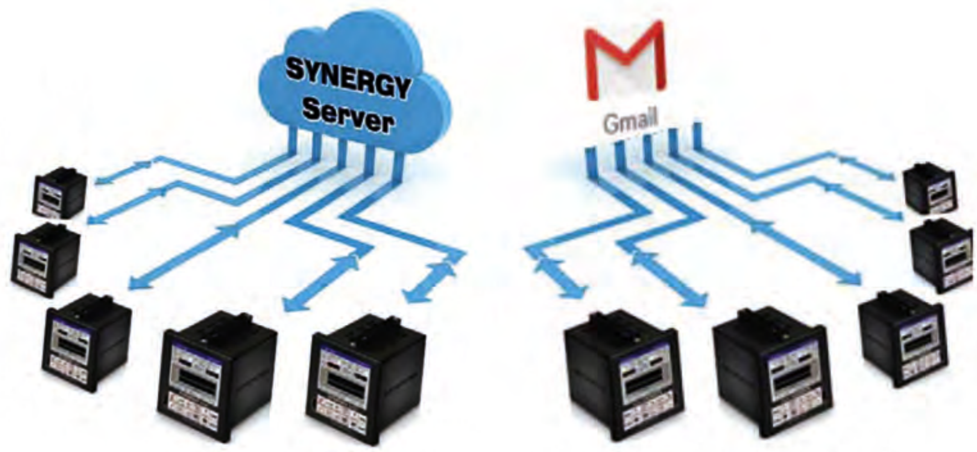
THE COMBINATION SOLUTION

Combining convection and conductive temperature controls has proved quite effective in producing rapid, repeatable results in a small benchtop chamber. Testing time can be half that required when using a thermal platform alone, the latter already substantially faster than testing in a temperature chamber.

The ability to control the air and thermal platform temperatures independently or together while monitoring selected points on the devices provides real results in terms of speed and efficiency, and the ability to rapidly produce automated printouts or verification of results. The hybrid benchtop chamber is a flexible wide-



LEFT: A hybrid benchtop chamber (green line) produces results



range system for optimizing thermal testing solutions.

REPORTING AND CONNECTIVITY

The Synergy Nano controller can produce custom printouts, making it easy to verify optimal performance. It also has numerous automation features, such as a general purpose interface bus (GPIB), serial communication, Ethernet email/text message reporting and FTP connectivity, which makes managing test systems far more cost effective. The contextual front panel helps reduce the need to refer to documentation.

Synergy server software coordinates result from network connected thermal platforms or chambers with a cloud based server. This gives flexible access for collaboration with substantial cost savings using Gmail and Google Drive cloud storage.

TotalTemp offers a wide range of solutions that help the test engineer set up and perform meaningful tests, and increase accuracy and efficiency with a variety of easy-to-use automation features and functionality. The experts at TotalTemp are happy to help clients in the selection of the best products to meet their requirements, at an affordable price. TotalTemp understands the trade-offs between types of coolant and system capacities, and the team is happy to consult with customers regarding standard or custom solutions. ∎

ABOVE: Synergy Nano produces printed PDF results via a network connected printer

John Booher is the chief technical officer at TotalTemp Technologies

TotalTemp
TECHNOLOGIES, INC.

TotalTemp offers new advancements in thermal testing with conductive heat transfer and easy to use automation features

Efficient, fast accessible temperature cycling on a thermal platform just got cooler.

❯Wide range Standard and custom solutions, typical range -100˚C to +200˚C.

❯**Many automation solutions:** GPIB, Serial, USB, FTP, LabVIEW drivers, multi zone capabilities, direct network printing, email/text messaging, Cloud server capabilities, flexible inputs and outputs, Retrofits to other brands

❯**New:** Innovative Hybrid Benchtop Chamber brings more speed and gradient control to thermal platform designs.

TotalTemp Technologies
San Diego, CA
888.712.2228

Sales@totalTempTech.com ▪ www.TotalTempTech.com ▪ @totaltemp

RECORDING TOMORROW

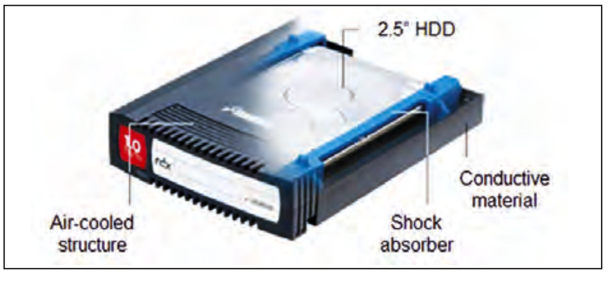
Knowing what test engineers require in a data recorder has influenced the ongoing development of recording solutions

BY MICHAEL SCHWEIGART

ABOVE: The WX-7000 main unit, shown with 16 channels, is configurable to 128 channels using eight 16-channel input/output cards

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.



LEFT: Data is stored on an RDX server-grade removable disk

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 and uses 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.

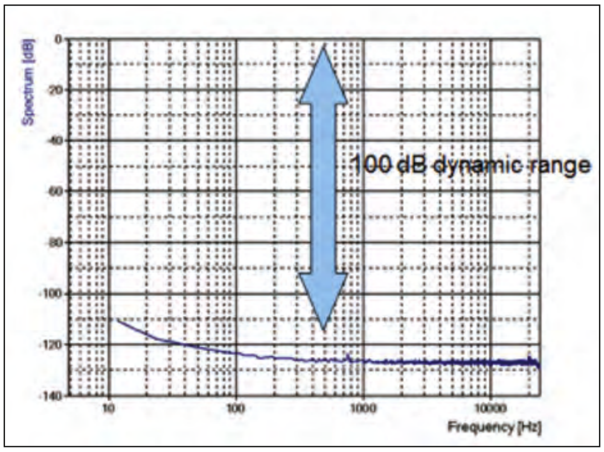
APPLICATIONS

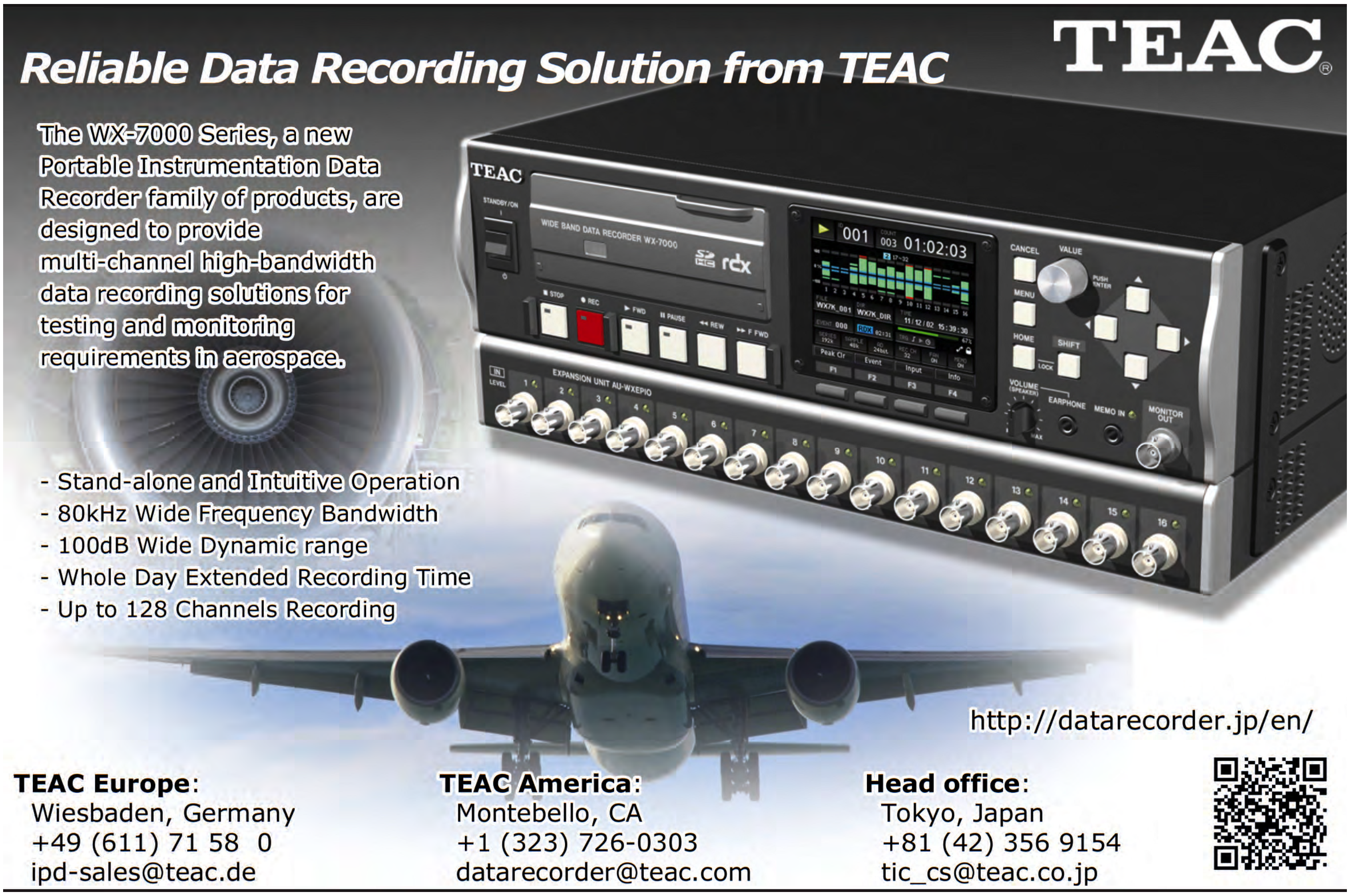
TEAC WX-7000 data recorders have been used for developing the Japanese LE-X rocket engine. Vibration testing and analysis is one of the most important parts of development. If levels exceed certain thresholds, vibrations might lead to decreased engine efficiency and damage. The test data collected can 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 considerable time and cost involved in this kind of testing requires 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. ∎

Michael Schweigart is division manager with TEAC Europe

BELOW: The dynamic range of the WX-7000 is over 100dB





FLEXIBLE UT INSPECTION

Ultrasonic testing is one of the most effective ways to validate the integrity of aerospace composites

BY SAM H SERHAN

ABOVE: A squirter gantry uses a water jet for ultrasonic testing

The introduction of automated ultrasonic testing for aerospace composites has benefited the non-destructive testing (NDT) field through increased inspection speed, imaging capabilities and repeatability. The issue with testing these unique and exotic materials is primarily due to their shape. NDT is by far the most efficient way to have advanced testing on complex components, and with automated systems it creates an added value due to highly repeatable inspections. The problem is this requires exceptionally capable NDT system hardware, electronics and software which guarantee inspection speed, reliability and repeatability.

Manual or conventional testing techniques are impractical or simply impossible in the case of complex composite parts or structures. This article discusses the generalities of using automated UT systems for composite materials designed for aerospace component testing.

AUTOMATED UT SYSTEMS

For those unfamiliar with NDT, UT involves the propagation of ultrasonic waves into the subject being tested. The frequencies used for standard UT testing can range between 0.5MHz and 25MHz, while select TecScan products can easily go up to 50MHz. Most often the couplant used which facilitates the transmission of ultrasonic energy from the transducer into the test specimen is simply water. This can be done through water jet (squirter) or immersion style testing.

Some of the solutions for automated testing include UT immersion, squirter gantry, phased array, robotic arms and more. Immersion systems are used for ultrasonic testing and detection of flaws in both metallic and composite materials. These systems are usually designed with highly accurate actuators, servo or stepper motors, and optical encoder modules, making them ideal tools for real-time signal acquisition during the axes movement. They also provide automation with increased inspection speed, real-time signal processing, imaging capabilities and scanning repeatability.

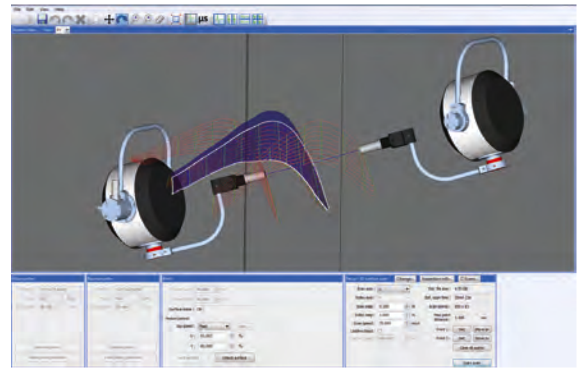
Ultrasonic C-scan and tomography are achieved using these automated systems by performing a raster scan on the inspected samples with appropriate ultrasonic transducers. Specifically, immersion scanners designed or retrofitted for 3D scanning applications perform at higher speeds and are well suited for the inspection of complex and curved parts by using contour-following features and/or full 3D scanning techniques.

Squirter gantries are most commonly offered in two configurations: a 9-axis system with a single bridge, or a 10-axis system with independent X-axis bridges. The 9-axis gantry system is best suited for larger parts with less complex geometries, whereas the 10-axis system is well suited for 3D scans of complex parts. Gantry systems can also be custom designed to meet clients' needs if necessary. Inspection can be conducted in through-transmission and pulse-echo from each side simultaneously.

Some of the modern articulated arm robots are believed to have appropriate characteristics to be used for automated NDT systems. More recently, and in order to increase productivity, a growing interest in robotic solutions was reported within the aerospace sector. However, despite these efforts, several inspection factors and design challenges need to be addressed to achieve robotic solutions for automated UT testing with reliable positional accuracy and repeatability performance capabilities.

NDT SOFTWARE

Due to the complex nature of composite parts and structures, the NDT software involved is much more complicated especially since many of these structures are geometrically unique, a common phenomenon in



aerospace. This begs the question: How can we use automated systems with generic motion control tools to scan something very specific?

TecView 3D, for example, is an NDT software with advanced data acquisition and control capabilities. It allows the scanners to achieve arbitrary motions and also performs path planning in order to follow all the contoured shapes that need to be scanned. This NDT technique is a complex and demanding feature for any software and electronics available today. There are multiple ways to set up scan plans such as: 'teach and learn' of parts that are slightly curved or axially symmetrical; or CAD import capabilities for full 3D inspections. Complex shaped parts can be scanned with a single probe, or an array probe.

ABOVE: An automated immersion UT system for aerospace parts

ABOVE RIGHT: NDT software with advanced 3D and CAD tools

SOUND ANALYSIS

Another common challenge with the testing of aerospace composite materials, which is also geometry dependent, is the variation of wave attenuation. These variations in the wave attenuation make 3D data analysis more difficult. Data manipulation and display modules need to be optimized for multiple computer processors and designed to handle large amounts of data.

Due to the required high-precision 3D scans, the collected data will result in large file sizes. Therefore to interpret the data correctly, we must ensure we have proper data position information, as well as the ultrasonic analysis tools in order to quantify defects correctly.

As we enter a new age of composite material manufacturing, not only in the aerospace industry but in all industries, faster, more accurate and especially more flexible automated UT systems with advanced inspection tools will be needed. ∎

Sam H Serhan is president of TecScan

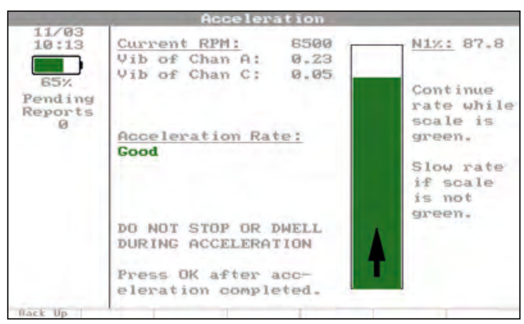
TIME SAVER

The technique of transient balance saves money by reducing the overall duration of the fan-balance process. A battery-operated analyzer incorporating this method is now available to flight line technicians, reducing diagnostic and engine run time, customer returns and recurring noise complaints

BY JOHN WILSON

The aerospace industry has long recognized the benefits of reducing engine vibration on aircraft, among them increased passenger comfort, less cabin noise, and a smoother ride. This has led to fan trim balance becoming a common maintenance practice in the test cell and on wing. Over time, automation of the process has made the job simpler for the A&P mechanic [aircraft maintenance technician], but it can still be a time-intensive task, requiring dwells at specific speed points.

The transient balance technique is an improved method of automating fan balancing through monitoring vibration at all engine speeds during a balance run. This automation removes the need to manually select and dwell at specific speed points. Another advantage is that the maintenance technician is no longer required to refer to a vibration survey to locate changing vibration levels because the entire range of speeds is monitored during the balance job. Transient balance also prevents the embarrassing occurrence of releasing an engine that passes vibration limits at one speed but which exceeds them at others.



ABOVE: ACES Systems' Viper II offers the transient balance technique

LEFT: For testing, a technician accelerates the engine, without stopping it, across the operating range

THE TRIM BALANCING STORY

Early fan balance jobs were typically done at a single steady-state engine speed. Fans had more narrow chords relative to the fan diameter than they do today, and the weight was placed on the fan disc. Over the years, the fan balancing process was simplified by moving the weight placement forward and adding washers to the spinner or using different length spinner attachment bolts. This simplified the process of fan balancing, but also moved forward the balance weight of the fan.

