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SHOWCASE 2015

AEROSPACE TESTING INTERNATIONAL

2015 SHOWCASE

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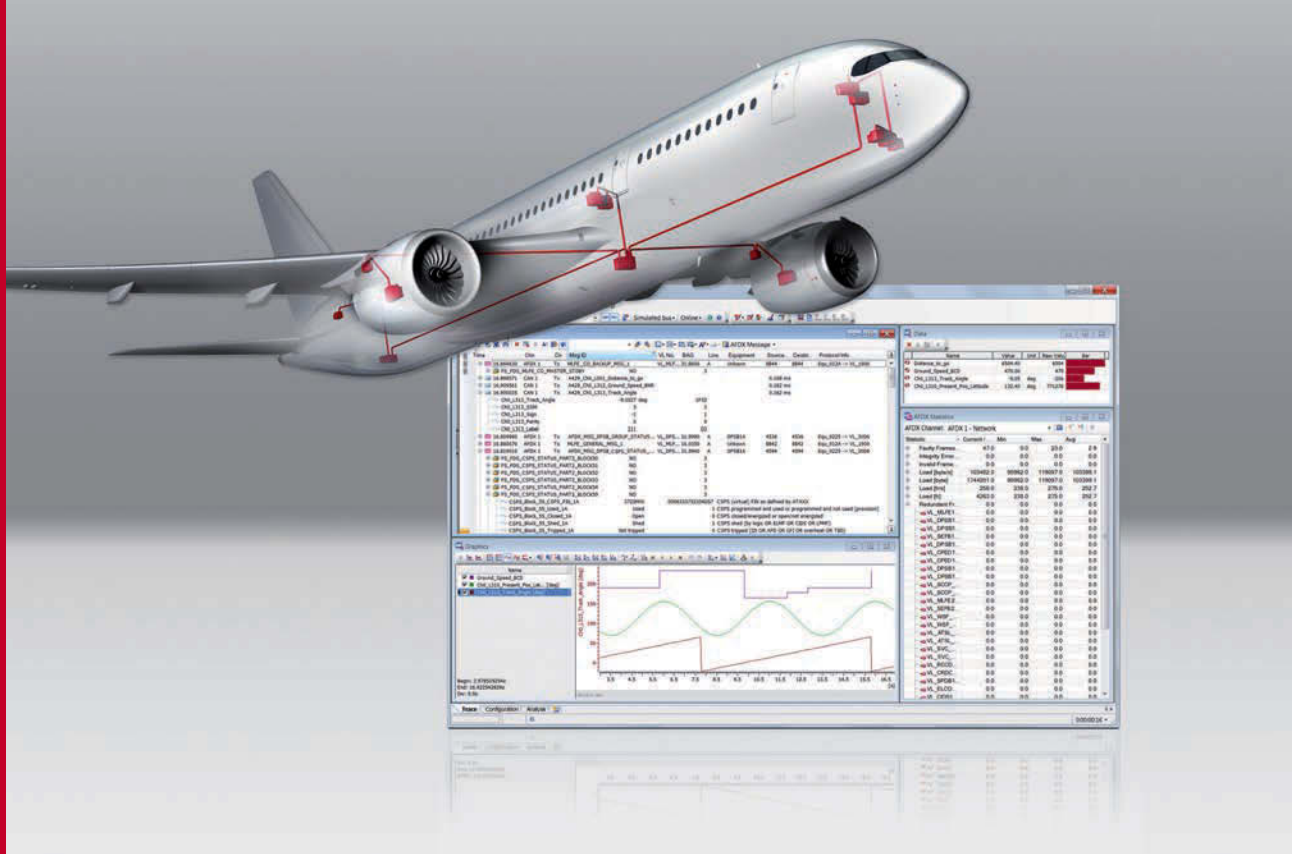


The space race gains pace... again!

Aerospace is an industry that evolves rather slowly, but of late there seems to have been an acceleration up into the air, much of which I put down to the demise of the Space Shuttle, some of which must be put down to East/West relations. This marks an upward curve in aerospace development – a technological hiatus.

Last year and the year before, our Showcase issues focused on composites. This year it is different – the primary aim is to bring readers up-to-date on the latest technologies. I think the aerospace industry is going hypersonic – and that is metaphorically and technologically true.

The US Defense Advanced Research Projects Agency, along with aerospace and defense contractor Lockheed Martin, has strapped a 360° laser turret to a jet for the US military's first test of laser-equipped military aircraft defense. Lockheed, the Air Force Research Laboratory, is working on the joint project for the Pentagon's forward-thinking research arm, the end goal being 'to give 360° coverage for high-energy laser weapons operating on military aircraft' via the Aero-adaptive Aero-optic Beam Control (ABC) turret.

So far, the company has conducted eight test flights of the turret, which is designed to enable high-energy lasers to engage enemy aircraft and missiles above, below and behind the aircraft, according to Lockheed's website.

This is something I could not have imagined even a decade ago. The initial tests verified the turret's airworthiness, apparently due to Lockheed's 'flow control and optical compensation technologies', which prevent turbulence affecting the aircraft that would otherwise be caused by the fuselage-protruding weapon.

But bigger than this, composites, winglet design and engine development is in the race back into space. You can list 100 reasons why – from the problems in Ukraine to commercialization, from technology to a belief that the world will end – we are going back into space, and not just on a Soyuz rocket. Just this week, as this issue went to press, there are countless stories about this, including on the commercial side. The space race is shaping up as a match of billionaires, with Jeff Bezos, founder of Amazon, facing off against Elon Musk, founder of SpaceX and Tesla, over the future of human spaceflight. Blue Origin, a private space company owned by Bezos, says it has agreed to work with a joint venture run by Boeing and Lockheed Martin to build new engines for the Atlas V rockets.

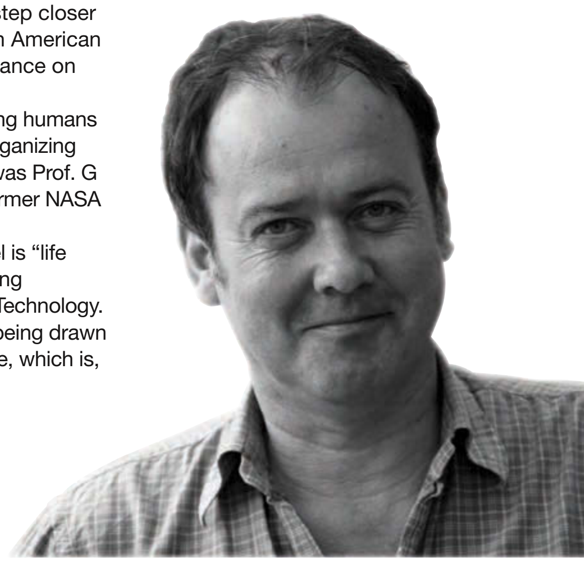
Then there is the political side: Boeing will receive a US$4.2bn Commercial Crew Transportation Capability contract to continue development of the company's CST-100 capsule, while SpaceX will receive US$2.6bn to press ahead with work to perfect its futuristic Dragon crew craft. NASA administrator Charles Bolden says, "From day one, the Obama administration has made it very clear that the greatest nation on Earth should not be dependent on any other nation to get into space. Today we're one step closer to launching our astronauts from US soil on American spacecraft and ending the nation's sole reliance on Russia by 2017."

Just recently one academic said, "Sending humans to Mars around 2033 should be the single organizing principle of future space exploration." That was Prof. G Scott Hubbard of Stanford University and former NASA Ames Research Center director.

Stephen Hawking noted that space travel is "life insurance". Bio-suits for space travel are being designed by the Massachusetts Institute of Technology. More and more institutions and nations are being drawn together to strive beyond Earth's atmosphere, which is, let's face it, a good thing.

From whichever soil rockets take off, the competition is well and truly back on…

Christopher Hounsfield, editor



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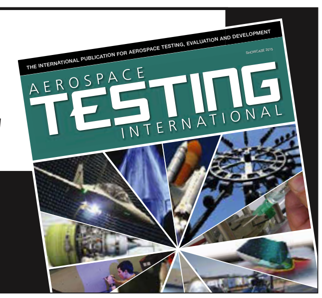
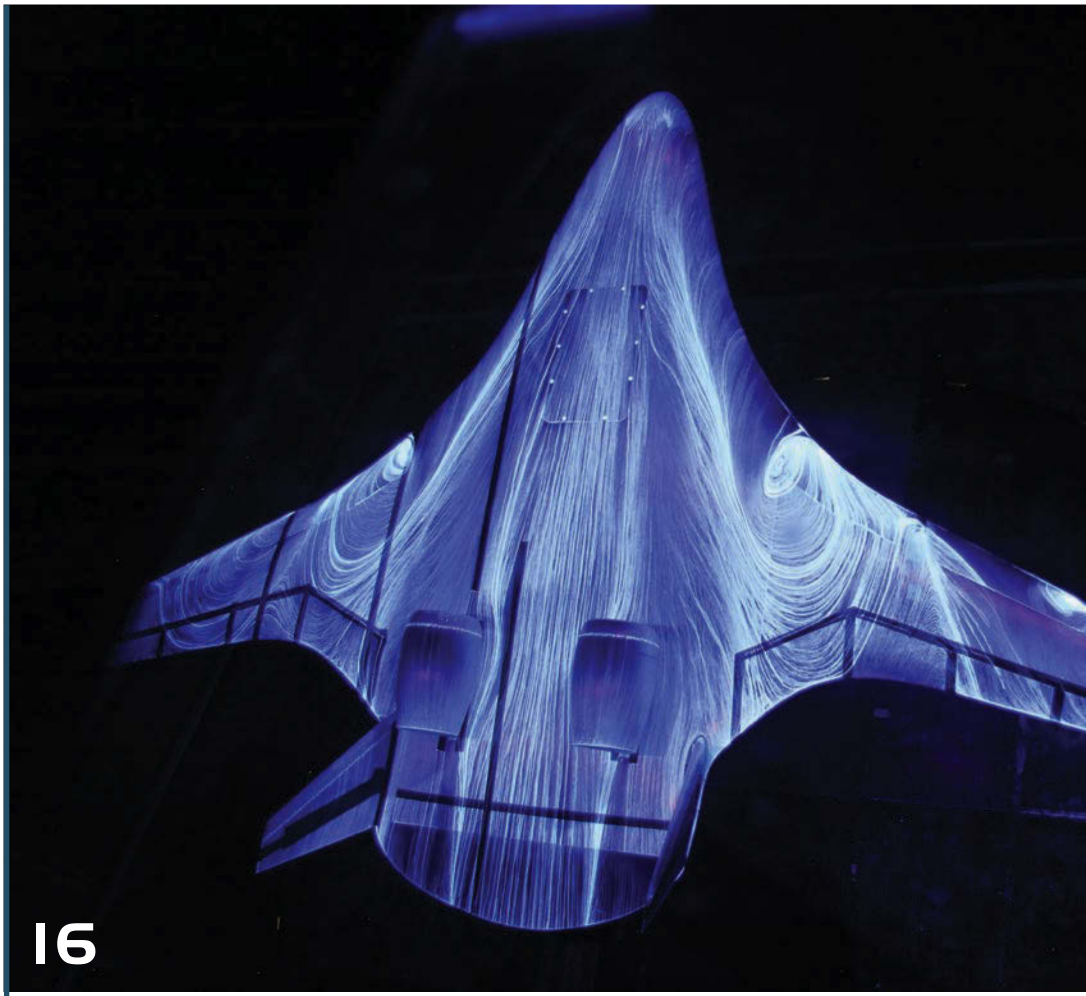
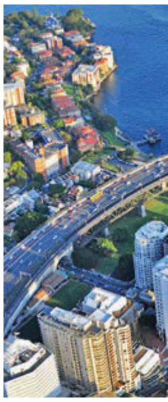
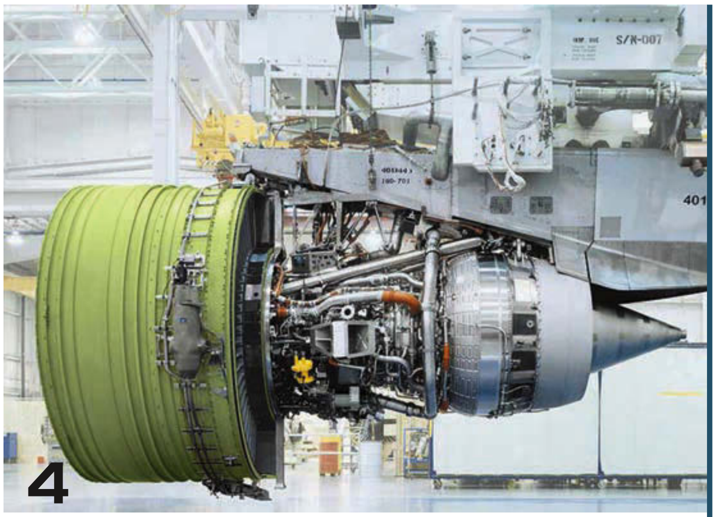


Contents



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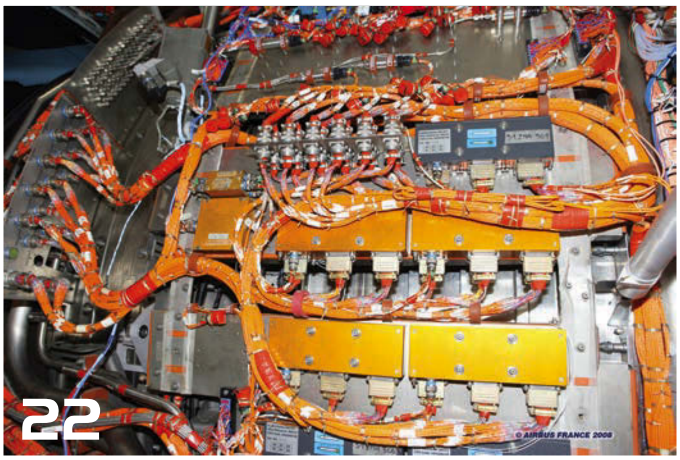
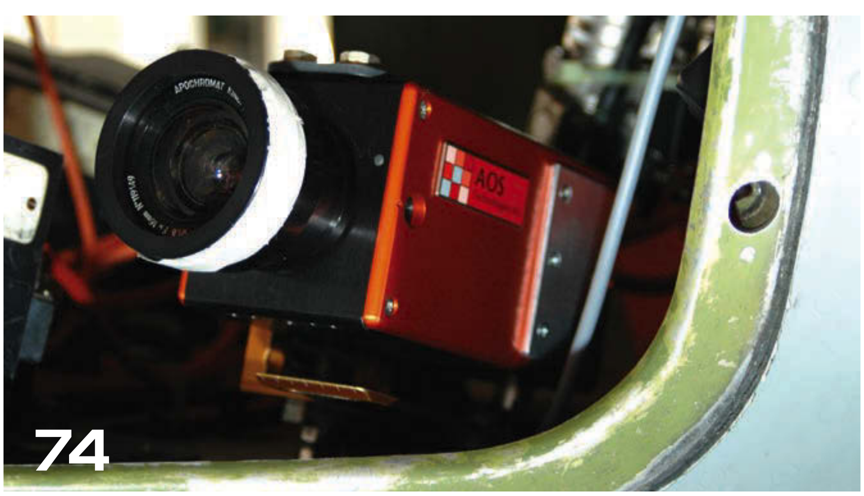