To improve efficiencies, engine manufacturers have adopted wide-chord fan blades. That is, the blades have more depth when looking into the engine and are more three-dimensional than before. This makes the process of fan balancing more difficult because the dynamics of the fan and the engine have become much more complicated. This manifests itself on some fans when the fan is balanced at selected speeds and then fails at other speeds. Multispeed balancing can address this if it is clear where the new imbalance will pop up. The challenge lies in not knowing this until the balance job begins. These balances reduce the vibration at a particular speed but leave other speeds uncorrected.

As balancing evolved, manufacturers began to recommend balancing at several different speeds. This complicated the process, requiring the user to perform a vibration survey, review the results and select the engine speeds where the vibrations looked highest. This largely manual process took time and did not address the shifting vibration response of the typical engine. On subsequent runs, it was possible that the original speed selections no longer contained the largest vibration peaks – those peaks may have moved to new engine speeds. This forced the technician either to run a new vibration survey to locate the new peaks and continue to try to manually reduce the vibration across shifting peaks throughout a wide engine speed range, or to release an engine that still had annoying noise signatures within the operational range of the engine.

BENEFITS OF TRANSIENT BALANCING

Today, using the transient balance technique incorporated in the ACES Systems Viper II, the technician only has to accelerate the engine across its entire operating range and follow the analyzer's recommended solutions. These solutions are derived by monitoring the changing conditions in the engine and eliminate the highest vibration peaks found on every run. The analyzer will search and eliminate multiple peaks in up to 300 'bins' during every balance run.

DATA COLLECTION

The actual data collection time is reduced relative to the multispeed balance method where vibration data is collected at multiple discrete speed points. In the multispeed method it is critical that every balance run returns to the same speed point. The technician must adjust speeds slowly to match the desired speed points, taking time and effort. Once the speed point is reached, data is typically collected for about 30 seconds before moving onto the next required speed. This is about a minute of fuel use per speed point measured. Larger engines will require a multispeed balancing using nine speeds, or approximately nine minutes of fuel consumption per balance run. Assuming this complicated job is completed with three runs, 27 minutes of fuel have been burned just in collecting data.

With transient balance, the data is collected during a slow sweep over the speed range of interest, taking between one and three minutes. For the same three-run balance job, the data collection time is only nine minutes. This is a 67% reduction in data acquisition time.

CONCLUSION

Transient balance saves time by reducing technician time searching for vibration peaks, reducing run time and eliminating long-duration stabilization at individual speed settings. It removes testing at non-problem engine speeds (focusing only on the problems), and reduces the need for a separate vibration survey to display the final fan vibration peaks. With the ACES Viper II, a survey is produced with every run and displayed in a final report generated by the analyzer that can be exported directly to PDF. ∎

John Wilson is executive VP of engineering with Technology for Energy Corporation

LOOP TEST SYSTEM

In any aircraft there are thousands of bonding points and ground circuits, which all need to be tested to ensure a low resistance path

BY JASON EVANS

Civil or military, rotary- or fixed-wing, aircraft are complex assemblies of mechanical and electrical components. Sound electrical bonding is critical in ensuring the safety of aircraft and passengers and that all control and communication systems operate reliably. The requirement and methods for correct, reliable and validated electrical bonding were established as far back as 1949 in MIL-B-5087, and have since been reconfirmed by numerous industry and OEM specifications.

Bonding requirements as defined by the majority of aerospace OEMs and industry specifications generally fall into the following five categories:

Current return: The bonding circuit is required to intentionally carry power current through the aircraft structure. The required resistance value of each bond in the current return circuit varies depending on the current that the circuit might carry, but can commonly be as low as 0.05mΩ.

Shock hazard: The bonding circuit is designed to carry fault current caused by a short-circuit fault to structure or equipment. Individual joint resistances here would not normally exceed 0.1mΩ.

Static charge: Here, the bonding elements ensure effective grounding of any items subject to electrostatic charging.

Lightning strike protection system: The bonding circuit is required to safely carry the current resulting from lightning strike through the aircraft structure to a safe exit point. Resistances as low as 0.002mΩ per joint are often specified.

RF systems: Applying to equipment and systems that could generate, retransmit, or be susceptible to RF. Typical maximum resistance values per joint here would be 2.5mΩ.

The elements that make up the bonding circuit are a combination of aerostructure sections, flight equipment housings/casing, cable harness shields, piping systems and bond straps. In short, these elements combine to provide a low resistance or low impedance path through which current can safely be carried. It is this combination that makes the design, control and validation of the bonding circuit so important. A single high-resistance joint in a circuit is all it takes to render a lightning strike protection circuit useless – worse than that, the single high-resistance joint becomes the focus of up to 200kA of lightning strike current trying to escape, which can lead to catastrophe. A single loose bonding connection can cause the system's HIRF protection to fail, or high current to flash across the high-resistance joint in the current return circuit.

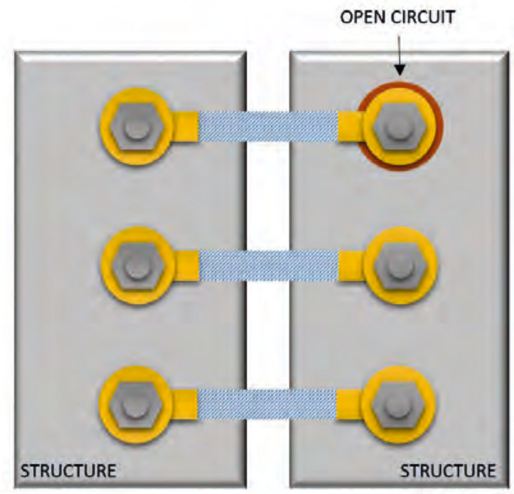


FIGURE 1: Two sections of aircraft structure are connected by a series of bonding straps. One of the bonding points has been badly assembled and is in fact an open circuit

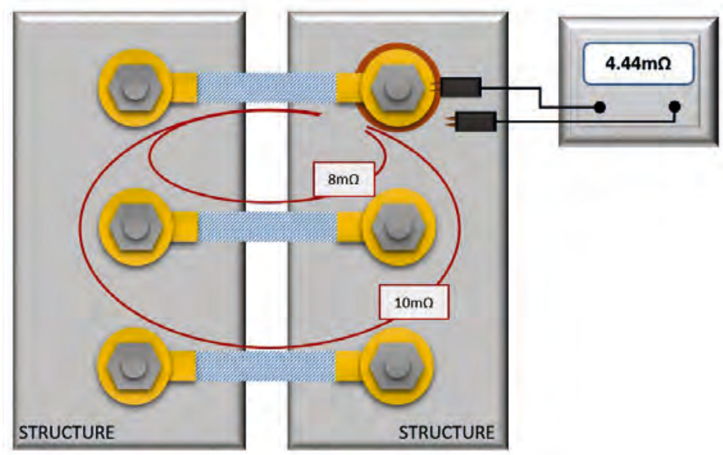


FIGURE 2: The measured resistance across the open circuit is 4.44mΩ

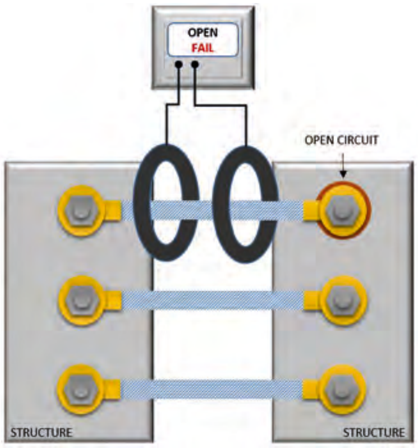
HOW CAN IT GO WRONG?

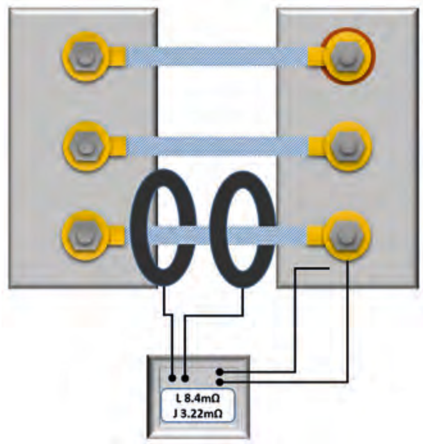
High-resistance bonds can be caused by surface contamination, bonding surfaces being incorrectly prepared, missing components, faulty materials, loose crimps, loose ring terminals, or incorrectly rated bonding straps. The list goes on. How we identify these bad bonding instances and stop them being integrated into aircraft is by implementing correct testing instrumentation and methods.

Simple electrical bonds between two discrete elements are relatively straightforward to test. Applying the Kelvin measurement principle, purpose-designed bond meters will cause a current to flow between the two elements, measure the volt drop across the bond, and report the resistance. Resistance values down to micro-ohms are accurately measured in this way. However, this method is not suitable when it comes to testing circuits containing parallel paths and here we frequently witness incorrect test methods.

Consider the example above (Figure 1). The two sections of aircraft structure are connected by a series of bonding straps. This figure also represents any structure with multiple parallel resistance paths. For ease of illustration, one of the bonding points has been badly assembled and is in fact an open circuit.

If this assembly is tested using the described bonding meter, the parallel resistance paths allow the current to flow between the meter's probes





(Figure 2). The volt drop is measured, but that volt drop is through the parallel bond straps. The resulting measured resistance is a sum of the parallel resistance paths. The measured resistance across the open circuit is 4.44mΩ. The requirement is <5mΩ, and the test passes.

Lightning strike current flowing through this system will arrive at the open circuit or high-resistance joint, and a massive amount of energy or power attempts to force up to 200kA across the joint. The results can be catastrophic.

The answer is to test the bonding loops with a purpose-designed loop test system (Figure 3). This technique involves injecting a current into the loop using current clamps. The current that is injected is then measured as it flows through the loop, the voltage required to cause the current to flow is monitored, and the impedance of the loop calculated. Phase correction is applied to isolate the resistive element, and to report the resistance of each individual loop. In the example (Figure 3), the loop test system would report the loop to be an open circuit.

In addition, MK Test Systems' Bond and Loop Resistance Test (BLRT) system includes a joint test capability that enables the resistance of each joint within the loop to be accurately measured, allowing the system to indicate which joints may be causing the high resistance and giving indication of imbalance or marginal passes that should be addressed.

Supplied to Airbus, Boeing, Spirit, GKN and Rolls-Royce, the BLRT and BLTU's integrated computer and test management software allows test sequences to be downloaded, operators to be guided through the test process, and automatic logging and recording of results, improving fault capture and test efficiency, as well as enabling the monitoring of through-life degradation of bond test resistances. ▮

FIGURE 3: **Loop test measures loop resistance of parallel circuits**

FIGURE 4: **Loop and joint test enables measurement of individual joints in loop**

Jason Evans is a director at MK Test Systems Limited, based in the UK

MULTISKILLED INSPECTIONS

Automated and assisted portable NDT tools with networking abilities are essential for making sure in-service aircraft are ready to fly

BY VINCENT BISSAUGE

ABOVE: **D-lamTool is an example of a monolithic fully automated phased-array device for delamination assessment**

As air traffic levels are rapidly expanding, airlines and maintenance, repair and overhaul (MRO) centers need greater efficiency and flexibility to perform their tasks. NDT inspections are in the spotlight as this activity requires multi-skilled and qualified personnel using a vast set of equipment to perform time-consuming operations. To meet these needs, equipment manufacturers are including recent technology developments into new solutions for service providers.

SMARTER, MORE CAPABLE

The first target is the rationalization of equipment by increasing its versatility and portability. The second objective is to ensure connectivity of the devices to enable links between a user and database or remote expert. Finally, step-by-step embedded procedures or traffic-light user-interfaces allow mid-qualified personnel to make faster inspections for specific applications.

The constant increase in the power of CPUs allows using tablets combined with miniaturized NDT electronic devices (eddy current, ultrasound, infra-red, assisted visual, etc) to provide lightweight and versatile equipment. At the extreme end, the market now has eddy current chips or even a phased-array electronic device embedded inside the sensor itself, or battery-powered digital x-ray solutions embedded in a backpack.

Other products, for example the Smart UE1 from Testia, contain multi-method technologies and can by themselves replace three to five conventional devices for inspecting by ultrasound, eddy current or resonance. Thanks to a standard computer core, Smart UE1 supports USB devices such as infrared cameras, basic endoscopes, and even augmented reality solutions.

CONNECTIVITY UPS PRODUCTIVITY

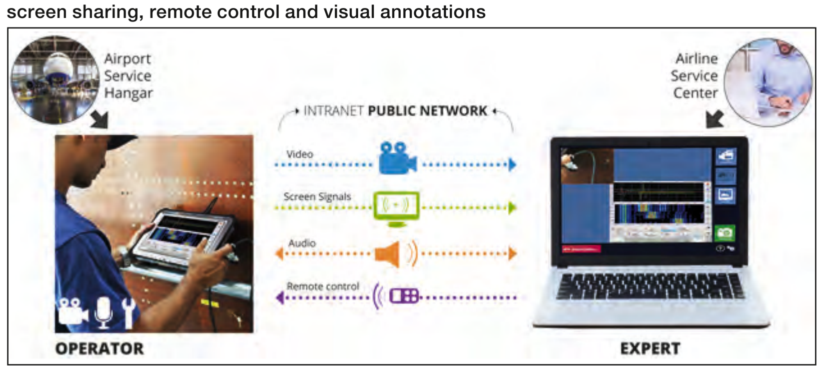
The integration of an off-the-shelf device with connectivity features such as Bluetooth, wi-fi and RFID opens new possibilities for NDT applications. The first advantage for users is continuous access to a common database. It makes the NDT processes paperless, as well as providing fast and direct access to up-to-date technical documentation, from the interface of the NDT device. The second advantage is online remote assistance. One remote expert is able to support several mobile operators across the world, with visual indications, controlling the device remotely to optimize the parameters or even sending more data.

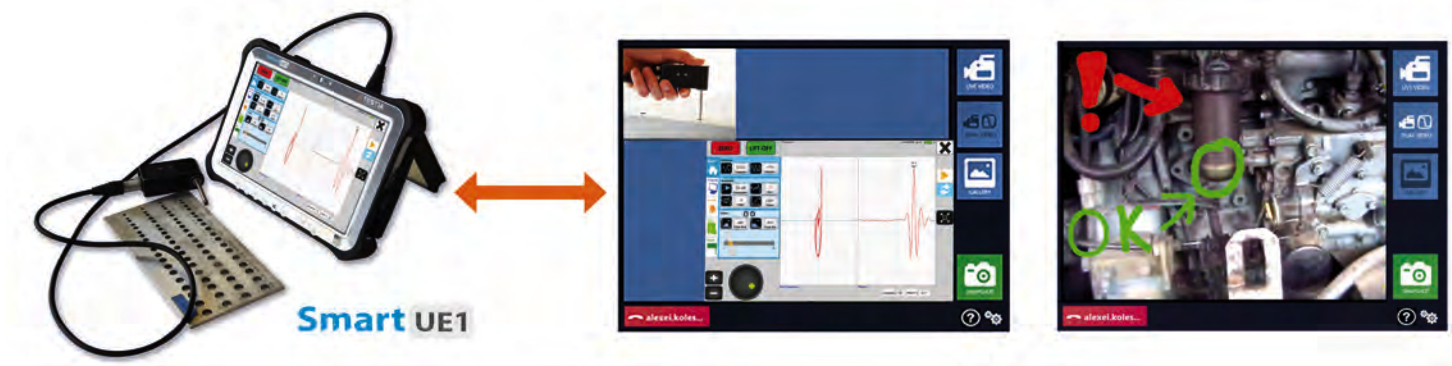
While maximum flexibility is obtained with versatile and connected tools, the efficiency of these devices is also increased by the automation of some of the NDT tasks. Depending on the complexity of the inspection procedure and the reliability of the process, various approaches are possible. A first level of automation is the guidance of the user to perform the different steps of inspection, from calibration to analysis. This assistance is available on a number of new products already on the market, among which are Testia's ThicknessTool and CladTool devices.

CAPABLE BUT EASY TO USE

The next level of automation is the extreme simplification of a complex

BELOW AND OPPOSITE PAGE: **The online maintenance assistance (OMA) application is fully compatible with Testia's Smart NDT tools, and provides remote help tools such as screen sharing, remote control and visual annotations**





system dedicated to one application by embedding it in a monolithic tool, without any access to the user to parameter setting or calibration, with the purpose of it being used by a non-specialist. In airports, maintenance centers, or on assembly lines, this is commonly carried out with the use of the LineTool or D-lamTool, which is a full phased-array detection system embedded to detect delamination after impact on the A350 composite skin. The automatic 'go/no-go' diagnosis given by the tool enables airlines to carry out their own preliminary assessment, before possibly calling upon an NDT specialist for further diagnosis if a defect is detected.

ARTIFICIAL INTELLIGENCE

Future automation progress for NDT relies on implementing artificial intelligence (AI) into systems. Thanks to automatic adaptation and learning, this evolution will lead to monitoring the quality of data acquisition and will be able to run complex analysis, usually performed by specialists. Airbus Group Innovations labs are developing applications for automatic sizing of impact damages by UT phased-array on complex composite structures with various thicknesses, stringers bonded on the backwall, etc. The system first checks and calibrates itself, then monitors in real time the acquired data acquisition stream and the quality of the coupling. The strength of this system is its ability to distinguish delaminations not only from the rules described by the technician, but also by self-teaching itself via hundreds of real cases.