22


34


40

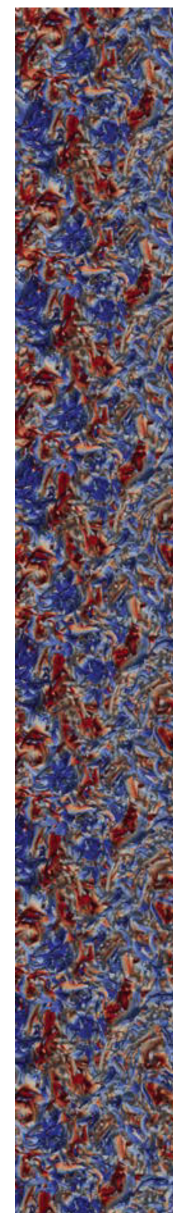

74


RICHARD SANDBERG

FIGHT THE FLOW

The University of Southampton in the UK, in collaboration with GE, gives an insight into the physics of turbulent flows inside the turbines of aero-engines

BY RICHARD SANDBERG



Researchers in the UK from the University of Southampton and General Electric are using large-scale computer simulations to shed new light into the physics of turbulent flows inside the turbines of aero-engines.

One of the greatest challenges to modern computational fluid dynamics is the accurate simulation of turbulent phenomena in complex environments, such as aero-engines. This is important because turbulent phenomena can have catastrophic effects on the lifetime performance of aero-engines. Capabilities for predicting these effects are hugely important for the development of the next generation of highly efficient aero-engines.

One of the most important components of an aero-engine is the turbine directly downstream of the combustion chamber, which must withstand extremely high pressures and temperatures. This so-called high-pressure turbine (HPT), is subjected to gas temperatures, which can be of the same order of the melting point of the steel/nickel alloys used for the turbine components. The surfaces exposed to these hot gases (rotor, stator and endwalls) are protected by specialist coatings and cooler gas, which is ejected through holes on the surface to create a protective film of air. The rotor and stator blades also have networks of complicated internal passages for internal cooling air.

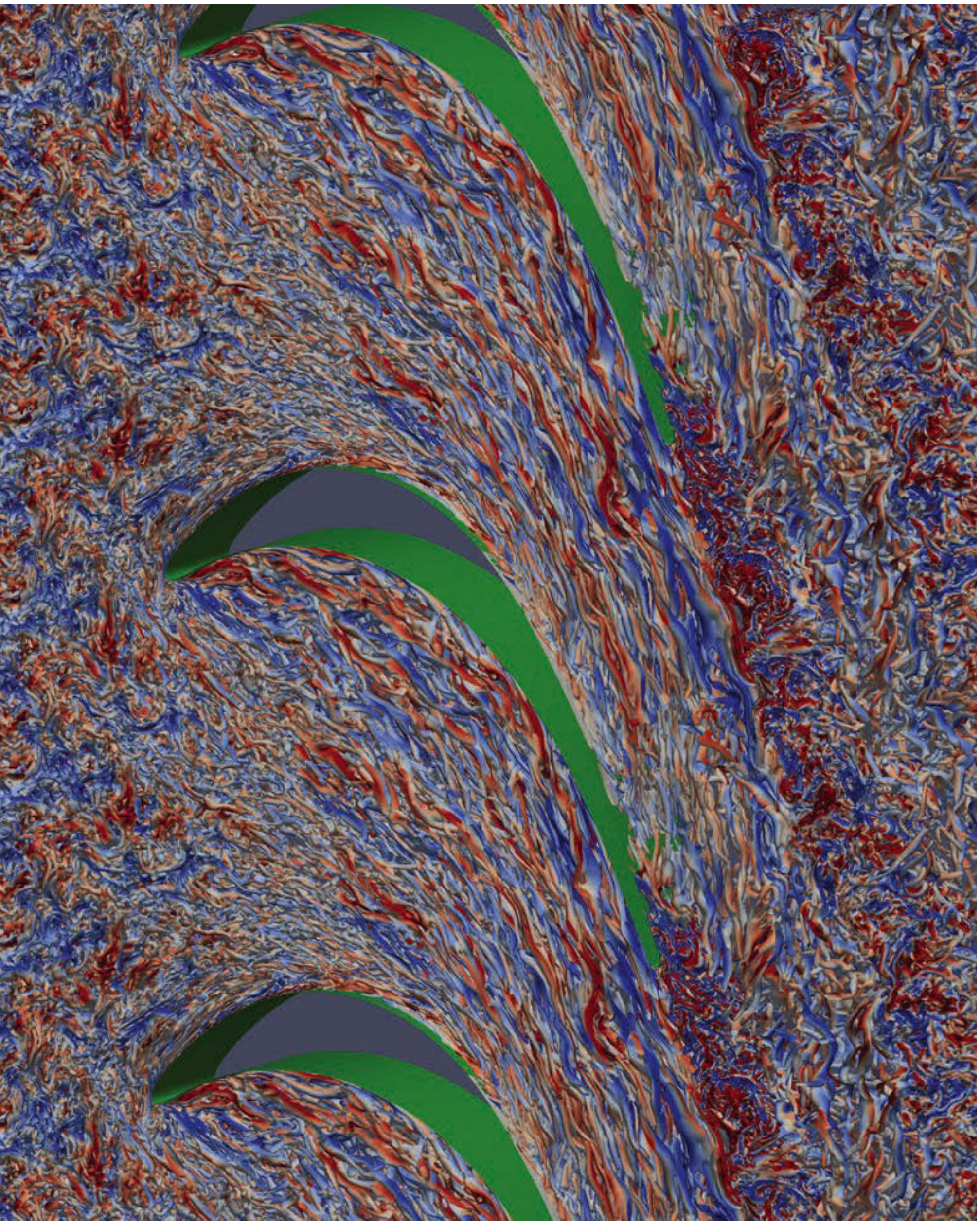
AERO-ENGINE ARCHITECTURE

Regardless of the choice of future aero-engine architecture (be it turbofan, open-rotor, or geared turbofan), the outlook for the next generation of aero-engines will almost certainly require large increases in gas temperatures within the HPT and managing the increased heat loads will be an enormous challenge. This is where an understanding of the flow physics plays a very important role, since we know that the generation of turbulent eddies is one of the most important ways in which heat is transferred to the blade surfaces. We also know that generation of turbulence affects the power delivered from the turbine – and therefore the efficiency.