The aerospace non-destructive testing world relies on new technologies, particularly miniaturization, the internet and artificial intelligence, which are trying to fulfill MROs' and airlines' needs. This evolution will lead to new portable tools that are customizable, connected and smart. ∎

Vincent Bissauge is a technical sales engineer with Testia

CONFIGURABLE ROBOTIC NDT

Advances in aeronautical non-destructive testing include new ultrasonic techniques and configurable robot-controlled testing

BY ESMERALDA CUEVAS AND MIGUEL TORRES

ABOVE: The robotic inspection system at Tecnatom's robot-based automated C-Scan system

Non-destructive testing (NDT) techniques for aerospace applications are improving as rapidly as the technology allows. The increasing use of composites, new materials and geometries makes it necessary to innovate with NDT. In particular, ultrasound (UT), from conventional piezoelectric transducers to phased-array technology, allows the generation of easily controlled and configurable sound beams, enabling the use of a multi-elements matrix of probes that can be electronically triggered. Popular UT techniques such as pulse-echo (PE) and through transmission ultrasonic (TTU) have been extended further by innovations such as laser ultrasonic testing and air-coupled ultrasound.

Repeatability, traceability, recording, independence of the operator and optimization of the inspection times are the main requirements for non-destructive testing of aeronautical components. Compared with manual or semi-manual techniques, automatic inspection offers better capabilities.

ROBOTS AND SIMULTANEOUS NDT

Tecnatom identified long ago the advantages of using industrial robots for NDT and collaborated with Kuka Robotics to create an automated, integrated and industrial NDT platform using industrial robots and specific UT products to serve the aircraft manufacturing industry. Robotic-based systems based on Tecnatom's platform ensure inspections with accuracy and reliability, and in maintenance they help with maintaining aircraft availability.

An important advantage of a robot-based solution is its flexibility to be adapted to simultaneous multiple techniques (for example, PE, TTU) by adopting different inspection areas in a single inspection layout within limited factory space.

At Tecnatom's plant different systems are under construction to provide a variety of solutions, such as a single robot-over-track with yoke configuration, which allows simultaneous PE and TTU. Another single-robot system has a turntable using air-coupling UT techniques.

Tecnatom has a complete suite of technologies for aeronautical parts inspection, including elements designed and manufactured in-house (electronics to acquisition/evaluation software), which provide an integrated capability for NDT.

HIGH DYNAMIC RANGE TTU

Components that show a high attenuation to sound – those with great thicknesses, foams or honeycombs, sandwiches or multilayers – are still a major challenge for the application of TTU. Sometimes no water can be used during inspections. Then air-coupled ultrasonics are a good solution, but the electronics used for the generation and acquisition of the ultrasonic signal have to ensure good signal quality.

Tecnatom has developed the Sonia family of ultrasonic high dynamic range modules for applications of TTU. Compared with conventional units, Tecnatom's electronic modules offer improved results with gains in resolution and quality of the signal, greater signal-to-noise ratio and better reliability in detecting defects.

RIGHT: Tecnatom's Sonia family of ultrasonic electronics modules

FULL PROCESS SOFTWARE

InspectView is Tecnatom's software suite for the entire NDT inspection process, from definition and planning, trajectory calculation, machine movements control and calibration to acquisition, evaluation and report generation. The process is integrated, from the definition of the inspection part to the evaluation of the acquisition data, as is machine control. All the aspects of the system are managed by one application – the same for all the ultrasonic techniques and the different electronics that might be used (such as for phased array and for conventional ultrasound).

The inspection overview begins with part geometry acquisition. InspectView supports direct import of CAD files, or geometry can be reconstructed by the Falcom 3D laser tracker, if the CAD file is not available or the part does not correspond completely with drawing, due to deformations in the part using the rototranslation feature or 'three-point correction'.

From known geometry, Tecnatom's Gentray 3 software generates the automatic inspection trajectories, ensuring 100% surface coverage including aerodynamic faces, edges and windows, and a simulation of robot movements, collision checking and trajectory feasibility.

Gentray 3, designed and developed by Tecnatom, is also used for coverage inspection estimations.

SUMMARY

Use of robotics with advanced ultrasonic techniques is a good solution for inspection of complex parts and those that cannot be contaminated. It increases productivity and the quality of manufacturing. ▮

Esmeralda Cuevas is aeronautical NDT techniques head and Miguel Torres is in business development with Tecnatom

CONFORM BEFORE SIGNING

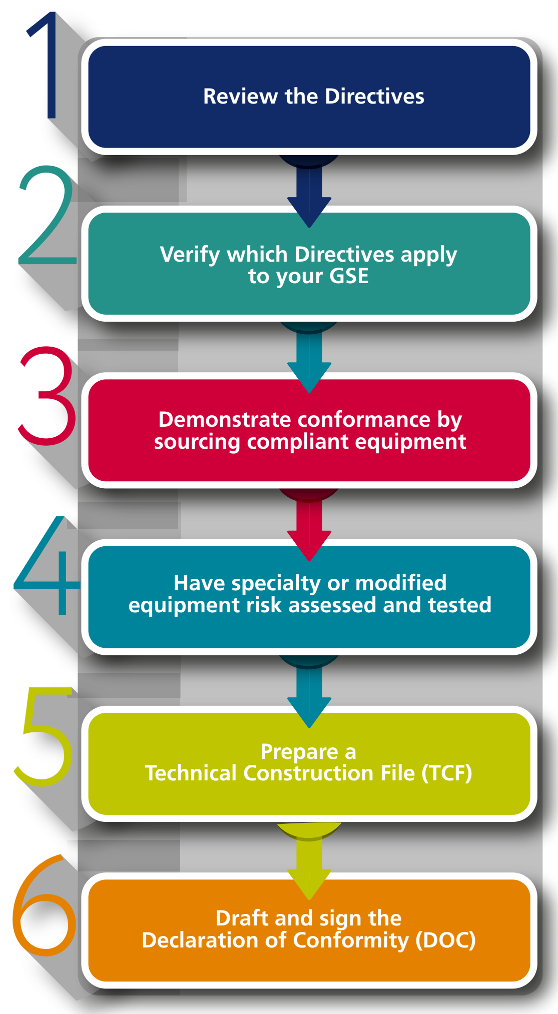
When importing ground support equipment into the European Union, there are six sometimes overlooked laws to consider before signing a Declaration of Conformity

BY ERIK REYNOLDS

With the scrutiny that surrounds aircraft certification for the European Union, ground support equipment (GSE) can be overlooked. Not only is GSE subject to EU directives, but there is also personal liability attached if one fails to sign a Declaration of Conformity when required to do so.

The EU directives cover product safety for a broad range of products and equipment. The onus is on the importer to determine which ones apply, how they apply, and to conduct due diligence to demonstrate compliance. The Declaration of Conformity serves as the legal basis for the claim of compliance to all applicable CE (Conformité Européenne) marking directives. Table 1 shows some common ground support equipment and a sampling of the directives that may apply. Others may also apply depending on the type of equipment and its end use.

Remember the directives are EU law – non-compliance is not a minor infraction. There are provisions for business fines and potential imprisonment for individuals. The following directives are applicable to some common types of GSE.



RIGHT: A flow chart for complying with directives which may be applicable for ground service equipment being imported to the EU

PRESSURE EQUIPMENT DIRECTIVE

GSE containing pressures over half a bar need to be considered carefully. Perhaps it has an air compressor, a torque testing kit, or other pressure vessels. If so, then the relevance of the Pressure Equipment Directive (PED) 97/23/EC, applicable to pressurized equipment placed on the market in Europe for the first time, should be carefully considered.

Four hazard categories could apply and each has specific requirements in order to bear the CE mark.

MACHINERY DIRECTIVE

If the GSE has moving equipment, lifting apparatus or machinery such as an air compressor or a start cart, then the Machinery Directive (MD) 2006/42/EC may apply.

A risk assessment according to a consensus standard (such as ISO 12100:2010) is also strongly recommended in addition to testing to harmonized standards. Both approaches should address the personal protective equipment, electrical safety, guarding, lifting, ergonomics, noise and control systems required to use the equipment.

LOW VOLTAGE DIRECTIVE

Equipment using voltages between 50V and 1,000V AC or 75V and 1,500V DC should be considered as falling under the Low Voltage Directive (LVD) 2006/95/EC, whose harmonized standards are essential to demonstrating compliance to the health and safety requirements. The LVD usually applies to communications, diagnostic and computing equipment.

ELECTROMAGNETIC COMPATIBILITY

All equipment producing an electromagnetic field or potentially affected by interference should be checked for conformity to the Electromagnetic Compatibility (EMC) Directive 2004/108/EC. EMC evaluations apply to both conducted and radiated emissions – those that come through mains power and those transmitted through the air. Equipment needs to tolerate a certain amount of interference as well as keep its generations below a certain minimum.

TABLE 1: Six common directives may be applicable in varying degrees to pieces of ground support equipment to be used in the EU

Equipment	PED	MD	LVD	EMC	RED	RoHS
Light Tower		Yes	Yes	Yes		Yes
Air Compressor	Yes	Yes	Yes	Yes		Yes
Ruggedized Laptop			Yes	Yes	Yes	Yes
Propeller Balancer			Yes	Yes		Yes
Portable Generator		Yes	Yes	Yes		Yes
Turbine Diagnostic Kit				Yes		Yes
Portable Printer			Yes	Yes	Yes	Yes
Avionics Toolset			Yes	Yes		Yes
Start Cart		Yes	Yes	Yes		Yes
Torque Test Kit	Yes					

RADIO EQUIPMENT DIRECTIVE

Equipment that intentionally emits or receives radio waves – anything from a wireless router to a radar system – should consider the implications of the Radio Equipment Directive (RED) 2014/53/EU. All radio receivers, even for GSE, are included in the scope of the RED.

HAZARDOUS SUBSTANCES

The Restriction of Hazardous Substances (RoHS) Directive 2002/95/EC is often missed, but it is very important to regulators. There are strict limits on substances, including lead, mercury, cadmium and hexavalent chromium, in electrical and electronic equipment. If there is lead solder in the equipment, for instance, in most cases it will not comply with the RoHS Directive.

The Waste Electrical and Electronic Equipment Directive (WEEE) covers disposal of electrical goods at the end of their life. Before importing a WEEE-covered product, manufacturers should plan how disposal of the item will be handled. Shipment back to the manufacturer is an option, or arrangements for disposal in a country can be made. WEEE needs to be addressed up front.

The breadth of applicable directives may seem very wide, but the due diligence process is straightforward. ∎

Erik Reynolds is senior consultant with Intertek Consulting Services

ADAPTABLE CAMERAS

High-speed camera-mounting adaptability is important, but so too are smart features that enable standalone operation and seamless networking integration

BY STEPHAN TROST

High-speed camera recordings that store separation or other events during test flights are standard equipment in today's design and development processes. Furthermore, cameras nowadays must allow for integration into unmanned aerial vehicles (UAV). Data collected by such camera systems delivers important feedback for design and test engineers for improving or validating systems. High-speed video data of 'hot spots' delivers accurate feedback for use by design engineers and integrators.

In UAVs in particular, space is always limited in airborne applications, requiring the camera shape to be adapted to the application. In more and more applications, cameras must be able to operate in a network with other components such as airborne recorders or mission controllers.

CAMERAS

In complex systems such as fighter aircraft it is imperative that the camera adapts to the aircraft and not the other way around. This is true for both the electrical and control interface, as well as for the mechanical outlines of the camera. In UAVs the camera may serve additional purposes such as delivering live video to ground staff for analysis. This occurs simultaneously while recording the high-speed event into the internal camera memory.

Some types of tests require that a camera be designed with the connectors located straight out of the back. Other mounting positions require connectors coming out sideways for a 90° view. Due to space limitations, almost every camera position requires a specific outline and mounting pattern of the camera.

All designs must meet environmental and electromagnetic interference specifications to be aircraft-ready. In addition, it is sometimes desirable to have aircraft-specific connectors on the cameras for ease of integration.

In some tests, availability of an extra housing that is attachable to the aircraft is advantageous and makes integration simpler. Such housings must meet all requirements of a test and measurement device on an aircraft. Furthermore, the camera must be immune to fast temperature changes – i.e. avoiding internal condensation that could harm the cameras or distort images by creating fog on lenses.

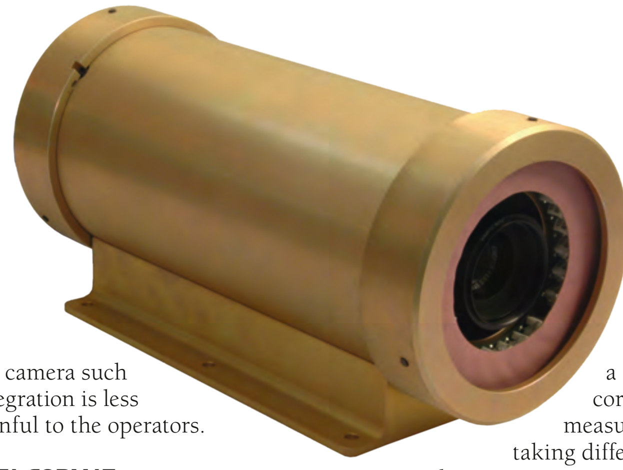
Camera system designers have to cope with these requests. One approach is to have a semi-customizable camera platform where functionality and identical operation of each camera is assured, the cameras perform reliably under the given environmental conditions, and last but not least are commercially attractive to the user. Also, the camera must fit seamlessly 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 result in the highest possible adaptation to mechanical design demands in order to fit the camera into the required space. Interface parts must easily adapt to given connectors and power requirements supplied in the aircraft. This type of camera design approach is highly beneficial to users.

SMART FEATURES IN THE CAMERA

With such camera design in place, the question arises of how to operate such systems that are filming different scenes under varied conditions. Smart features in the camera can be used to ensure maximum standalone operation, not interfering with the flight operating but providing the precious image data required. This is especially true when integrating the camera into an unmanned combat aerial vehicle. These features are pre-programmed on the ground by flight engineers, recording according to these parameters once the camera powers.

COMMUNICATION STANDARDS

For cameras intended to work in a network environment, it is important to standardize their communication. The new ANCS 466-15 standard was approved by the IRIG committee as better suiting airborne applications. Cameras must meet new networking



LEFT: Typical airborne camera from AOS Technologies with customized, specific MIL connectors

ABOVE RIGHT: Airborne high-speed camera built with specific housing for external aircraft mounting

standards for downloading image data via network to a central control unit. In such cases, captured sequences are downloaded to the control unit and new commands are sent to the camera for subsequent takes. Such protocol enables enhanced video data collection during the flight. In UAV applications where data download to ground stations for live view is a prerequisite, the camera must be able to manage the data bandwidth of the image data sent to telemetry systems. It is important to remember that images are large data files that may jam any telemetry systems and block sending vital parameters to the ground. By integrating smart algorithms within the camera such integration is less painful to the operators.

DATA FORMAT

For later 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 cope with many different data formats, sometimes in manufacturers' proprietary format. This made an exchange of data difficult. Here, the IRIG-106 data is a viable base for all data gathering and later analysis. A common data format eases the use of analysis tools, whereby a secure correlation of measurements, taking different sensors and cameras into account, is achieved. It is a very economical way to produce results and gain insight information. More importantly, comparisons between measurement data are simpler.

Semi-customized cameras are state-of-the-art in inflight image data acquisition for both manned and unmanned aerial vehicles – the perfect fit for each application, on a reasonable scale economically. ∎

Stephan Trost is the MD of AOS Technologies

AOS Technologies AG

AOS Q-MIZE EM: high resolution airborne camera

The Q-MIZE EM digital high-speed camera is specifically made for airborne and defense applications. Some of the outstanding features are: high image resolution, frame rates up to 100,000 fps, built-in image memory (up to 10.4 GB), models with connectors on the back or on the side.

Q-MIZE EM

... meets and exceeds standards for most airborne applications.

... meets criteria for integration in onboard networking systems and supports IRIG-106 data format.

... is functional ready to go into UCAV/UAV, supporting functions such as manageable data bandwidth to telemetry system.

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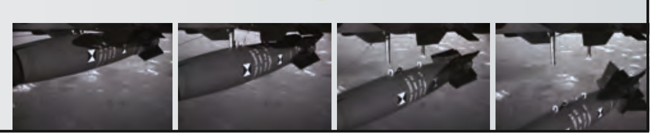


SHOCK ACCELEROMETERS

A new micro electromechanical system sensor has been introduced to capture the full pulse in high-impact environments

BY ROBERT SILL

Acceleration measurements in high-velocity impact and penetration environments require damped piezoresistive (PR) shock sensors to capture the complete pulse width and avoid extraneous out-band frequencies. Three high-g accelerometer signals can now be provided by a single surface-mount triaxial package embedded in the circuitry of a shock recorder. This configuration replaces the mounting of three discrete conventional single axis packages, routing and handling their individual cables, and attempting to get shockproof connections.

PR single crystal silicon (SCS) accelerometers with micro-electromechanical systems (MEMS) technology are used in many high-shock impact measurements. An undesirable characteristic of SCS is its extremely low internal damping, which results in susceptibility to overshoot and resonant excitation. Older MEMS devices for extreme shock applications were designed to maximize their resonant frequency. The intent was to avoid accelerometer over-range problems by fixing the resonance of the accelerometer above the frequency content of any mechanical excitation stimuli.