Turbulence exists in many forms within the HPT, and its nature and effects on HPT performance are by no means fully known. A large amount of turbulence comes from the upstream combustion chamber because of the highly unsteady flows, which are generated during the combustion process, and the complex shape of the combustion chamber. As the turbulent flows from the combustion chamber pass through the HPT, the acceleration and turning of the flows distorts and stretches this turbulence. This so-called free-stream turbulence can trigger further turbulence generation near the blade surfaces, which increases the heat transfer and can also reduce turbine efficiency. The flow is also transonic, which means the flow speeds are close to the speed of sound, and as a consequence shockwaves are often present, which can create or amplify turbulence. There is also a strong interaction of stationary and rotating blades, which creates a rather unsteady and non-uniform flow field. There are many other ways in which turbulence is generated within the HPT, and many of these are not fully understood.

The fact that large parts of the flows within the HPT are turbulent presents probably the most difficult challenge for accurate computer simulations. This is because turbulent flows are characterized by the presence of a large range of length and time scales of the eddying motions and their multiscale interactions. The range of sizes and frequencies of eddies and their interaction is increased with larger characteristic length of the flow (e.g. turbine blade chord, higher speed of

"ONE OF THE GREATEST CHALLENGES TO MODERN COMPUTATIONAL FLUID DYNAMICS IS THE ACCURATE SIMULATION OF TURBULENT PHENOMENA IN COMPLEX ENVIRONMENTS, SUCH AS AERO-ENGINES"



LEFT: Turbulent flow through a linear low-pressure turbine cascade at real engine conditions

FAR LEFT: The GE90 engine, specifically designed for the Boeing 777, is the world's most powerful turbofan engine

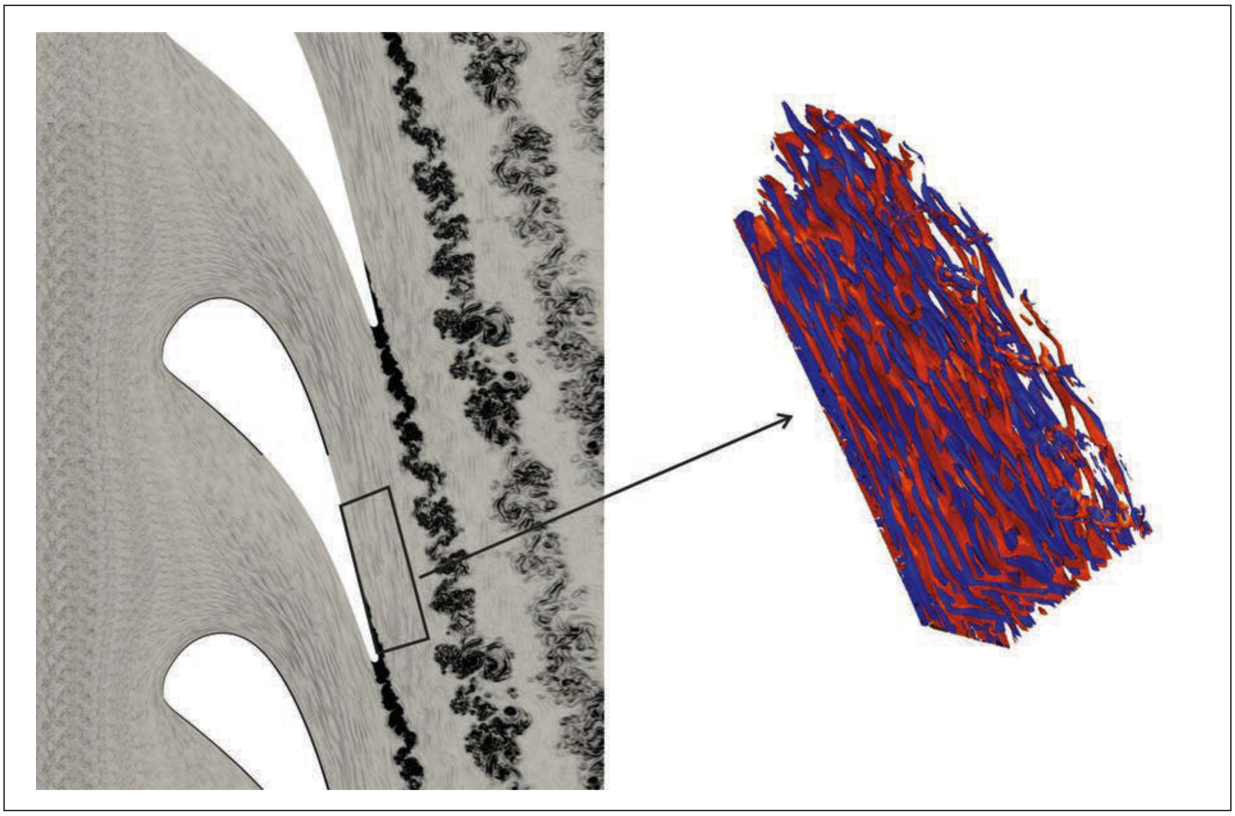
the flow, or a decrease in the viscosity of the fluid) and leads to more complexity. This escalation in complexity is captured by a single non-dimensional number: the Reynolds number, Re, which is proportional to the ratio between the largest and smallest length/time scales of the flow. The Reynolds number can also be interpreted as a measure of the importance of inertial forces compared with viscous forces.

NAVIER-STOKES EQUATIONS

One approach for obtaining detailed information about flow inside turbines is to conduct numerical simulations. The Navier-Stokes equations, a set of non-linear coupled partial differential equations, based on first principles, govern the behavior of the flow and can, using appropriate numerical methods, be integrated directly to obtain accurate flow predictions. These so-called direct numerical simulations (DNS) are therefore free of modeling assumptions.

However, the challenge lies in the need to resolve all the relevant scales of motion. This requires large computational domains with closely spaced points and long computational times with very small timesteps. It can be shown that the computational effort required to fully resolve all length and time scales of turbulent flows increases approximately with Re3, which means that a modest increase in Reynolds number results in a significant increase in computational power and long simulation times.

A remedy for this problem is to rely on turbulence modeling. In large eddy simulations (LES), only the larger and slower motions are simulated, while the scales that cannot be resolved are modeled. Nevertheless, although



LEFT: Snapshots of the simulated flow through the turbine vane row

modeling the small scales can considerably reduce computational effort, LES remains computationally very costly in high Reynolds number wall-bounded flows. This is because the scales that need to be resolved by the simulation to satisfy the inherent model assumptions become increasingly small when approaching the wall. Thus, LES does not offer large savings over DNS in wall-bounded flows despite introducing model uncertainties.