However, surprisingly low energy impacts were still found to cause resonance amplification and resultant failure. More energetic impacts easily exceeded the capabilities of this older design. As a by-product of these megahertz resonances, resultant sensor seismic element displacements were so small that effectively no internal damping was possible. Therefore bulky external mechanical isolators often had to be employed to protect the transducer and isolate it from high frequencies. Isolator design had to pay considerable attention to preserving enough bandwidth to track the residual rigid body motion and/or structural dynamics of interest for the device under test.

In PCB's new damped approach, the resonant frequency is intentionally lowered to reduce the response of the accelerometer to higher frequency energy that may be present in shock events. The relatively low resonance enables displacements of the seismic element sufficient to introduce squeeze-film damping using air as the medium. Air is used since thermal effects on its performance are negligible. The design is manufactured using recent advances in semiconductor processing, and targets a mildly under-damped sensor with sufficient bandwidth to accurately measure test item rigid-body or structural response over the frequency range of interest. Accelerometer resonant amplification is reduced by orders of magnitude and accelerometer survivability is increased.

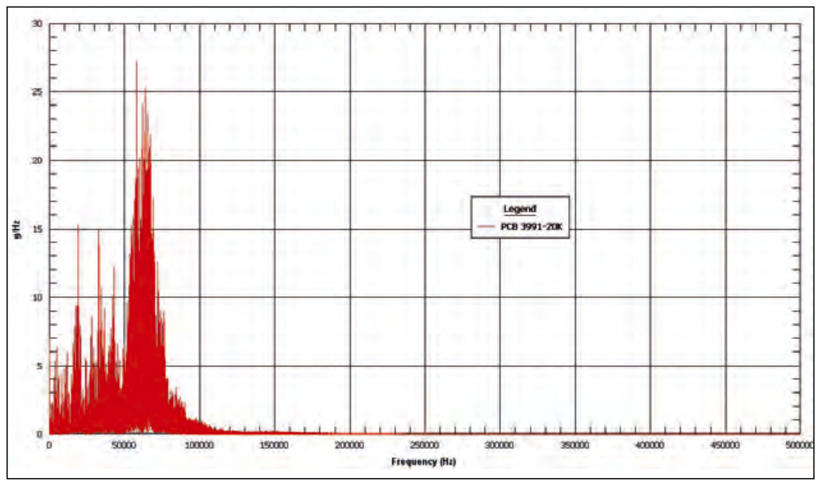
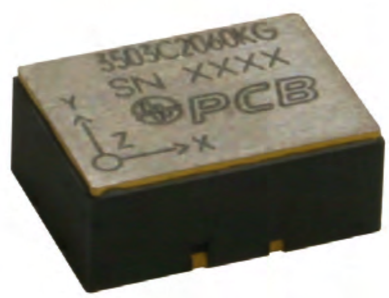


FIGURE 1: The low resonance and squeeze-film damping of PCB's new sensor effectively filters higher-frequency components



The new MEMS sensor PCB Model 3503C2060KG

The advanced design of the new Series 3503C matches bandwidth to shock applications. Single DOF above resonance acts as a two-pole filter and squeeze-film damping reduces resonant amplification. Test FFTs of impact data were taken to show the benefits of damping. Figure 1 is the new PCB sensor and Figure 2 is the legacy sensor mounted in its mechanical isolator. The two agree for data below 20kHz. These FFT results show that the new sensor's low resonance and squeeze-film damping effectively filtered higher frequency components, whereas the broadband noise and high-Q, 380kHz resonance of the 20kG legacy sensor comes through. Note the difference in how much the high-frequency energy is filtered.

Squeeze-film damping can eliminate the need for mechanical filtering when measuring penetration and pyrotechnic events. Resolution is improved over undamped sensors as the gain of conditioning and data acquisition systems can be scaled to the measurement range rather than the high Q of undamped sensors. Data acquisition can be simpler. The sample rates and filter requirements needed to avoid aliasing of the new sensor are much less severe than required with older sensor types. Compared to the older mechanical isolation techniques, increased miniaturization is possible by putting the new sensor on a circuit board with surface mount options. Another differentiator in the new sensor is the resistance of the bridge, which is approximately 5,000Ω

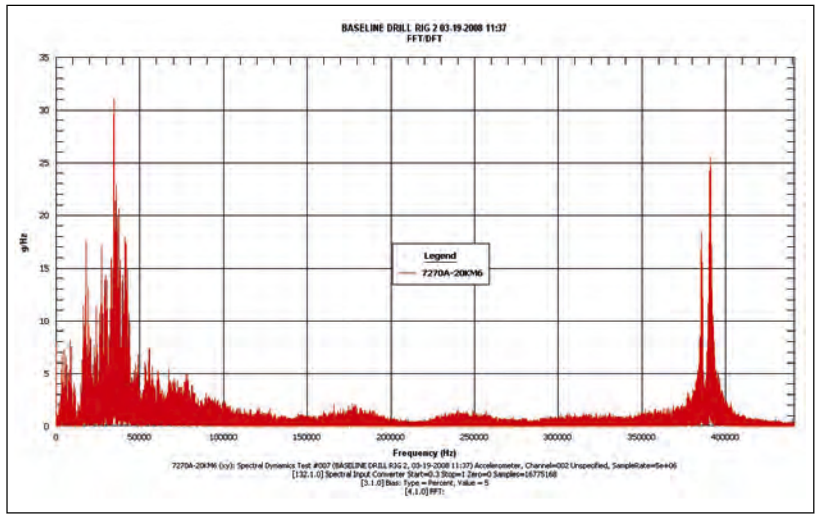


FIGURE 2: **The broadband noise and high-Q, 380kHz resonance of the 20kG legacy sensor comes through despite mechanical isolation**

– almost 10 times higher than the traditional design. For applications requiring battery power, this new sensor has high-resistance gauges with power dissipation that is an order of magnitude smaller. Since they are implanted into the heat sink of the flexures, these self-heating effects are further minimized, and the parameters of sensitivity and zero are a more linear function of excitation. Similarly, the warm-up thermal drift is small.

Transverse sensitivity – the resistance to side impacts – is also of an advanced design. The inherent transverse sensitivity in older sensors results from structural asymmetries in the mass and flexures, or electrical asymmetries in the piezoresistive gauges. After a transverse input, the new sensor generates strains of such magnitude and polarity that the outputs of the gauges cancel in the bridge. The result is a reduction in transverse output from 5% of the input shock for legacy sensors down to less than 3%.

The new design is installed into a co-fired ceramic leadless chip carrier with hermetically sealed cover and solderable surface mount pads. Overtravel stops are also installed to work with the damping to improve survivability in over-range conditions. Measurements have proven the dynamic and thermal performance, and exceptional transverse sensitivity confirmed the symmetry of the SCS inherent in the advanced techniques used in processing this new sensor. ∎

Robert Sill is senior scientist at PCB Piezotronics

OUT FOR A SPIN

Balanced constant current, a technique invented by Precision Filters, is less susceptible to noise pick-up than other techniques and is designed specifically to test rotating machines

BY DOUGLAS R FIRTH AND ALAN R SZARY

Determining dynamic strain characteristics helps validate gas turbine engine designs and establish safe operating margins. Dynamic strain measurements define stress and deflection limits, casing clearances and onset of high cycle fatigue. Analysis of the strain ratios from gauges strategically positioned along the fan, compressors and turbines is useful for further modeling, including detecting potential problems with vibration.

Designers of measurement systems for turbine engine testing deal with a complex set of challenging environmental conditions. Hundreds of sensors and lead wires collect data on pressure, strain, vibration and temperature, while interacting with the extremes of these conditions.

Even in such extreme conditions, exceptionally accurate measurements are possible. Advanced signal conditioning techniques and equipment eliminate electrostatic noise and compensate for resistance and temperature variations in test materials, active gauges and lead wires, while recording data from hundreds of sensors simultaneously.

For dynamic strain measurements, Precision Filters' balanced constant current (BCC) excitation offers an advantage over traditional Wheatstone bridge and single-ended constant current excitation. With BCC excitation, a pair of matched current sources excites a strain gauge or other transducer and a differential amplifier measures gauge voltage.

In a typical test setup, special high-temperature strain gauges are welded, cemented, or flame-sprayed onto a test article. A slip ring allows for connection of signal conditioning instrumentation to gauges on the rotating part of the engine. Lead wires or cables run from the gas turbine to a signal conditioner in a remotely located control room. The signal conditioner excites the strain gauges and measures dynamic resistance, which is proportional to dynamic strain.

Obtaining accurate measurements from strain gauges exposed to intense heat and vibration can be problematic and can include issues such as gauge insulation, which breaks down, allowing resistive leakage to ground. Strain gauges can fatigue or crack, causing shorts to the test material, and lead wires – made of alloys that won't break, melt, or corrode – have high electrical resistances that surge dramatically under start-up temperature escalations. High levels of electrostatic and electromagnetic noise may be present and these are difficult to shield because of how leads must be routed. Finally, slip rings are a source of modulated resistance and contact noise. Several approaches can amplify, filter and capture the signals coming from the strain gauges.

WHEATSTONE BRIDGE

Traditional signal conditioning methods have limitations. The Wheatstone bridge with constant voltage excitation should be avoided for high-temperature dynamic strain measurements since lead-wire resistance will result in large and unpredictable measurement sensitivity errors. Single-ended constant current excitation corrects this problem, but the circuit is intolerant of insulation breakdown and direct shorts – potentially leading to loss of critical data during testing. Both methods are unbalanced and highly sensitive to electrostatic noise pick-up.

BALANCED CONSTANT CURRENT FOR MEASURING DYNAMIC STRAIN

BCC excitation uses a pair of matched current sources to excite the gauge and a differential amplifier to measure gauge voltage (Figure 2). This balanced approach offers the benefits of a single-ended constant current source – measurement sensitivity and immunity to lead-wire resistance changes – with several additional advantages.

With respect to noise sources, the two connections to the differential amplifier are balanced both physically and electrically. With the right cables and hook-up techniques, noise pick-up on the two balanced inputs are nearly equal and, consequently, suppressed by the differential amplifier's common-mode rejection (CMR). The balanced circuitry also provides tolerance of certain gauge fault conditions, such as deterioration of gauge wiring insulation. Correct strain signals can

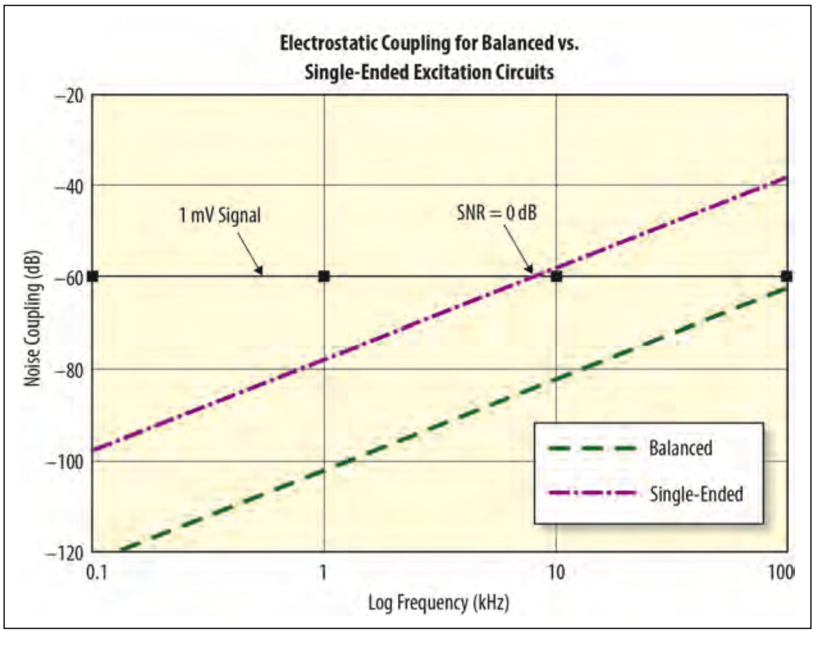


FIGURE 1: Electrostatic noise coupling for balanced versus single-ended excitation

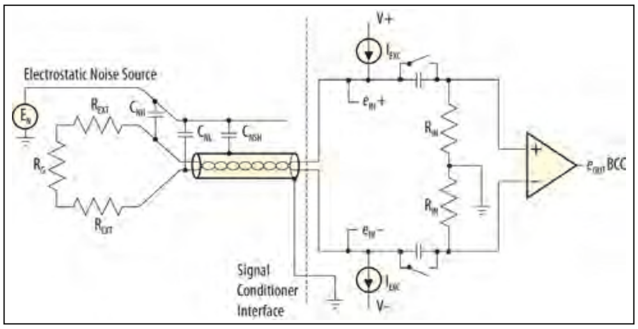


FIGURE 2: Balanced constant current excitation circuit

be measured even with a short to ground on either gauge terminal.

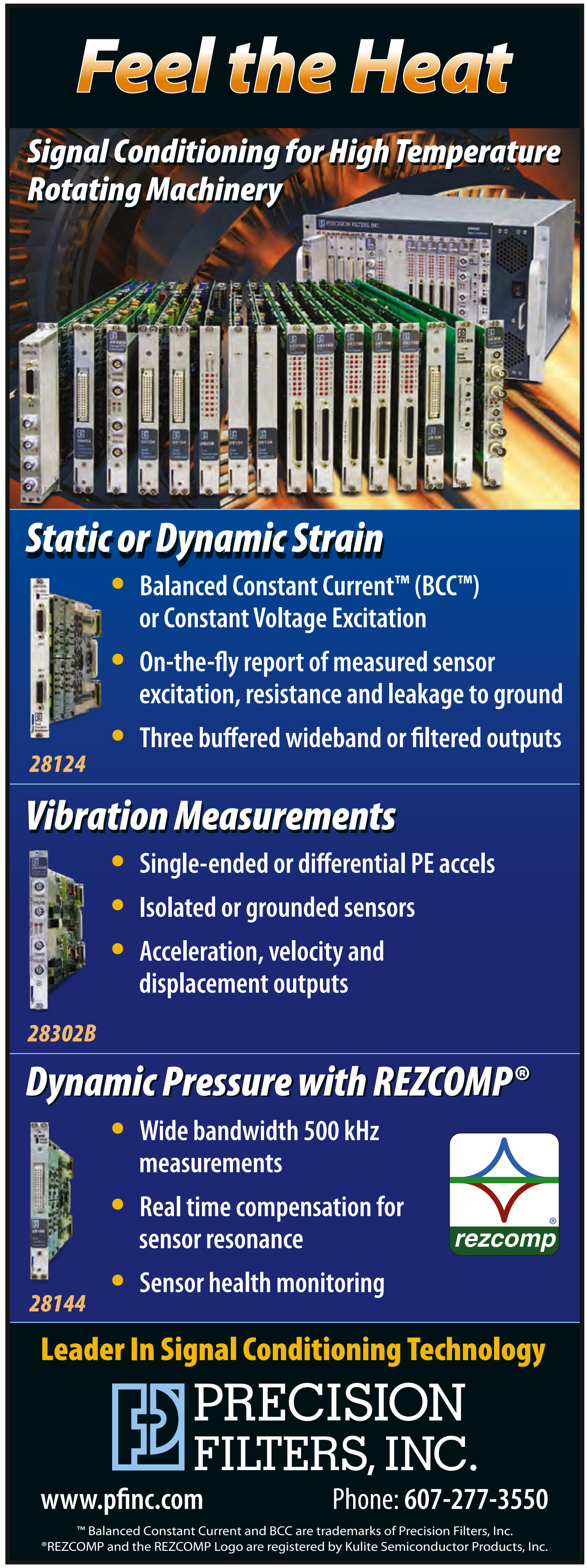
Figure 2 shows how BCC excitation suppresses electrostatic noise better than a single-ended excitation circuit. The graph plots noise pick-up eOUT BCC and eOUT SE versus frequency for RG = 1,000Ω, CNH = 22pF, and CNL = 20pF. With increasing frequency, electrostatic coupling increases by 20dB per decade. In this example, the balanced design results in 26dB less noise pick-up than the single-ended design. The reduction of noise pick-up in the balanced circuit depends largely on the match of stray capacitors CNH and CNL. The shield termination's effectiveness determines whether CNSH couples noise to the shield. With improperly terminated shields or in extreme test conditions with long cable runs, noise may be pronounced. In Figure 2, noise coupling from the shield to the center conductors is a potential issue because the coupling capacitance is approximately 40pF per foot. Fortunately, the balanced design's built-in CMR rejects the induced noise.

BCC is less susceptible to noise pick-up than other techniques. The push-pull configuration maintains accurate gauge current, even with insulation breakdown or a short on either gauge terminal – preventing loss of critical data.

BCC excitation offers four key advantages, including, first, less susceptibility to electrostatic noise. Second, immunity to certain gauge faults, including direct shorts to the test subject. Third, wide current source compliance to accommodate large gauge+cable resistance and fourth, insensitivity to lead-wire resistance.

Precision Filters invented BCC technology. The company's 28000 signal conditioning system and conditioner cards, designed specifically to test rotating machines, offer flexible, reliable, verifiable solutions for measuring dynamic strain gauges and a range of other transducers. ∎

Douglas R Firth is the president of Precision Filters and Alan R Szary is the company's vice president of engineering



ADAPTABLE POWER TESTER

An efficient power compliance testing regime requires versatile equipment to accurately trial both AC and DC systems coupled with an ease of use

BY PHILLIP CHOU

Electronic devices and instruments installed on commercial and military aircraft require stringent AC and DC power system compliance tests in accordance with generic avionics standards such as RTCA DO-160 and MIL-STD-704. The main purpose of compliance testing is to simulate the range of power characteristics that avionic electronic devices and instruments may experience during their lifetime, and doing so ensures that the test subject is capable of meeting the performance requirements under such electrical operating conditions.