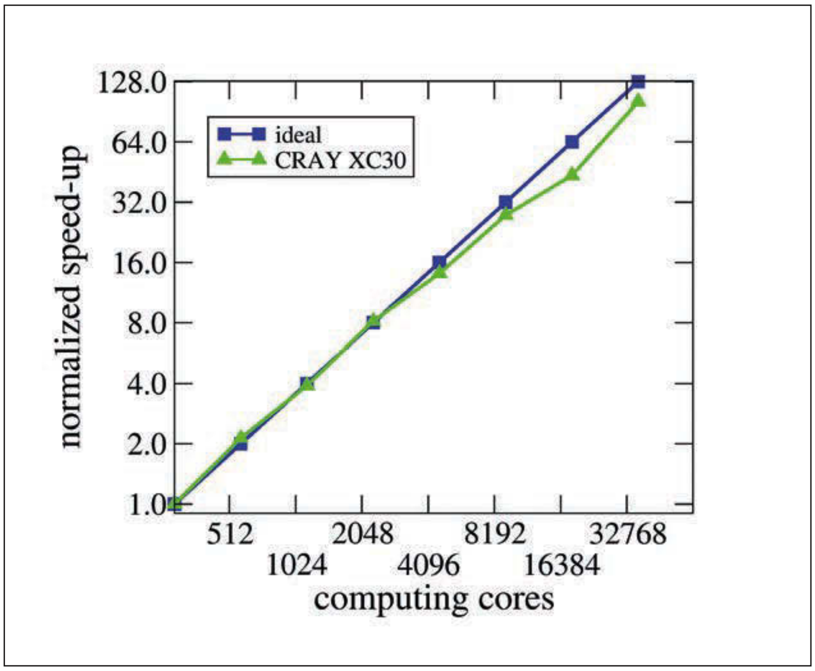
To date, the only practical solution for affordable simulation of turbulent flows in an industrial context has been to model the entire range of turbulence scales. This approach – called Reynolds-Averaged Navier-Stokes (RANS) – has been able to deliver reliable results for many flows encountered in applications of engineering interest. RANS approaches do not require the calculation of any turbulent fluctuations and are only concerned with the evaluation of mean flow quantities, reducing the computational cost by several orders of magnitude. However, the price for this reduction in computational effort is loss of predictive accuracy due to deficiencies in the turbulence models that need to represent the effect of all spatial and temporal fluctuations on the mean flow. There are many situations where even the most sophisticated RANS models do not perform well. These include, but are not limited to, streamline curvature, separated flows, complex three-dimensional geometries and transition to turbulence, all of which can occur in high-pressure turbines.

Despite the known inaccuracies of RANS- or LES-based approaches, virtually all computational work of HPT flows up to now has used methods that rely on turbulence models. It is well known that turbulence models fail to capture the correct flow physics, particularly where turbulent mixing is significant, such as in convective heat-transfer processes, which determine HPT blade heat load. Mixing also affects the strength of convecting phenomena, such as stator wakes, which interact with the rotor blades. This is exacerbated in a multistage machine where wakes and turbulence convect into the downstream stages, affecting the turbulence intensity and unsteadiness throughout the machine. Experimental measurements of turbulence properties within the HPT are lacking due to the difficulties of performing engine-scale experiments; most data has focused on time-average effects and the propagation and generation of turbulence within this environment is not well known. Hence, laboratory data does not provide enough depth to identify fundamental weaknesses of RANS and LES, and possible ways to improve turbulence modeling.

JOINT RESEARCH PROGRAM

The joint Southampton research team, led by Richard Sandberg, professor of fluid dynamics and aeroacoustics, and including Dr Andrew Wheeler and Professor Neil Sandham, in collaboration with researchers at GE, have set up a program to conduct fully scale resolving DNS of high-pressure turbines. The reward for facing the numerical challenges and expending enormous computational resources to perform DNS is the generation of a

RIGHT: Speed up of simulation code for a problem with 1.5 billion grid points on a CRAY XC30 supercomputing facility (ARCHER)



wealth of reliable data free from modeling uncertainties, which can be used to answer basic questions regarding the physics and for determining the validity of current turbulence modeling approaches.

The first-ever direct numerical simulations for an HPT configuration at transonic conditions and a Reynolds number of 500,000 are currently ongoing. In order to fully resolve the flow, the computational domain is discretized with close to one billion grid points for a single blade and passage. In order for the flow to advance through the HPT for a sufficiently long time to gather converged statistical quantities, such as heat transfer coefficient or losses induced by the blade, the governing equations need to be evaluated on every single spatial point for at least one million times – so-called timesteps. The vast number of numerical operations that thus need to be performed require a simulation code that can exploit large-scale supercomputers. Prof. Sandberg says, “For this project, we are using software that has been developed at Southampton and is proven to be highly efficient for large parallel computations.”

The graph above, demonstrates that the numerical code used achieves considerably higher speed when increasing the number of computing cores. For a simulation with 1.5 billion grid points, the speed-up factor of the code was very close to the ideal for a range of computing cores. In particular, when using 49,152 cores, the simulation ended 103 times earlier than when using 288 cores. This considerable reduction in wall time, enabled by large-scale supercomputing facilities and software tailored to exploit them, is what makes DNS of HPT configurations at engine conditions possible. The team has been awarded 35 million hours of computing time on a supercomputer in Stuttgart, Germany, through a grant from the Partnership of Advanced Computing in Europe (PRACE). The team has also received a grant in the US for another 10 million CPU hours on the world’s second-fastest supercomputer (Titan) at Oak Ridge National Laboratory. The combined allocation corresponds to more than 5,000 years of computing on a single processor, or more than 600 years on an 8-core desktop, provided it had sufficient memory to fit the simulations.

The figure on page 7 shows an example of the calculated flow fields. The picture on the left shows a snapshot of the flowfield as observed on a spanwise (two-dimensional) plane. Regions of high vorticity magnitude are shown in darker shades of grey, and these occur wherever turbulence is being generated near the surface of the blades and in the wakes downstream of the blades. The picture on the left shows a three-dimensional snapshot of the structure of the turbulence near the blade surface over the aft portion of the blade. The turbulence is characterized by long streaky structures in this region. This region is important because this is where much of the turbulence is generated in-part due to strong pressure gradients within this region.

The simulations will be run for longer, until sufficient data is available to shed more light into the precise flow phenomena occurring in the HPT. It is paramount to address the urgent need to reduce emissions from aviation, and this work will be an important milestone in the development of the next generation of high-efficiency aircraft.

This project on fundamental mechanisms in turbomachinery flows is in close collaboration with GE Global Research, which is providing technical support and will play an integral part in the analysis of the data. GE is a world leader in aero-engine and turbomachinery technology and recognizes the requirement for DNS of high-pressure turbines for the development of future aero-engines. GE will be able to implement the results of this work throughout its international aero-engine business and therefore this work has the potential to deliver a significant change to global aviation. ▮

Richard Sandberg is a professor of fluid dynamics and aeroacoustics in the aerodynamics and flight mechanics research group at the University of Southampton, UK