The tests covered by avionics standards such as MIL-STD-704F are divided into a number of power groups (see table, *Power Group Acronyms*) based on the input electrical power for utilization by the instruments. The power groups detailed in the table have test frequencies consisting of constant values, noted as 400Hz for example, or variable ranges from 360-800Hz when not noted.

The acronyms in the table are further appended with a code number that indicates the aircraft electrical operating condition together with a test number to define the specific test item under the individual power group. One such example is the SAC303 test item, which defines the Abnormal Frequency Transient test conditions. This is test number 3 of aircraft electrical operating in abnormal condition defined by the MIL-STD-704F standard. Please note, a similar nomenclature method is also applied for defining each test item for other avionics standard procedures such as RTCA DO-160G.

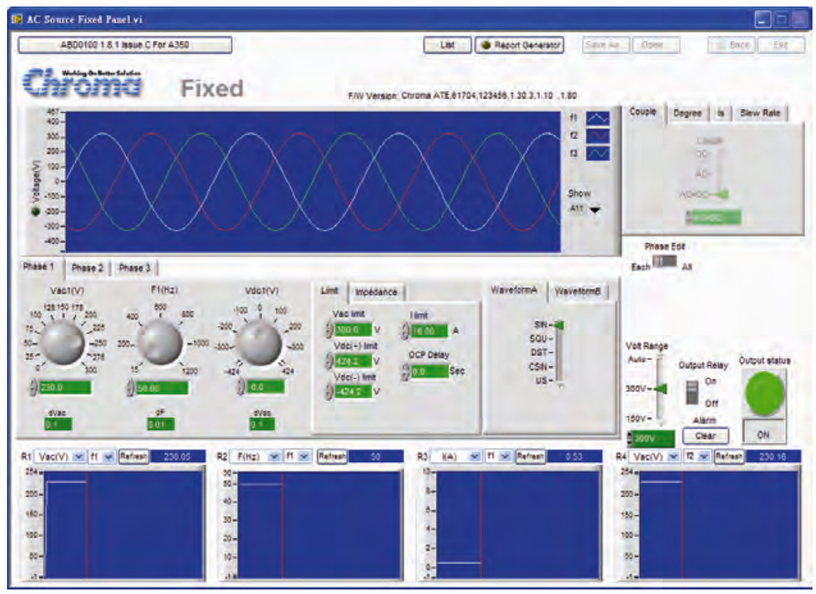


FIGURE 1: The Chroma Avionics Softpanel ABD0100.1.8.1 for the Avionics Standard test solution which is a GUI extension of a control panel

POWER GROUP ACRONYMS

Power Group	Acronym
Single phase, 400Hz, 115V	SAC
Three phase, 400Hz, 115V	TAC
Single phase, variable frequency, 115V	SVF
Three phase, variable frequency, 115V	TVF
Single phase, 60Hz, 115V	SXF
Low-voltage DC (28VDC)	LDC
High-voltage DC (270VDC)	HDC

THE GUI FRONT-END

The Chroma Softpanel is a graphical user interface that provides extraordinary capability and convenience to users for controlling the unit. The avionics softpanel is designed to be user friendly, easy to operate, and most importantly, able to deliver the required avionics standard's test items.

The avionics softpanel consists of two parts. The first is the fixed-mode page (Fig 1) that can be viewed as the GUI extension of control for an AC source product, and the second part consists of the test items coverage page that is required by the avionics standard.

TEST SYSTEM POWER SOURCE

In order for the avionics softpanel to fully accomplish its tasks, an AC source like the Chroma 61512 has to be used. This unit is a high-performance AC power source that is capable of simulating a wide range of AC line conditions, and meets market requirements by providing the ability to simulate various AC line input conditions as well as measurement of the critical characteristics for unit under test (UUT). These features make the 61512 AC source ideal for commercial, power electronics, avionics, military, and regulatory test applications, including bench-top RD design verification, quality assurance, and mass production. Using state-of-the-art PWM technology, the 61512 can deliver maximum output voltage up to 300V AC with typical distortion of less than 0.3% at 50/60Hz and output frequencies from 15-1,500Hz. The AC+DC mode extends the applications by not only providing pure AC voltage, but also a DC component for DC offset testing.

POWER TESTS AND RESULTS

The Chroma 61512 is capable of providing precision measurements that include RMS voltage, RMS current, true power, power factor, current crest factor, and more. By applying advanced DSP technology, the 61512 easily simulates power line disturbances through LIST, PULSE and STEP modes, and allows users to compose different harmonic components in order to synthesize various harmonic distorted waveforms. By applying this advanced feature, users can program a sweep frequency component incorporated with the fundamental voltage for finding the resonance points of the UUT, thus providing the user with in-depth analysis results. To simulate the natural waveform, the 61512 provides an external analog input used to amplify the analog signal generated from arbitrary signal generator. The user can implement this feature to duplicate a unique waveform observed in the field. The user-friendly interface allows quick access to the 61512 AC source's functions through the large LCD front panel display with a clearly indicated keypad. The GPIB (IEEE488.2), RS-232, USB, and Ethernet interfaces are available for users as standard to allow control of the AC source remotely. ∎

Phillip Chou is project leader for Chroma ATE

ABOUT CHROMA

Chroma ATE is a leading supplier of precision test and measurement instrumentation, automated test systems, manufacturing execution systems and turnkey test and automation solutions marketed under the brand name Chroma. Significant markets served include LED, photovoltaic, Li battery, electric vehicle, semiconductor/IC, optical device, flat-panel display, video and color, power electronics, passive component, electrical safety, and thermoelectric test, as well as automated optical inspection and manufacturing execution systems.

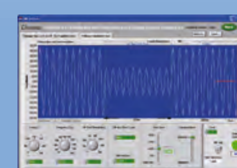
Chroma

Avionics Test Solution

High Performance AC Sources Capable of Simulating Test Conditions for Avionics Standards


61500 Series High Power Programmable AC Source with Transients


Softpanel Main Screen


Voltage DIP, Short, Variation Test


Avionics Softpanel for ABD0100.1.8.1 A350

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WHEN DATA MATTERS

Measurement equipment specialist Gantner Instruments advances its Q.series data acquisition system for validation and certification of aircraft structural components

BY STEPHAN PLOEGMAN

For static strength, damage tolerance and fatigue evaluation of aircraft structural components, strain is the single most important measurement. The accuracy and the precision of strain gauge measurements is of the greatest importance to exactly determine the durability and damage tolerance of a component. As manufacturers are continuously looking for ways to reduce risk and shorten the time to market, advanced numerical analysis technologies are being introduced for structural strength and fatigue assessment. The ability to accurately validate finite element models raises the need for precise microstrain measurement to single-digit accuracy.

VERSATILITY

The Q.series A116 strain gauge module was designed to meet these requirements. The A116 module features eight galvanically isolated channels for full-, half- and quarter-bridge strain gauges. Each channel is individually configurable and comes with pre-engineered conditioning functions such as linearization, filtering, shunt calibration and error compensation for long cables. The A116 is capable of sample rates up to 10kHz, with each channel having its own 24bit ADC (without multiplexing).

In line with customer need, Gantner now offers the Q.series A116 module with an extended input range of 25mV/V. This enables quarter-bridge measurements up to 50,000µm/m, making it suitable for testing highly flexible composite structures such as wings and rotor blades.

The Q.series' channel granularity, combined with the flexibility to freely mix and distribute modules, maximizes equipment use and increases productivity.

PRECISION

Every test engineer knows that for ultimate load testing it is important to capture high strains in the smallest detail. But it is equally important to precisely measure lower strain levels during fatigue and damage tolerance testing. The introduction of composite materials in aircraft structures has further increased the need for measurement systems with a higher dynamic range. Strain levels might vary from 1,000µm/m up to 30,000µm/m or higher. It is not realistic to expect such a wide range of signals can be reliably measured simultaneously using only one input range. Either the high signals will be clipped and distorted, or the low signals will be buried in system noise.

For quarter-bridge measurements, the A116 module comes with independently selectable input ranges of 1mV/V (2,000µm/m), 10mV/V (20,000µm/m) and an optional 25mV/V (50,000µm/m). Two per-channel user-selectable excitation voltages are available – 4V for better signal-to-noise and 2V to minimize self-heating when using strain gauges on composite structures.

Component fatigue tests can run for several weeks up to several months, day and night. Variations in ambient temperature are among the most common causes of measurement error when using metallic-foil strain gauges.

RIGHT: The portable and scalable Q.brixx

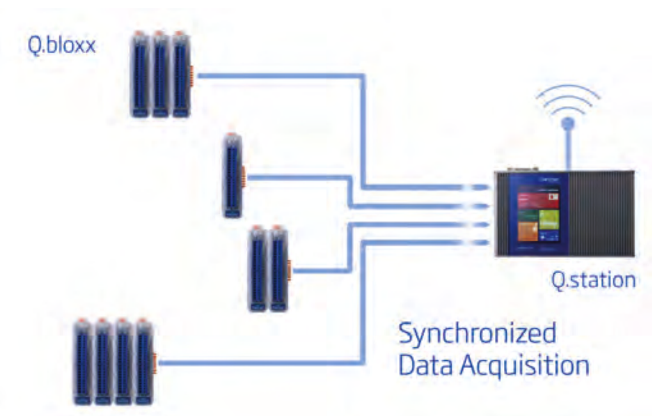
A temperature-related resistance change as small as 0.1% could result in an elongation of 500µm/m. Engineers want to avoid their strain measurements turning into temperature measuring, so it is of utmost importance to use a completion resistor with a low temperature coefficient of resistance (TCR). The Q.series A116 module comes with 120Ω and 350Ω completion resistors that have a TCR of 0.05ppm/K. A temperature drift of 10K will result in a measurement error of only 0.025%. Using a resistor with a higher TCR will increase the error accordingly. For example, a TCR of 0.5ppm/K will result in a substantial measurement error of 0.25%.

"We recommend that special attention is paid to the stability of the completion resistor. All too often low-stability resistors are used to save cost. This results either in unwanted errors or forces you to program complex temperature correction curves in software," says Reinhard Kehrer, CEO of Gantner Instruments.

RELIABILITY

Gantner Instruments understands that the higher a structure is in the

ABOVE: Types of stress acting on an aircraft during flight



ABOVE: **The flexible and distributed Q.bloxx system**

'pyramid of test', the higher the test complexity, number of measurement channels and amount of data produced. The risk in terms of time delay and cost associated with a test program increases disproportionately to the increase in test complexity.

Data skew in a multichannel, distributed data acquisition system is a major uncertainty during a test program. Often measurement modules need to be synchronized by means of field-programmable gate array (FPGA) programming, inaccurate network time signals or extra module-to-module synchronization lines. The Q.series data acquisition system comes with a built-in, hardware-based synchronization between the modules. Even when the system is distributed over long distances it ensures precise time synchronization with a maximum jitter of 1μs, thereby eliminating long cable runs.

To be certain that a single sample is not missed, the Q.series system has three levels of redundancy for assured data availability. Measurement data can be broadcast in parallel to an online database as well as to an FTP backup server. Both data ports are continuously monitored. If a broadcast fails, the Q.series system will automatically start logging data to its local disk.

Gantner's know-how is reflected in all its products and associated services. Despite today's fast-changing industry, the company stays focused on what matters most: high-quality data that users can rely on. ∎

Stephan Ploegman is business development manager, aerospace at Gantner

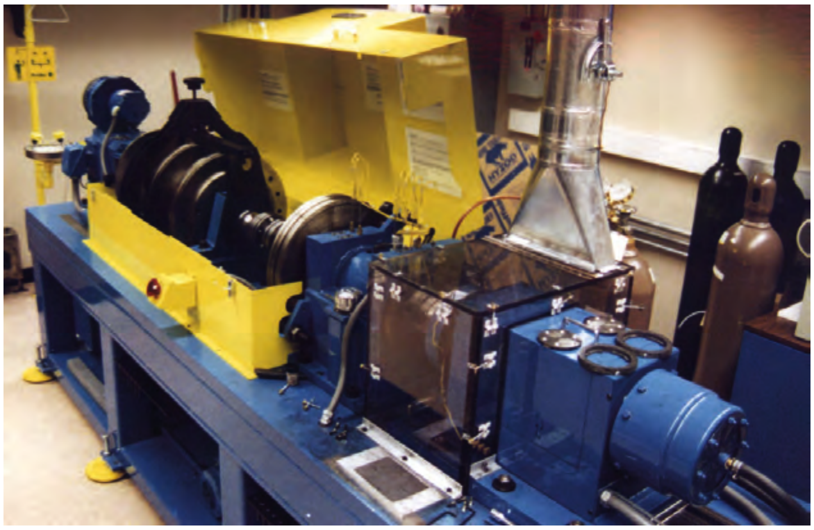
SMALL TESTS, BIG RESULTS

Sub-scale brake testing is a reliable and affordable alternative to full-scale testing

BY DR PETER FILIP

Reliability of aircraft brakes is paramount for the safety and operation of the aircraft. Friction performance can be considerably influenced by several factors including contaminants interacting with carbon-carbon composites. Extensive testing is essential for the brake research and development process. However, full-scale testing can be impractical and prohibitive for many companies and researchers. Sub-scale testing provides these companies and researchers with a solution for their testing needs.

To test the effects various contaminants would have on carbon-carbon composites, a widely used commercial carbon-carbon composite material was used for friction tests performed on a Link Engineering sub-scale aircraft brake dynamometer equipped with an environmental chamber. The scaling strategy adopted was based on equal power absorbed by unit mass of carbon-carbon composites during real braking in the full-scale aircraft brake and the sub-scale test. The carbon-carbon composite discs (one rotor and one stator in each dynamometer test) with outer diameter of 95.25mm (3.75in), inner diameter of 69.85mm (2.75in) and thickness of 21.6mm (0.85in) were machined from commercial brakes. Temperatures were measured by K-type thermocouples installed in the stator.



ABOVE: Sub-scale aircraft brake dynamometer (model 2076 by Link Engineering), 7,000rpm capacity, adjustable inertia (0.27 and 6.37 kg•m^2), maximum normal force of 13.3kN, and maximum torque of 34.6 kg•m

PREPARE TO TAXI

The testing consisted of 'taxiing' at 4.5%; and landings at 12.5%, 25%, 50% and 100% of normal landing energy, performed at 50% relative humidity. Friction was calculated from the measured torque and wear (mass change) measured after a sequence of 150 taxiing and 50 landing stops. Prior to each test, the carbon-carbon brake discs were immersed into different contaminants – hydraulic fluid, runway deicer, aircraft de-icer, or salt water – for 20 minutes. The friction of both 2D and 3D carbon-carbon materials differs and varies during each landing simulation. The 'transient behavior' and different level of friction oscillation can be easily seen.

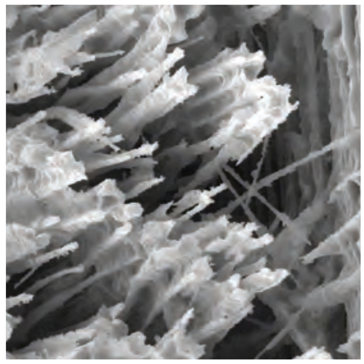
Transients and friction oscillation negatively impact the lifetime of landing gear and can lead to audible noise during braking and higher wear of carbon-carbon. Brake design has to adopt these factors correspondingly. Wear and the average coefficient of friction (CoF) values were obtained from the dynamometer tests.

Testing confirmed that a combination of mechanical and oxidative wear can result in a negative wear (or mass gain) due to formation of oxygen containing complexes attached to the exposed surfaces. While the wear values can vary in both directions, the friction level typically decreases when contaminants are present. These factors impact the critical braking distance and lifespan of brakes. All contaminated samples exhibited lower friction compared with the virgin materials. The lower friction means a lower heat and a lower temperature generated during stops. In contrast to behavior of carbon-carbon samples exposed to hydraulic fluid, the increased energy/temperature does not cause burnout of the runway de-icers and the CoF is highest for the lowest energies. Potassium from de-icers will convert into potassium carbonate, which dissociates into K_2O/K_2O_2 at temperatures above 500°C and forms an amorphous friction layer at 700°C. The development trend of the CoF detected for aircraft de-icer contaminated materials is very similar to the dependencies obtained for the virgin 3D material, with a lower average value of the CoF.

Upon review, the 2D material was found to be more sensitive to contaminants than the 3D material, particularly at higher temperatures. The 2D carbon-carbon material is heavily oxidized in the presence of the Na, K, Cl, and Mg contained in the sea-salt water. The heavy attack of the 2D samples related to oxidation of disc edges is shown as a macro-image and scanning electron microscopy image. The maximum temperature is lower during testing of the contaminated samples, particularly at higher energies. The 3D material exhibited considerably lower temperatures compared with the 2D composites for all testing conditions.