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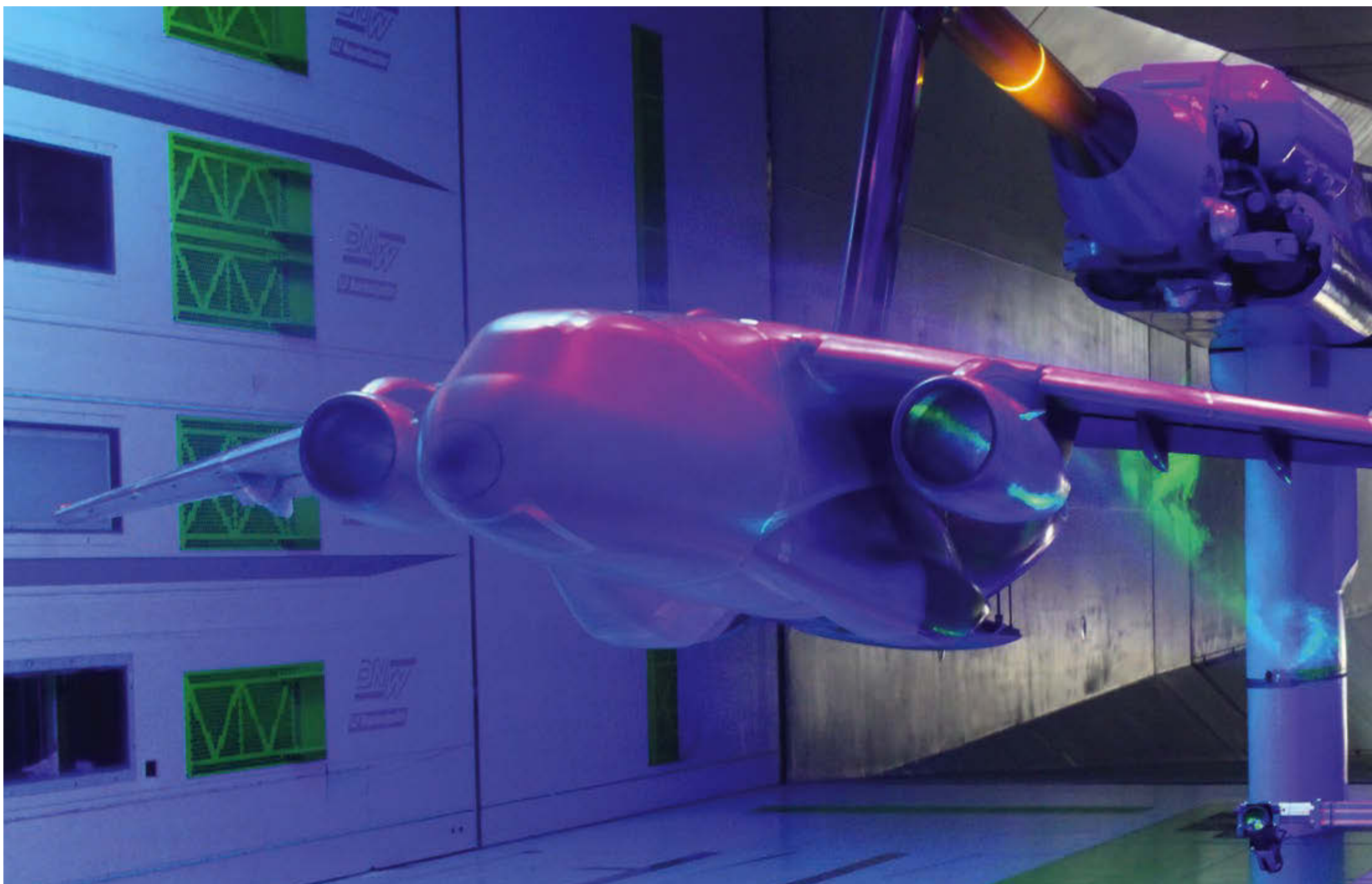
A HEAD IN THE WIND

DNW is the leading wind tunnel facility in Europe testing the latest aircraft and its managing director predicts a strong future

BY CHRISTOPHER HOUNSFIELD



MAIN: Embraer KC-390

LEFT: Georg Eitelberg is managing director of DNW and professor at the Delft University of Technology

"RECENTLY THERE HAVE BEEN ACTIVE ROTOR AERODYNAMIC AND ROTOR ACOUSTIC TESTS FUNDED BY THE EUROPEAN COMMISSION IN THE LLF"

In May 2014, Henk Kamp, Minister of Economic Affairs for the Netherlands, visited German-Dutch Wind Tunnels (DNW-LLF). After being welcomed by DNW director Prof. Georg Eitelberg, he was taken on a tour. The visit itself would be fairly normal, but it did highlight the huge importance of the DNW-LLF as part of the strategic European aerospace research infrastructure.

The landing and take-off performance and acoustic characteristics of the whole current Airbus aircraft family was tested at the facilities at large model scale, and testing projects are ongoing. Meanwhile, projects with other partners with regard to the next generation of propulsion systems, and the counter-rotating propeller are ongoing.

The DNW as an organization grew out of the two major national laboratories for aerospace research – the DLR and the NLR. These two organizations had decided in the late 1970s to achieve efficiencies by pooling their projects for a large low-speed ground test facility in a joint project and placed it in the hands of a single independent organization, a foundation under Dutch law. This was the start of the establishment of a joint new wind tunnel – the DNW-LLF – in the Netherlands, to which, over time, all large wind tunnels, previously operated by the parent institutes, were added.

THE MAN BEHIND THE TUNNEL

Georg Eitelberg is managing director of DNW and professor at the Delft University of Technology. "I am seconded from DLR, which, together with the NLR, is a parent institute of the DNW and legal owner of the German wind tunnels of DNW," he explains. "Both technological and commercial aspects of running the whole organization fall under my responsibility."

The organization's wind tunnels are used in different ways: some primarily in industrial product development processes and some used primarily for more phenomenologically oriented work. None of this is exclusive; the large industrially used tunnels like LLF and the HST are also used for research, and across other industries.

The tunnels can be classified according to the Mach number range. There is the low-speed range (HDG, KKK, LLF, LST, NWB) and the high speed range (HST, TWG, KRG). The high speed is related to the transport aircraft. For even higher speed, the Ludwieg tubes (RWG) are operated. On top of these continuous and blow-down wind tunnels, the company also operates the ECF, which is an engine calibration facility for the engine simulators, which are used with powered models.

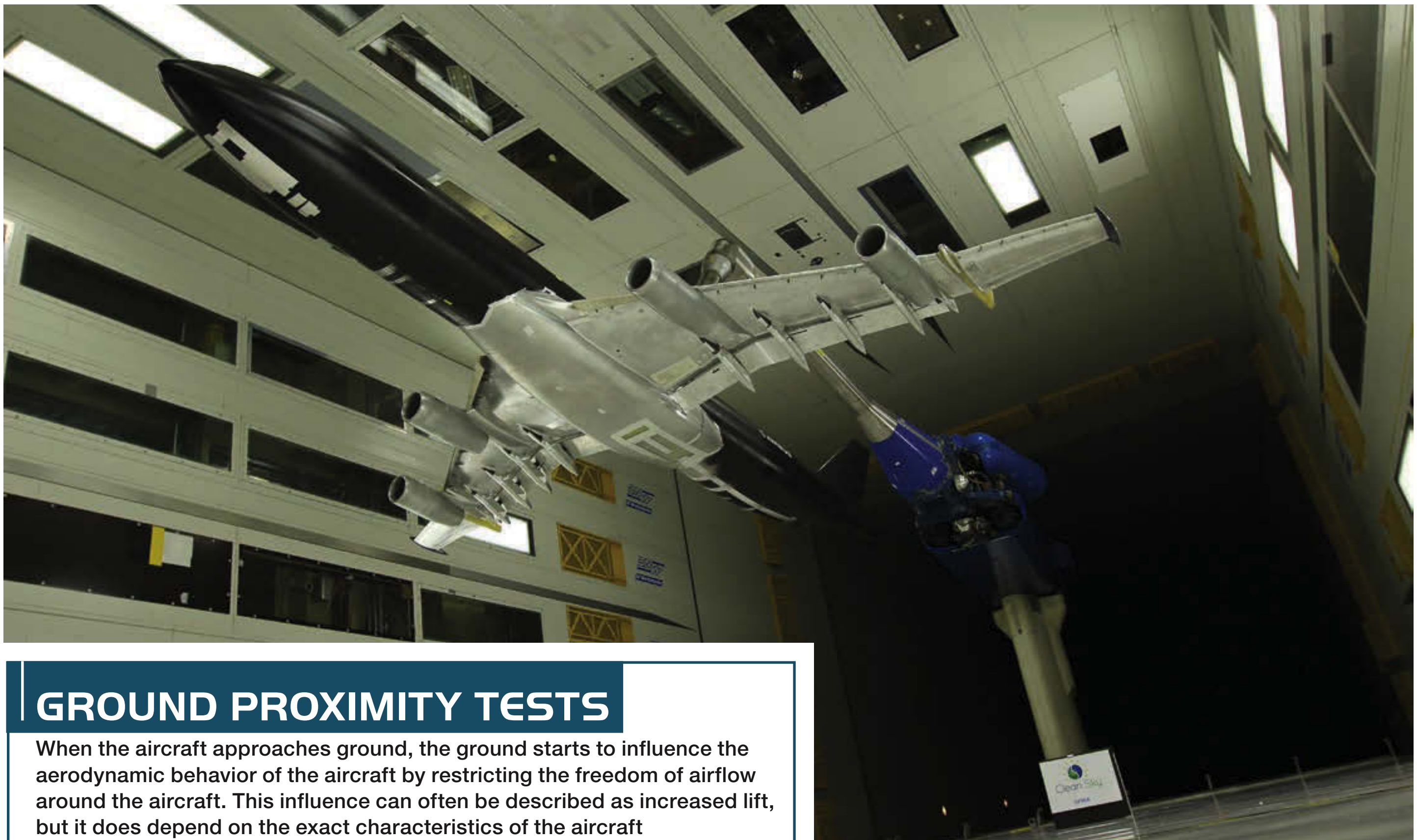
DNW is unwilling to give specific details to current projects, but Eitelberg does say, "I cannot divulge any of the industrial customers' projects, but there are a number of fundamental research projects also pursued by the research community using the capacity offered by our wind tunnel. Recently there have been active rotor aerodynamic and rotor acoustic tests funded by the European commission in the LLF.