Using Link Engineering sub-scale aircraft dynamometers for testing can serve as an effective tool when assessing frictional behavior and understanding fundamental mechanisms responsible for different friction and wear phenomena. Although the friction and wear are system properties, inexpensive and relatively speedy sub-scale testing can serve as an efficient tool for making 'educated' decisions during the research, development and design of aircraft brake materials. This research clearly showed differences between two tested commercial materials and demonstrated that their exposure to different contaminants significantly influences braking performance. ∎

Link Engineering sponsored the research performed by Dr Peter Filip, Southern Illinois University; Dr Milan Krkoska, University of Technology Delft; Dr Katerina Pieszynska-Bialczyk, University of Torun; and Dr Soydan Ozcan, Oakridge National Laboratories and University of Kentucky



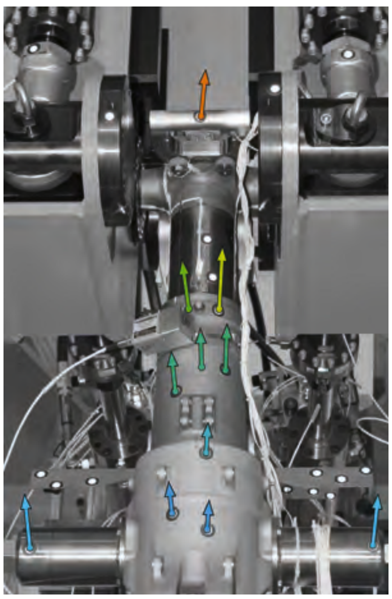
ABOVE: A scanning electron microscope image of the 2D material after testing

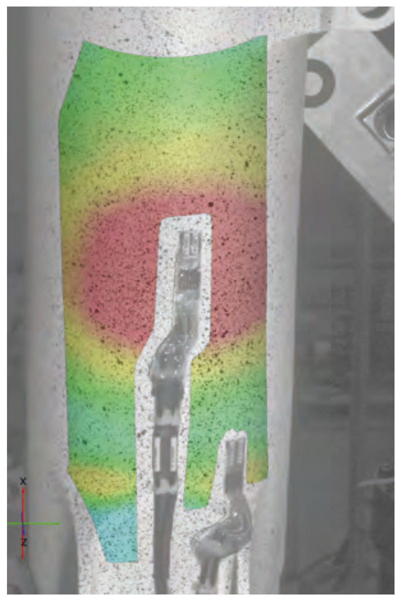
RIGHT: A macro image of 2D carbon -carbon material after being exposed to salt water during simulation testing using normal landing energy

STRUCTURAL TESTS IN 3D

Optical metrology from GOM accelerates certification tests for new landing gears at Liebherr-Aerospace

BY STEPHANIE ADOLF AND THOMAS PFEILSCHIFTER





FAR LEFT: **Aramis delivers measuring data for part geometries as well as three-dimensional displacements and provides information about the behavior of the components under load**

LEFT: **Full-field displacement and strain measurement**

Optimized processes that enable efficient and lean design are becoming increasingly important in the aerospace industry and ensure competitive advantages. Innovative test methods for validating simulations and the latest approaches in virtual testing have enabled Liebherr-Aerospace, a leading supplier of systems for the aerospace industry, to further examine material properties and develop new design concepts for its landing gears.

Liebherr-Aerospace uses the Aramis 3D Camera to perform structural tests at the subsystem level for certification of newly developed landing gear systems. Structural compliance falls into two categories: limit and ultimate strength tests, and fatigue tests. During limit and ultimate strength testing, the landing gear system must demonstrate its structural integrity under quasi-static peak loads, whereas during fatigue tests, cyclical operating loads are applied to verify the fatigue strength of the landing gears in relation to the applicable specifications. For this, loads are applied to the landing gear structure using hydraulic cylinders and representative loading systems. Besides ongoing limit strength tests, Liebherr is also concurrently performing fatigue tests for certification purposes. Each test can last more than 12 months and has up to 2.2 million load cycles.

Each landing gear is subjected to multiple critical load cases during static certification tests. These tests focus on a point-based analysis of the component behavior during ground loads, which describe the loads on the landing gear while landing and taxiing. The optical sensors deliver measured data for part geometries, as well as three-dimensional displacements and information about the behavior of the components under load. The most interesting question is whether the components suffer permanent deformations while loaded.

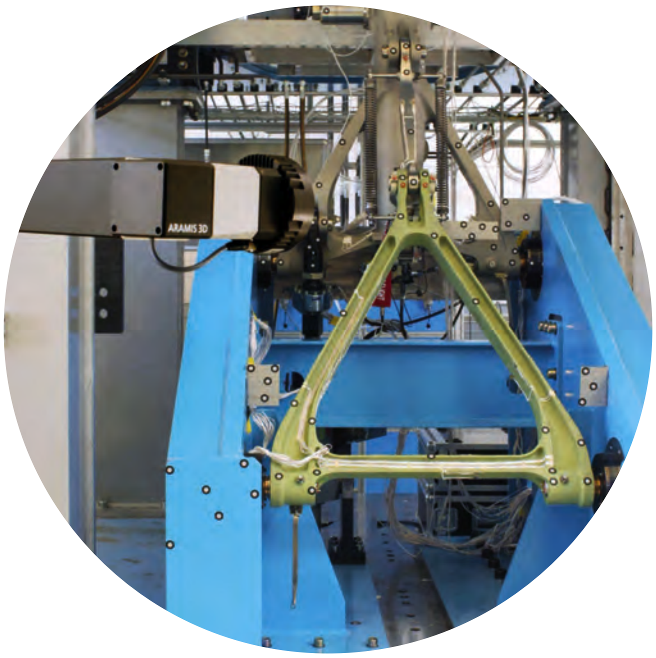
Each test rig is individually designed for the specific test campaign. They are approximately 6m wide, 7m tall and 5m deep, occupying a total space of 70m², and are powered by a central hydraulic system that can deliver loads of up to 560kN, which is equivalent to 57 metric tons.

MULTIPLE SCENARIOS

The specimen experiences multiple scenarios during the structural test, including maximum torsion and braking torque, as well as upward and downward vertical loads. The test engineers increase the loads in stages and analyze component behavior using the measuring data obtained.

Unlike conventional devices, optical systems such as Aramis determine three-dimensional displacements, deformations, and speed and acceleration. Using point-based measuring data, 6DOF analyses are performed to determine translational and rotational motions in relationship to each other or as absolute movements in all directions in space. The test engineers can then pinpoint the exact locations at which the landing gear becomes heavily deformed. Aramis can be easily integrated into the test setup, with inspection points identified by measurement markers. Using an optically tracked GOM Touch Probe, nominal positions can be determined and adapters can be measured.

Liebherr evaluates its measuring data with Aramis Professional and rates the simplified workflow as an essential advantage of the new parametric system. Thus, changes can be made during the entire stage evaluation, both during the test run and during post-processing. At the push of a button, all corresponding elements are updated automatically.



ABOVE: **The new landing gear – placed within an individually designed test rig at Liebherr-Aerospace's testing facility in Lindenberg**

Optical measuring systems also accelerate the test setup. Aramis enables Liebherr to set up the measuring task once at the beginning of the test campaign and conduct the remaining tests using reliable project templates. Liebherr-Aerospace also uses the Aramis system to check that the load cylinders are correctly aligned in accordance with specifications before and during the series of tests.

The measuring task is performed by GOM's Tritop system, which uses photogrammetry to determine the coordinates of 3D objects. After the data is aligned with CAD, the strain gauge positions are projected back. This saves time as otherwise the strain gauge positions would have to be determined manually. Once set up, Liebherr uses the GOM Aramis 3D Camera with a measuring volume of 5m for the actual test run. Two sensors are often used.

The 3D measuring data is permanently available and can be evaluated long after testing and in different contexts. The results can be displayed in formats such as charts, videos and images.

GOM's 3D measuring data is also being used to optimize test design and to measure the load-specific directions of the flight cycles that affect the structures. At the same time, GOM systems can find the root causes of failures by supporting complex analysis methods and can even simplify or replace them entirely. ■

Stephanie Adolf is manager for measuring applications at GOM and Thomas Pfeilschifter is test and qualification engineer at Liebherr-Aerospace Lindenberg, Germany

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LUFTWAFFE TESTS GO NORTH

Updated CH-53GA Luftwaffe helicopters underwent testing in the difficult winter conditions of northern Sweden at the Vidsel Test Range

BY JONAS LINDE

ABOVE: German CH-53GA helicopters soak up the cold of northern Sweden to test their avionics upgrades and conduct winter training

The Swedish Defence Materiel Administration (FMV) Test and Evaluation (T&E) directorate is the operator of several test offices and test ranges in the country, including the premier air range near Vidsel, in northern Sweden.

The Vidsel Test Range (VTR) is Europe's largest overland test and training range. The vast 100% unpopulated air and ground space makes it the perfect place for live firing of air-to-air, air-to-ground, ground-to-air and surface-to-surface weapon systems, as well as live deployment of electronic warfare and countermeasure systems, including GPS-jamming. The test range is heavily instrumented with radar, theodolite, telemetry and flight-termination systems as well as target drones and other systems.

The very large restricted air and ground space also makes the range an ideal place for tactical training with full combat loop scenarios, for example joint exercises between air and ground forces such as close air support (CAS).

Over the years many test campaigns with fixed-wing aircraft as well as helicopters performing live firing and other trials, including several German military-related projects, have been hosted at the range. The ability to stage advanced tactical scenarios has especially been employed by the European Defence Agency (EDA), which runs the flying part of its 'train the trainer' course at Vidsel.

For helicopters, the VTR can accommodate almost any weaponry that can be fitted to a rotary wing aircraft, for example PARS 3LR, Hellfire, Stinger, HOT, etc.

POLITICS AND CLIMATE

Winter and cold climate operations have in past decades played a minor role in deployments and operations. However, the growing strategic importance of the Arctic has forced nations with political interest in the region to maintain and (re-)develop their winter- and cold climate operational capabilities.

Political development in Russia has also forced military strategists to consider future operations in northern Europe and the Baltic region, where snow, ice and cold weather are still conditions that can be encountered.

The arctic climate at Vidsel, with temperatures down to -40°C, enables demanding winter and cold climate trials and exercises.

WINTER OPERATIONS

Early this year, Vidsel Test Range hosted some CH-53GA helicopters from Germany's Luftwaffe for winter and cold climate trials and training. The aim of the campaign was to test the newly updated helicopter during winter and cold climate conditions and to train crews in white-out operations. The updates included a new full glass cockpit and modifications to the four-axis autopilot, were tested with landings on flat and inclined surfaces.

The German test team had two CH-53GA from the German Air Force Helicopter OT&E unit and 30 crew.

ABOVE LEFT: A German Luftwaffe Tiger helicopter maneuvering over the Vidsel Test Range during an earlier visit

ABOVE: Practicing flight operations in white-out conditions with a pair of CH-53GAs

The trials concept was quite straightforward. Very early in the morning, the helicopters were rolled from the hangar to cool them down. When the temperature had dropped in the cockpit and avionics bays, initial ground and engine runs were performed, including functional checks of mission-critical systems. The test team then conducted flight trials lasting for 1.5-2 hours. These covered general handling, low-level flights and white-out trials, as well as tests of the modified and updated tactical systems.

The GH-53GA trials at Vidsel experienced severe winter conditions, with lots of snow and temperatures around -26°C, lowest recorded was -35°C. In total six test flights were performed during the campaign.

WHITE-OUT TRAINING

In recent years, the aviation corps training has been focused on operations in brown-outs – where sand and wind restrict visibility, due to the characteristics of the current operational theaters. However, the sand and dust particles are bad for helicopter rotor blades and engines.

In all major aspects, the methodology and procedures for brown-out operations are the same as for white-outs. This means poor visibility trials and exercises can be done in white-out conditions which cause minimal wear and tear on the main rotor-blades and engines. Maintenance and helicopter lifetime will be saved – a vital factor. White-out training also gives the opportunity to combine it with other activities, such as live firing and electronic warfare (EW) campaigns.

FUTURE TRIALS

The Bundeswehr has more winter helicopter trials planned including the NH90, Tiger and the new LHU SOF (Airbus H145M). ∎

Jonas Linde is director of marketing and a senior test flight engineer with FMV T&E, Swedish Defence Materiel Administration

SPEEDY WING SCANNING

Merging existing automation technologies has resulted in a dramatic decrease in inspection times for aircraft wings. Aerospace manufacturers need to consider these advances, even in low-production environments

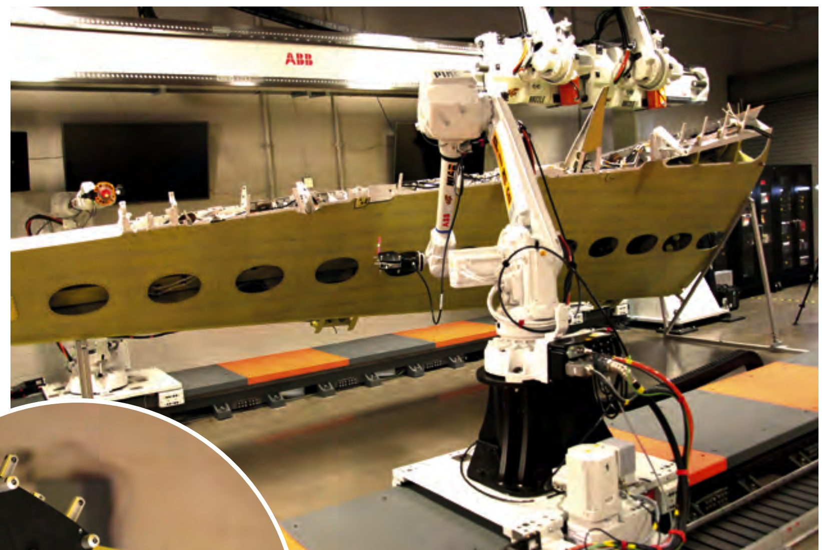
BY JAMES RAWSTRON

One of the key challenges for the aircraft industry is determining how to leverage automated manufacturing technologies for improved speed and throughput. Although automobile manufacturers have embraced automation, in part because the production volume is so large, the aerospace industry has been slower to make this investment.

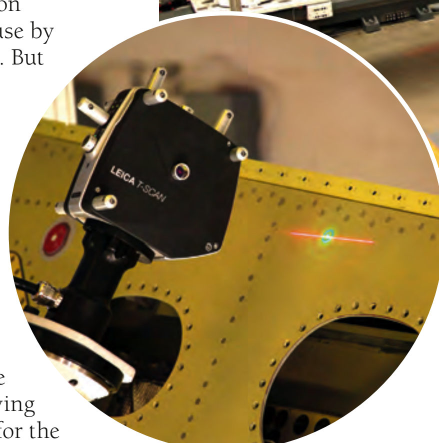
One reason for this is the difference in production volume. Many aircraft manufacturers are considered low-volume producers, which has delayed their adoption of automation technologies currently in use by modern automotive OEMs. But that trend is changing, as organizations like Wichita State University's National Institute for Aviation Research (NIAR) demonstrate that it is easier to employ automation in lower-production markets.

Recently, NIAR teamed with Hexagon Manufacturing Intelligence to develop an automated wing surface scanning solution for the aerospace industry. Using a small business jet wing measuring approximately 25ft x 6ft, NIAR and Hexagon engineers were able to reduce a scanning process that previously took all day, to less than four minutes. Leveraging the multitasking capabilities afforded by the automated solution, NIAR was able to demonstrate that an integrated network of robots, scanning technologies and software tools can accurately and repeatedly manage metrology and inspection tasks.

To make this breakthrough, the team used a combination of the Leica Absolute Tracker and a Leica T-Scan 5 mounted to an ABB IRB 4600-40/2.55 robot. Brian Brown, director of NIAR's Robotics and Automation Lab at Wichita State, spearheaded the project. Working closely with application engineers from Hexagon Manufacturing Intelligence, his team was able to get the automated scanning process up and running in a matter of hours.



ABOVE: An ABB IRB 4600-40/2.55 robot was used with Leica equipment to quickly collect accurate scanning data from a small business jet wing (25 x 6ft)



LEFT: The Leica Absolute Tracker and a Leica T-Scan 5 were used in the development of an automated wing surface scanning solution

"Rather than spending hours to days of manual labor inspecting large aerospace components, we can now leverage the Leica T-Scan 5 and ABB Robotics to turn the job into an automated process that only takes minutes," Brown says.

The results were positive. Despite the challenges of scanning a large, metallic-finish wing section, the surface scanning data was collected quickly with a high degree of accuracy. NIAR identifies itself as a place "where test plans become results" – full structural elements are a focus for this initiative. The ability to rapidly and accurately provide a surface scan of a jet wing is a departure from traditional aircraft metrology processes, offering an automated, accurate and fast way to ensure that aerospace assemblies are fabricated as intended.

"Since we can now inspect large aerospace components in minutes rather than hours or days with the use of automation and high-end metrology equipment, productivity and efficiency can be greatly increased throughout the entire product line," Brown said.

"As more aviation manufacturing processes become automated, organizations are looking to increase speed, efficiency and precision. By combining the expertise of the NIAR labs at Wichita State and the insights of the Hexagon Manufacturing Intelligence team, high-value, low-cost solutions can be developed and implemented quickly and efficiently."

The robots used in this project will soon be part of a new 3DExperience Center at Wichita State. The 3DExperience Center, a partnership with Dassault Systèmes, will focus on enabling advanced product development and manufacturing, next-generation manufacturing materials and technology using Dassault Systèmes' 3DExperience platform, a multirobotic advanced manufacturing system, and simulation validation using an immersive CAVE system.

Wichita, Kansas, is known as the 'air capital of the world' due, in part, to NIAR, a leading advanced aircraft manufacturing laboratory. The area is home to notable aerospace and defense OEMs, including Boeing, Textron Aviation (Hawker, Beechcraft and Cessna), Bombardier Learjet, Spirit Aerosystems and Airbus. The local economy is powered by aviation manufacturing: Wichita is home to 7,000 engineers and 26,400 aerospace production jobs – 43% of the USA's general aviation aircraft are built there. Wichita and its vicinity was also recently designated a manufacturing community by the US Department of Commerce Economic Development Administration. This distinction makes NIAR part of a network of research institutes across the USA which focus on developing and commercializing manufacturing technologies through public-private partnerships between industry, universities and federal government agencies.

In the competitive world of advanced aircraft manufacturing, developing world-class talent that can drive innovation is essential to the longevity of the industry. It is also a key goal in Wichita State University's strategic plan, and the university is using NIAR to do just that – partnering with industry to provide applied learning opportunities for more than 150 students each year.

ABOVE: NIAR demonstrated that an integrated network of robots, software tools and scanning technologies can accurately and repeatedly manage metrology and inspection tasks

NIAR is uniquely positioned to assist both the local and global need for highly skilled aircraft assembly professionals. With more than 20 laboratories focused on certification testing for airframe technology and a US$45m yearly budget, NIAR is paving the way for advanced aerospace manufacturing processes in the USA. ∎

James Rawstron is a senior marketing specialist with Hexagon Manufacturing Intelligence

VERSATILE I/O CONNECTOR

A major European airline turned to the small i2 MX connector to achieve a single standard-based system in its testing program

BY JASON DIGGS

In 2016, a major European airline contacted Virginia Panel Corporation (VPC) in search of an interface to test power drive units (PDUs) that would be installed in commercial aircraft. The airline was seeking a connector solution that could use both power and signal lines simultaneously, but also be able to prevent one from influencing the other during the course of a test application.

PDUs are used in many aircraft flight control systems to convert electrical power to mechanical movement. They cover a wide range of actuation systems, such as landing gear, wing flaps and slats, and braking mechanisms. Their responsibility for vital aircraft systems makes them important to test and maintain.

To complete the test, the airline needed a connector that could use the standard power supply of an airplane, which supplies 400Hz/115V DC or 230V AC. Notwithstanding, it also needed a connector that could use signal pins with discrete inputs/outputs of 0-28V and sensor lines from 0-20mA and 0-10V. What the airline found was that the i2 MX connector had intermixable module types that would allow it to funnel both contact types into the same connector. Inside the space-saving design, the i2 MX connector was able to separate the signal and power lines into different harnesses and prevent the power lines from influencing the signal lines. The electromagnetic interference-shielded backshell of the connector also helped to quell possible interference with other electrical drives aboard the aircraft.

The i2 MX was the ideal connector for the job. The airline was able to connect the i2 MX directly to its unit under test (UUT) from the test fixture. While the UUT was powered by a three-phase power supply, the i2 MX protected the system from interference and provided power to the PDU. Depending on the test requirements, the engineer was able to apply currents ranging between 2-13A per phase.

When asked why it had chosen a VPC solution, the major European airline commented that VPC was its standard. It sought a solution from VPC because it had previously fielded numerous receivers and interchange test adapters (ITAs). Its engineers insisted on having one standard-based system with the same contact and module platform. "This standardization is a big benefit for us," an anonymous source commented.

The i2 MX capabilities stretch beyond power and signal contacts. Today, customers are using the connector for coaxial, fiber-optic, and digital high-speed inserts for their test applications. The connector has already been fielded in aerospace, automotive, and defense industries. There are four popular configurations, but more configurations are available. ∎

ABOVE: An i2 MX connector with high-speed digital configuration (on top) and hybrid signal and coaxial configuration (on the bottom)

"THE CONNECTOR HAS INTERMIXABLE MODULE TYPES THAT ALLOWS BOTH CONTACT TYPES TO BE FUNNELED INTO THE SAME CONNECTOR"

Jason Diggs is a marketing design specialist with Virginia Panel Corporation ets european test services

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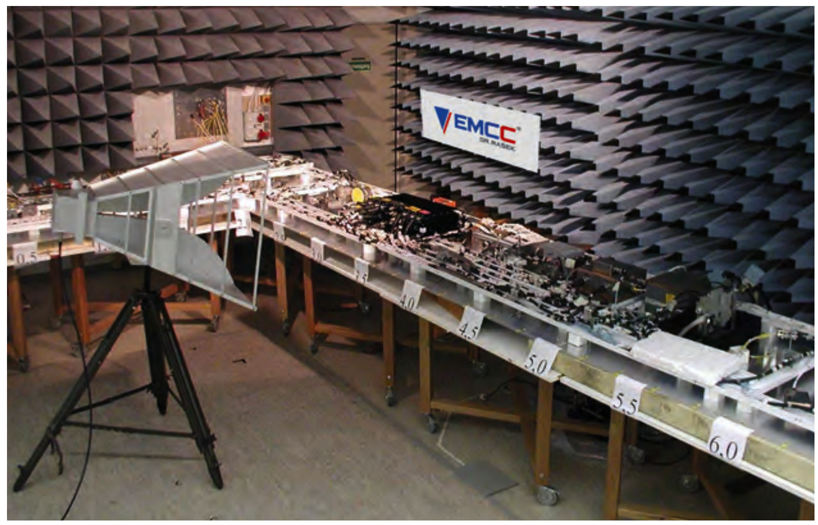
Aerospace TESTING INTERNATIONAL

CURRENT THINKING

What is the best external EME certification approach to follow for general aircraft?

BY MARTIN GABRIŠÁK AND STEFFEN LOOS

Aerial vehicles are exposed to a significant incidence of electromagnetic hazards that penetrate into the internal operating environment of an aircraft. There is a danger for both the external-mounted and internal-mounted aircraft systems, which must be designed to ensure electromagnetic compatibility (EMC) with the electromagnetic environment (EME) in which they are intended to operate. This includes all electromagnetic phenomena present at the location of the installation; that is, the superimposition of energies emanating from sources arising through natural occurring phenomena, as well as those generated by man-made activities.



ABOVE: A test bench for testing electromagnetic compatibility

EXTERNAL THREATS

The first external electromagnetic threat is the potential radio frequency (RF) exposure of aircraft, commonly denoted as the high intensity radiated fields (HIRF) environment. This energy is radiated from radio, television, and radar emitters such as airport fixed ground emitters, instrument landing systems (localizer and glide scope), ground-controlled approach radars, weather radars, and VHF and UHF communications frequencies.

The frequency range of interest extends from 10kHz to 40GHz, with the corresponding wavelength ranging from 7.5mm to 30km.

The second external electromagnetic threat is from lightning strikes. The natural interaction of a strike with the fuselage of an aircraft is technically subdivided into two.

The first is the direct effects of lightning as a result of the attachment or passage of the lightning channel currents. These include metal burn, hot spots and ohmic heating, mechanical forces, voltage and thermal sparking, and dielectric breakdown of non-conducting surfaces such as occurs during welding.

The second concerns the indirect effects as a result of the coupling of the lightning-induced electromagnetic fields with the electrical and electronic installations in the aircraft (transient voltages and currents induced in aircraft wiring).

Lightning and HIRF are therefore external EME elements that pose a threat to the complete aircraft at the same time.

The need to protect avionic electrical and electronic systems against external electromagnetic energy has increased substantially in recent decades for a number of reasons. Perhaps the most significant of these is that many mechanical, electromechanical, hydraulic and pneumatic devices and systems have been replaced by electrical and electronic systems. These systems are more susceptible to electromagnetic energy because of higher data transmission speeds, higher density integrated circuits and lower voltage signal levels.

In addition, some composite materials now used in the manufacture of aircraft have a lower level of electromagnetic shielding.

DETERMINATION OF INTERNAL EME

The well-known effects of electromagnetic energy on electrical and electronic systems range from slight functional upsets to component failures and permanent damage. The most flight-critical systems, called 'level A' systems, are tested in a particular way: for each aircraft type, transfer function measurements are conducted on complete aircraft.

Low-level swept coupling (LLSC) tests establish the bulk or common mode induced current on cable looms for an applied external electromagnetic field in the frequency range from first airframe resonance roughly between 800kHz and 2MHz up to 400MHz. The determination of loom currents in a lower frequency range starting from 10kHz is conducted via direct injection of the RF signal into the fuselage, called low-level direct drive (LLDD). The low-level swept field (LLSF) coupling method is used to determine internal fields at the location of equipment installations in the frequency range from 100MHz to 18GHz as a function of the external electromagnetic field.

For lightning transfer functions, all possible airframe lightning current paths must be tested; that is, the lightning strike entrance point in the nose through to the exit area at the tail of the aircraft. While a pulse is applied to the fuselage, the actual transient levels (ATL), voltage and current amplitudes and waveforms actually induced on a particular aircraft are determined for the cable bundle currents, individual wire open circuit voltages, and wire short circuit current.

ABOVE: Numerical simulation result for a surface current distribution of lightning pulse – nose to tail

ATL MEASUREMENTS

The measured quantities from transfer function measurements specify the electromagnetic threat affecting the component of an avionic system. The next stage is a standard bench test. The system is impinged with the tailored high-level amplitude to verify if it can withstand the effects of lightning and RF electromagnetic fields. Should the test show the system is not compliant, the design of the unit will likely be changed. All the measures suppressing the external electromagnetic threats must work perfectly together to achieve maximum safety and compliance during flight.

Estimations of transfer functions can be made using advanced 3D computational codes for the solution of Maxwell's equations. Different codes implement or even combine different frequency or time domain methods of finding solutions to these equations in differential or integral form. However, the simulation of the hazards is very complex and involves a detailed understanding of the topics and problems involving electromagnetic interactions and the limitations of the method used. The increase in the number of frequencies of interest also makes a detailed simulation more difficult and increasingly error prone.

However, these measurements are a valuable tool for estimations of the internal high intensity radiated fields environment in the early stages of an aircraft's design, when no real aircraft is available. It is also important throughout the design phase to judge the effect of modifications to the aircraft's structure or during the preparations of final aircraft certification tests to identify the worst cases and therefore reduce the amount of testing required. ▮

Dr Martin Gabrišák is head of EMCC Labs and Steffen Loos is deputy head of aerospace and defence at EMCC

NEW ANALOG 6DOF SENSOR

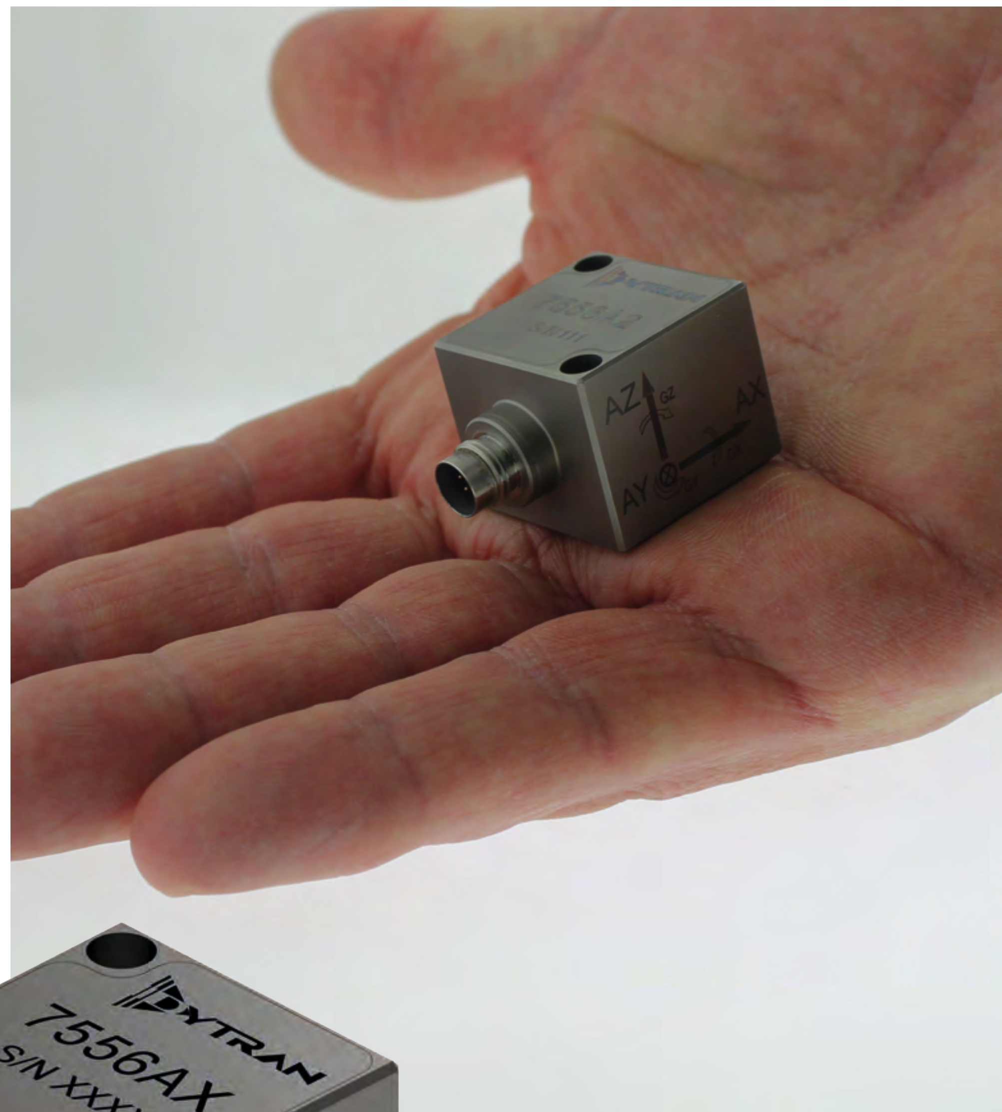
The versatile analog sensor from Dytran Instruments measures six degrees of freedom and is easily installed for a wide range of applications in testing

BY DAVID CHANGE

Since 1980, Dytran Instruments has successfully designed and manufactured piezoelectric sensing technologies, including dynamic accelerometers, pressure transducers and force sensors, to support a range of demanding customer applications and testing program requirements.

Dytran sensors are used in a variety of aerospace and automotive testing applications, such as: noise, vibration and harshness (NVH); component durability; modal and structural analysis; squeak and rattle evaluation; road load data acquisition; transmission, powertrain and exhaust manifold testing; ride quality and durability; and whole-body and hand-arm vibration measurements. In response to a growing number of customer requests for expanded offerings to support low-frequency vibration applications, Dytran has created a new analog 6DOF sensor, series 7556AX.

The series 7556AX is a fully analog, 6DOF sensor containing a micro-electromechanical (MEMS)-based triaxial accelerometer, as well as three MEMS-based gyros. The sensor provides the end user with X, Y, Z acceleration (*g*) data, as well as rotational information (roll, pitch, yaw expressed in degrees/sec) around three orthogonal axes.



The 7556AX sensor produces a single analog output per measurement channel. There are six measuring channels available for X, Y and Z directions (acceleration along the axis and rotational rate around the axis). The sensor is powered with any power supply that is capable of producing voltages from 5V DC to 30V DC with at least 12mA of current. All six outputs of the sensor are 'zero volts output for zero engineering units input', which means when zero acceleration or angular rate is present, the sensor outputs zero volts nominally. Some minimal offset is present due to analog component tolerances, but this is precisely measured and reported on the calibration certificate. The voltage output from the sensor depends on the measurement and can swing around zero volts, and as high as ±1.2V.

The 7556AX has a basic sensitivity of 200mV/g for the acceleration output and 1mV/degree/sec for the gyro outputs. The sensor, weighing 25g, comes in a compact, lightweight,

rugged, titanium, hermetically sealed package for harsh environment survival. It also has a removable cable for convenience during installation and removal from the test article.

Dytran recommends its cable 6445AXX, which has a nine-pin connector to the sensor and seven BNC connectors for power and signals to the data acquisition system. Optionally, the 6964AXX cable (with flying leads) can be used. Cables up to 15m (50ft) can be used. For longer runs, check each individual installation for the voltage drop at the sensor side; use of a higher voltage power supply (per the specification) is recommended.

This sensor is designed for two 0.175in-diameter mounting holes. If the sensor is mounted with adhesives, its calibration cannot be guaranteed. The selected (or prepared) mounting area should be flat to within .001in TIR for best high-frequency response.

Before mounting, be sure to clean the mounting surface thoroughly to avoid inclusion of machining chips and other debris between mating surfaces. Intimate contact between mating surfaces is important for best performance. If a fair amount of motion is expected during the test, it is good practice to tie the cable down to a stationary point as close as possible to the sensor (but not closer than 1in) to avoid potentially damaging cable whip.