"The two most recent projects are particularly interesting, as they were

CHALLENGES

There are challenges in our field, such as the lack of training by universities, leading to a lack of understanding of the possibilities and limitations of wind tunnel testing. No training institution or university can afford our scale of operation, so the challenge is to find European funding for academic usage of professionally operated wind tunnels. DNW generally commits to its specialists for a long duration and provides a large part of the training.

Another challenge is the 'feast or famine' cycle of the wind tunnel usage. There are only a few ongoing aircraft development programs active at any given time; when the time comes to enter the phase of the wind tunnel testing, the program does not tolerate any delays due to some other occupation of the tunnel. On the other hand, it is difficult to find anybody willing to take responsibility for the survival of the technology when there are no current or ongoing programs active.



GROUND PROXIMITY TESTS

When the aircraft approaches ground, the ground starts to influence the aerodynamic behavior of the aircraft by restricting the freedom of airflow around the aircraft. This influence can often be described as increased lift, but it does depend on the exact characteristics of the aircraft aerodynamics and, importantly, on the engine power settings during operation in ground proximity. To obtain sufficiently reliable and accurate data, the wind tunnel wall has to simulate the runway. This is achieved when the wall is formed by a moving belt, moving with the same velocity as the airflow, so that the relative movement between the aircraft (held stationary in the wind tunnel) and the wall is the same as between the aircraft and the air. In DNW's case, we can perform this up to the velocity of 80m/sec.

An interesting aspect of the ground proximity effect is that its characteristics can vary significantly with the type of airfoil shape used in the wing design. This is particularly noticeable in cases of high aspect ratio wings.

funded through the EU Transnational Access mechanism for academic institutions, which generally have no other means to obtain access to professionally operated large wind tunnels. One, the so-called New Mexico project, is related to the efficiency, predictability and noise of wind energy production; the other one is called APIAN-INF, and is related to open rotor propulsion integration. Both the noise and the performance efficiency related aspects are investigated. Both projects were funded through the strategic wind tunnel project, ESWIRP, and both produce data that will enter the public domain, which is also useful for further research by institutions not directly involved.

"Some of the recent industrially motivated tests were performed under the CleanSky mechanism, for example the BLADE project, where the laminar flow potential for air transport is explored," Eitelberg says.

LATEST TECHNOLOGIES

The facilities have been updated continually, as Eitelberg explains: "We have continuously improved the flow quality and the aeroacoustic characteristics of our low-speed wind tunnels. In particular, the recent acoustic upgrades of NWB and LLF are worth mentioning. These tunnels now belong to the quietest wind tunnels used in aeronautics tests, and the background noise generated by them is sufficiently low for identifying the noise sources of even the most advanced aircraft configurations on the model scale. The LLF, in particular, offers sufficiently large scale in combination with the low background noise and high-resolution instrumentation, so that realistic Strouhal number similarities, relevant for aircraft take-off and approach conditions, can be achieved. In this, the LLF can claim to be unique.

"Another new inclusion in DNW-LLF is the capability to realistically simulate powered aircraft behavior in ground proximity. Having the ground move at the same velocity as air relative to the aircraft in wind tunnel simulation is important at high lift to relative height (height versus span) ratios, even in unpowered conditions. Predicting it becomes even less accessible to analytical and numerical tools when asymmetric power or thrust reversal conditions need to be determined," says Eitelberg.

In the high-speed tunnels, the wall corrections and adaptations are typical areas for continuous improvement. Furthermore, the instrumentation and the complexity of experimental simulation is continually evolving. This is also due to the growing capacity for data acquisition and processing required by non-intrusive

ABOVE: CleanSky project BLADE Airbus A330

BELOW: F-35 Joint Strike Fighter

RIGHT: NAVAIR Advanced Hawkeye E-2D

BELOW: EU ESWIRP project New Mexico

measurement techniques for acoustic phenomena (acoustic phased arrays) and flow field quantification by optical techniques. All very technical.

Is there more detail? What test processes are involved – high-pressure/transonic/cryogenic, low speed, etc? "Of course, the large trends like open rotor propulsion due to its efficiency and laminar flow technology for low drag design are some of the very current concerns where we are heavily involved," Eitelberg says.

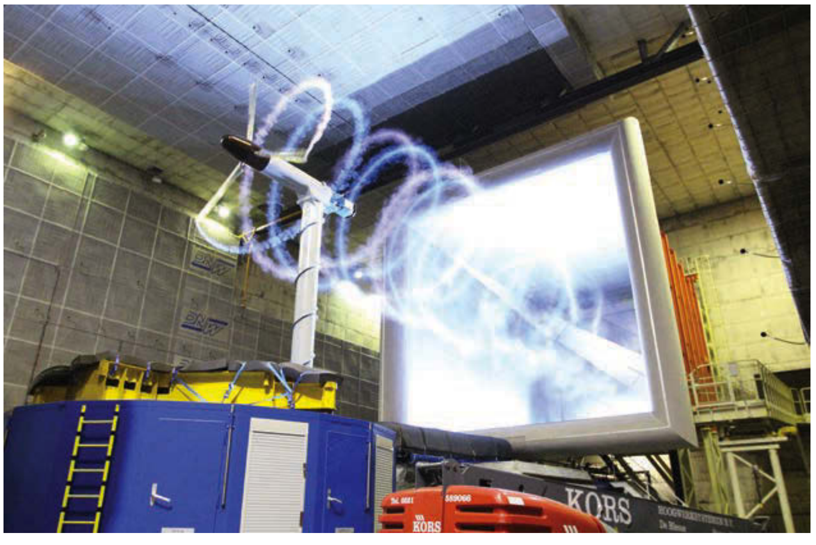
"The LLF, for example, has been shown to have such a high free stream quality that the transition to turbulence obtained in the wind tunnel is comparable to that obtained in free air. Experts talk about N-Factors of 13.5, obtained in the LLF, and with the same airfoil shape also in free flight. Very good laminar flow conditions have also been shown to exist in the HST and in our research facilities.