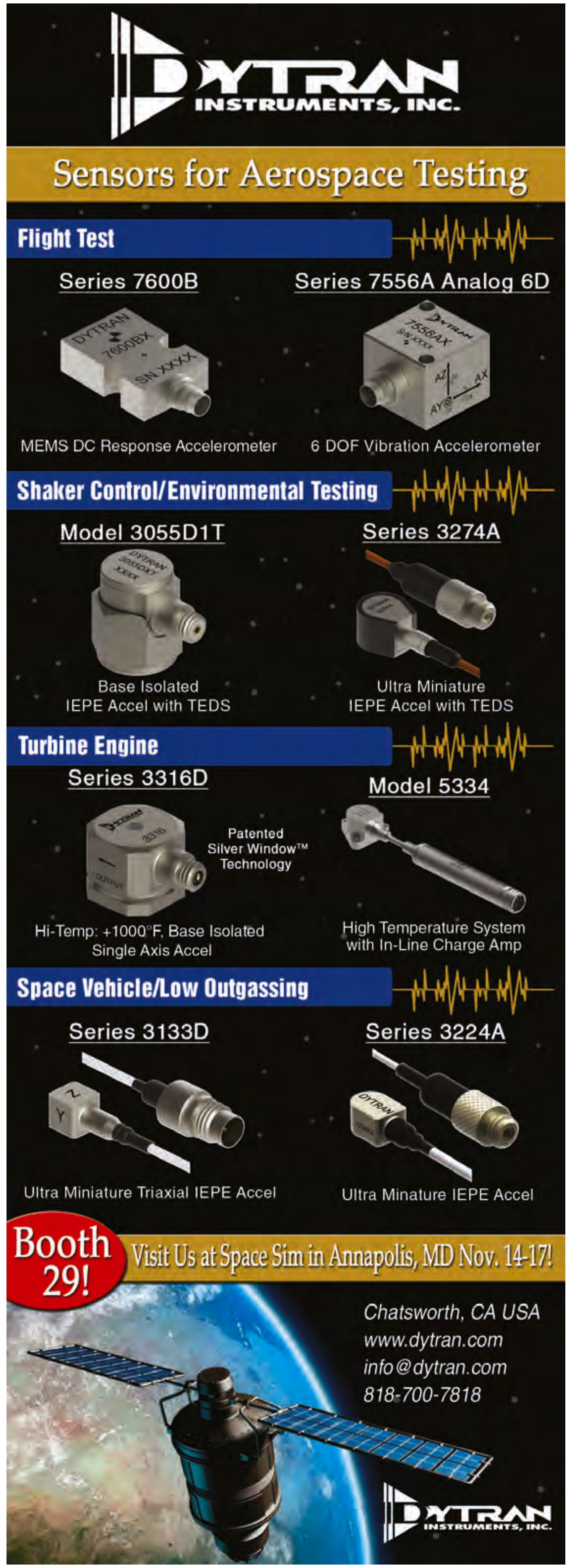
Uses for the 7556AX include, but are not limited to, the following test applications: vehicle dynamics, ride/handling, rollover, automotive safety, aerospace testing, large machinery including industrial off-road, aircraft flight dynamics, aircraft ground test, helicopter evaluation, amusement ride, and playground surface investigation.

Dytran has built a solid reputation for trusted, field-proven experience in the design and manufacture of sensors for dynamic testing. Today, the company is adapting new sensor technologies to broaden the product line and to better serve customers across the dynamic measurement spectrum. ∎

David Change is vice president and technical director for Dytran Instruments

ABOVE: The Dytran 6445AXX sensor is compact and easily connected to data acquisition systems

LEFT: The sensor's small size enables easy mounting in numerous locations

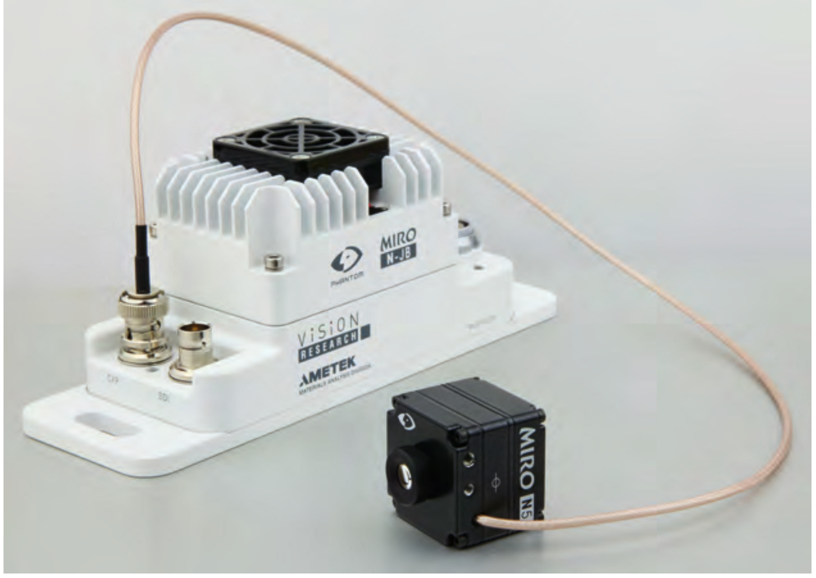


TINY CAMERA, BIG IMPACT

The newest camera from Vision Research is small, rugged and fast, and designed to capture critical information in previously inaccessible spaces

BY DOREEN CLARK

Technology must advance to meet humankind's demand for knowledge. Information and data from situations or environments that are difficult to reach is critical to that goal. How do researchers access smaller spaces and hostile environments to obtain the data required to push projects past the current ceiling? They find the proper tool for the job.



ABOVE: The new Miro N-Series head and N-JB base

PHANTOM MIRO N-SERIES

Enter the Phantom Miro N-Series, by Vision Research. This tiny, high-g (tested to 150*g* shock) camera enables researchers to access and record previously unattainable but critical information from an event. The camera head may be small, measuring just 32mm x 32mm x 29mm, but the high-speed imaging capabilities are not. The Miro N5 captures 560 frames per second (fps) at a maximum resolution of 768 x 600 and is capable of over 1,000fps at 512 x 472. At even lower resolutions, the Miro N5 camera can achieve over 9,000fps. The N-Series is a member of the Phantom Miro family of cameras, which enables application customization and flexibility. That means this powerful little camera is compatible with the Miro Junction Box (J-Box) and is easy to synchronize with other Miro cameras.

The tiny Miro N-Series also boasts the same important Phantom features as can be found in all Phantom cameras. Extreme dynamic range (EDR), used for shooting high-contrast events, is often key when discussing aerospace applications. When recording great differences in brightness, such as a rocket blast or an explosion, EDR delivers the proper balance of exposure to keep dark areas detailed while bright areas do not become overexposed.

A Phantom feature that will aid in recording in small spaces is the ability to set the Image Based Auto Trigger (IBAT). IBAT enables researchers to set the camera to trigger the instant the image being recorded changes. This feature ensures that if a researcher cannot see an event occur, due to size limitation, the event itself will tell the camera to trigger and save the recorded information. Another level to this is that in a similar situation, the camera can also send a message to the J-Box to tell all other synchronized cameras to trigger and save their data.

LEFT: A Phantom camera captures payload take-off

DATA SECURITY

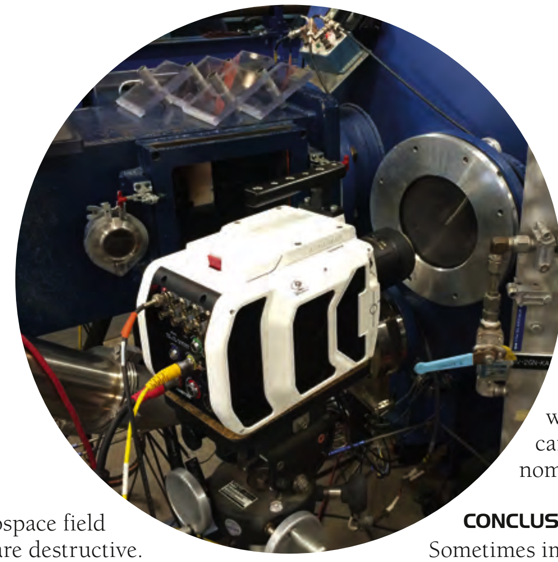
Recording in harsh environments raises concerns for the safety of the data. The Miro N-Series solves this problem by incorporating the use of a detached camera base – the Miro N-JB base – a CXP cable and the CoaXPress protocol. The camera head can be placed up to 10m from the base, allowing researchers to position the camera where they see fit. The base can then be placed up to 60m from a J-Box for even more distance possibilities.

If the camera head is destroyed or the cable is severed during recording, all images including the last one captured before destruction will be safely and stored in the Miro N-JB base via the CXP cable. The base stores all the images, ensuring that the data is safe.

The Miro N-JB base's primary function – securing data – is reinforced through the 8GB RAM and 128GB non-volatile CineFlash. The camera can be set to save automatically to the CineFlash to ensure that images are safely stored until they can be retrieved. The base also has battery backup. In the case of a power loss during an event, the battery activates and will feed power to the camera until all critical data can be properly saved.

AFFORDABILITY

Quite often in the aerospace field the events that occur are destructive. Explosions, crashes, high g forces and more can all place stress on the cameras used in high-speed imaging. That raises the important question of affordability. High-speed cameras are a valuable resource and researchers do not want to risk their safety to capture a single event. The Miro N-Series addresses the destructive possibilities of aerospace study by separating the camera head from the base. If a destructive event occurs, only the head will be destroyed and can be replaced at a nominal cost.



ABOVE: Phantom ultra high-speed camera being used in astronaut gear safety tests

CONCLUSION

Sometimes important phenomena occur faster than the human eye and in places impossible to see. These can happen at the most dangerous time of an event - just before combustion or impact. Until now, scientists and engineers drew conclusions without the aid of images. Now the Phantom Miro N-Series helps technology advance one more step. ▮

Doreen Clark is senior product manager with Vision Research

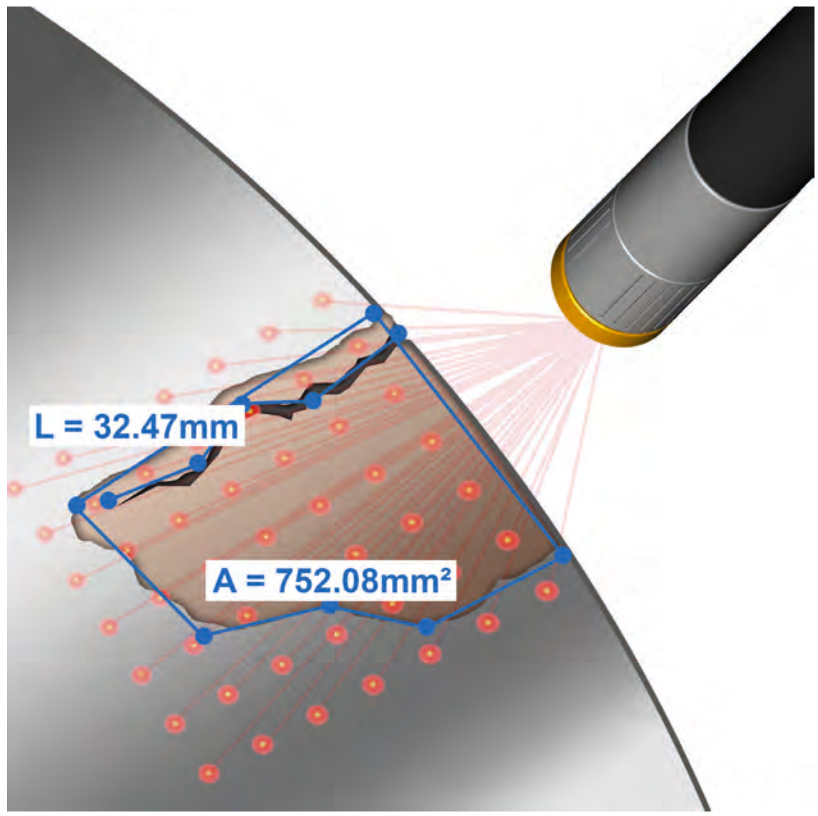
CHANGING THE FACE OF RVI

In remote visual inspection, time is money and image is everything. This applies particularly to the aerospace industry, where decisions to fix or fly are based upon the accuracy of the results

BY TRISTAN WILLIAMS AND KLAUS HAMMERL

The clue is in the name where Remote Visual Inspection (RVI) is concerned. This is an examination technique for wholly inaccessible areas; its technology enables the user to inspect parts of a pipe, engine, gearbox, bearing or similar that would otherwise be impossible to view. Using RVI means inspections can be carried out without dismantling an entire assembly. So great are its benefits that it is proving increasingly popular, with multiple applications in different technological groups. From a maintenance, repair overhaul (MRO) perspective, this technology provides a detailed and accurate measurement of the engine/airframe internal components, among them blade/vane erosion, dents, 'V'-nicks, combustor liner cracks or erosion, and fuel nozzle wear.

Karl Storz believes that engineers should have the most accurate information in the shortest time possible, faced as they are with an increasing emphasis on 'on-condition' monitoring and the enormous responsibility involved in, for example, the decision to remove an engine or allow it to continue in service.



ABOVE: Multipoint 3.0 uses a 3D laser system with 49 points

MEASURING SUCCESS

Historically, remote visual inspection was used mainly for visually locating a defect in an inaccessible area. Today there is a much greater emphasis on being able to see and actually measure the defect. This has been driven primarily by the aviation market and its need to ensure airworthiness and operational safety. Maintaining the operational uptime of turbines and aircraft is absolutely key. Inevitably, this has placed an emphasis on faster turnaround times in MRO workshops. From an engine perspective, maximization of 'time on-wing' is now viewed as one of the primary objectives for stakeholders, among them airline operators, lessors, MRO providers and turbine OEMs. Therefore, borescope and videoscope inspections are key enablers in supporting safety, performance and quality control of turbines and other important airframe structural parts.

LASER-BASED MULTIPOINT SYSTEM

In 2007 Karl Storz launched a proprietary laser-based measurement technology called Multipoint. It was the first solution in the market with the 'see and measure' concept, which enabled fast measurement results and a full-scale view without the need to change measurement tips, leading to significant workflow improvements. Multipoint uses a 3D laser system with 49 laser points, allowing the camera, in cooperation with the software, to detect the surface structure of the subject area being examined.

Current understanding of this sector shows that the holy grail of measurement technology – suitable for every kind of measurement task and application – does not exist at the moment. This will drive measurement technologies forward at an increasing pace and complexity.

The Karl Storz laser-based Multipoint measurement technology provides extremely precise, certified, calibrated measurement results. It now offers enhanced three-dimensional depth measurement processes. Automatic 3D plane detection supports users in operating the system to allow easy and rapid measurement. The new Multipoint 3.0 measurement software can perform up to eight types of measurement. These include its existing depth, height, length, area and line-to-point measurement functions, and the Multipoint also offers 3D surface, tip curl and blade clearance measurements to enable operators to obtain optimal measurement of gap and angle dimensions.

Since the position of the measuring videoscope within the object cannot always be precisely determined, it is crucial to ensure that measurements are unambiguous. The Multipoint enables absolute measurement precision for areas within the maximum measuring distance, and automatically compensates for the parallax error caused by videoscope tilt and at distances of up to 80mm. It can even deliver exact measurement results in cases with strong vibration and in heavily soiled environments. This simplifies users' work processes and provides a higher degree of process confidence. The technology has also been miniaturized and is now available in a 4.4mm diameter tip.

TIME IS MONEY, IMAGE IS EVERYTHING

RVI exists to save time and money. The requirement for cost saving will drive the RVI sector to complete more complex tasks in less time. This will occur only if the imaging improves and the increasing requirement for better resolution, connectivity and guided software will inevitably change the face of the remote visual inspection market as it stands (image is everything).

The future RVI market will see more compact, more versatile equipment providing smarter processing and reporting, and offering increasingly reliable measurements. ∎

Tristan Williams is manager, industrial group (RVI) with Karl Storz Endoscopy (UK). Klaus Hammerl is director, product management, industrial endoscopy, Karl Storz, Germany

BELOW: A technician demonstrates the Multipoint 3D laser system before doing an inspection

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DAUtec GmbH........ 21
DEWETRON GmbH........ Inside Back Cover
dSpace GmbH........ 5
Dytran Instruments........ 143
EMCCons Dr. Rasek GmbH & Co KG 141
European Test Services BV 139
FMV 135
Gantner Instruments 89
GOM – Gesellschaft für Optische
Messtechnik mbH........ 133
HGL Dynamics Ltd 73
IMV Corporation 15
Intellifast GmbH........ 101
Intertek 119
KARL STORZ GMBH & CO KG........ 147
Kistler Instrumente AG .... Outside Back Cover
Lansmont Corporation 95
Link Engineering Company 131
M+P International Mess-und Rechnertechnik........ 65
Matec Instrument Companies Inc 34
MK Test Systems........ 113
MTS Systems Corporation 37
Müller-BBM VibroAkustik Systeme GmbH........ 7
North Star Imaging 69
Olympus Scientific Solutions Americas........ 49
PCB A&D 123
Precision Filters Inc 125
Purdue University 2
Resonate Testing Limited 12
Siemens Industry Software NV........ 27
Space Electronics LLC 41
TEAC Europe GmbH 107
TEC Materials Testing........ 111
TechSAT GmbH 57
Tecnatom SA 117
TecScan Systems Inc 109
Teletronics Technology Corporation (TTC) 97
TESTIA (Formerly NDT Expert)........ 115
TotalTemp Technologies Inc 105
Treo – Labor fur Umweltsimulation GmbH 34
Unholtz-Dickie Corp 85
Vector Media Services OHG........ Inside Front Cover
Vibration Research 77
Virginia Panel Corporation........ 18
Vision Research........ 145
W5 Engineering 45
Wichita State University 137
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Yxlon International GmbH........ 61

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