"For open rotor propulsion, the efficiency is beyond doubt; the need for experimentation stems mainly from the need to verify the noise alleviation techniques and the installation effects. For that, DNW provides the best acoustic environment available, together with the air supply, to drive the pneumatic motors installed in the wind tunnel models.

"DNW EXPECTS COMAC TO EVENTUALLY DEVELOP SPECIFIC PRODUCTS PARTICULARLY SUITABLE FOR THIS MARKET AND HOPES TO BE ABLE TO PROVIDE SPECIFIC TESTING CAPACITY"

"Some of our customers prefer to use their own engine simulators; for others we can procure the engine simulators together with the required instrumentation, such as the 'rotting' shaft balances, to isolate the rotor effects from the airframe effects.

"The cryogenic and high-pressure testing is also used to certify ground-based vehicles, trains, for side wind sensitivity studies at sufficiently high Reynolds numbers. We are also involved in verifying designs for wind energy production," notes Eitelberg.



THE FUTURE

Eitelberg has two predictions, the first of which involves southeast Asia: "We are very involved with Comac, which is a significant customer for DNW and, like all customers, obtains the best service we can provide. Since most of the recent growth in civil air transport is taking place in Asia, DNW expects Comac to eventually develop specific products particularly suitable for this market and hopes to be able to provide specific testing capacity for the development of those products," he says.

Secondly, he deals with the future of the wind tunnel: "When the design and calculation methods stop using turbulence and transition models, then wind tunnel models might also become superfluous. A recent serious and scientifically founded prediction for numerical developments put that into the beginning of the 22nd century.

"Although I am not aware of an estimation of the time of the maturity of aeroacoustic modeling, with the help of numerical methods, it won't occur before the maturity of turbulence simulation. The very developments that are intended to make wind tunnel testing obsolete require verification in the wind tunnels for the coming 100 years. But only the best wind tunnels will rise to that challenge." ■

UNDER PRESSURE

Wind tunnels, air-breathing propulsion test facilities and flight operation services are available to the US government, corporations and independent institutions

The Aeronautics Test Program (ATP) was created to set the strategic direction for NASA's versatile and comprehensive portfolio of ground and flight test aeronautics research capabilities. It is now being re-structured and possibly re-named.

NASA's wind tunnels continue to make targeted investments in its capabilities so that the nation's aeronautics community has the tools to deliver the technology innovations and breakthroughs necessary to address the increasingly complex research and development challenges associated with safe and effective real-world flight. ATP is built upon an experienced team of highly trained and highly skilled individuals who manage, operate and maintain an extensive array of capabilities at: Ames Research Center in Mountain View, California; Armstrong Flight Research Center in Edwards, California; Glenn Research Center in Cleveland, Ohio; and Langley Research Center in Hampton, Virginia.

TESTING WITH A PARTNERSHIP

ATP actively participates in the National Partnership for Aeronautical Testing (NPAT), a council co-chaired by NASA and the US Department of Defense. The council's charter is to develop an integrated strategy for the management of national aeronautics test capabilities and to enable national cooperation and coordination.

The NPAT initiative has led to: an agreement on the guiding principles for facility pricing and access, the inventory and technical assessments of wind tunnels, the improved understanding and collaboration between operators and users from government and industry, and the establishment of a national force measurement technology capability.

NASA AERONAUTICS ON BOARD THE BOEING ECO DEMONSTRATOR PROGRAM

NASA plans to fly a trio of technology demonstration experiments as part of Boeing's ecoDemonstrator program. One will fly aboard a Boeing 787 airliner during 2014, while the other two will be integrated into a Boeing 757 for flight tests planned during 2015.

The ecoDemonstrator is Boeing's development and test program designed to accelerate advancements in technology for use on future airliner designs in the areas of airplane efficiency, noise, and airspace modernization, all while generating a reduced environmental footprint.

The Boeing 787 will feature a test of a NASA-developed air traffic management tool that is intended to help pilots automatically maintain safe spacing with aircraft in front of them during an approach to an airport.

The Boeing 757 will feature a pair of NASA technology demonstrations. The first involves using active flow control on the aircraft's tail to determine if future tail designs can be altered to reduce drag. The second will test the effectiveness of coatings applied to a section of the wing's leading edge to reduce turbulence-inducing build-up of residue from insect impacts.

787/EAGAR

NASA calls the test on the Boeing 787 the 'ecoDemonstrator ASTAR Guided Arrival Research', or EAGAR. ASTAR is short for 'airborne spacing for terminal area routes'. EAGAR is a test of a speed-plotting computer algorithm designed to enable flight crews to maintain spacing – measured as an interval of time – between their aircraft and the one in front of them as they both approach an airport on the same path.

NASA plans to take its prototype software residing on a laptop and plug it in to the aircraft data source. A NASA engineer sitting in the 787 will be able to see on their laptop the same display that a flight crew would see, and will coordinate the speed commands with the cockpit crew.

757/ACTIVE FLOW CONTROL

An airliner's vertical tail size is based on the amount of 'sideways lift' it must generate so the pilots can maintain control of the aircraft in the event of an engine failure during take-off. But after take-off, the extra vertical tail surface area is no longer needed. That means the aircraft spends most of its flight with a tail that is bigger and heavier than it needs to be, which adds drag and reduces fuel efficiency.

Modified by Boeing to include an active flow control system on the starboard side of the 757 ecoDemonstrator's vertical tail, NASA will flight test the system in which a stream of pressurized air from a source on board the aircraft is blown over the tail's surface, increasing the sideways lifting force acting on the tail.

NASA managed successful wind tunnel tests of active flow control during 2013, but this will be the first full-scale flight demonstration. If the technology works as expected, future airline designs might include active flow control, which would allow vertical tails to be smaller and thereby reduce drag and increase fuel efficiency.

757 – INSECT MITIGATION

The second NASA technology demonstration destined for the 757 ecoDemonstrator is officially known as Insect Accretion Mitigation. This is an effort to reduce or eliminate the build-up of insect residue (bug guts) on the forward leading edge of aircraft wings that is an all-too-common occurrence in certain parts of the world during various times of the year.

This sticky residue can disrupt the smooth airflow over the wing, increasing drag and reducing fuel efficiency. To mitigate this problem, NASA will test a number of different coatings that can be applied to the wing's surface to reduce the build-up or prevent it altogether.

A 10ft-long section of the 757's starboard wing will be treated with a selection of coatings and the airliner repeatedly flown through a bug-prone area to determine how effective the coatings are.

Both the active flow control and insect accretion mitigation tests are being done in support of NASA's goal to demonstrate and mature technologies that will reduce drag by 8% and fuel burn by 50%.

ABOVE: NASA has tested a full-sized tail from a 757 commercial aircraft that was modified and equipped with tiny jets

RIGHT: Researchers have tested the aerodynamic characteristics of a Hybrid Wing Body (HWB) aircraft design in the National Transonic Facility at NASA's Langley Research Center in Hampton, Virginia

With funding provided through the American Recovery and Reinvestment Act, NASA's ATP has completed a series of facility improvements that rank as the largest and most ambitious in the past 20 years. These five projects are a combination of much-needed, large-scale reliability and maintenance upgrades, and ensure the development of new testbeds for upcoming research.

The improvements incorporate Environmental Protection Agency-approved refrigerants, energy-efficient motors, and faster, flexible tunnel data systems. This approach underscores NASA's commitment to the integration

TUNNEL VISION

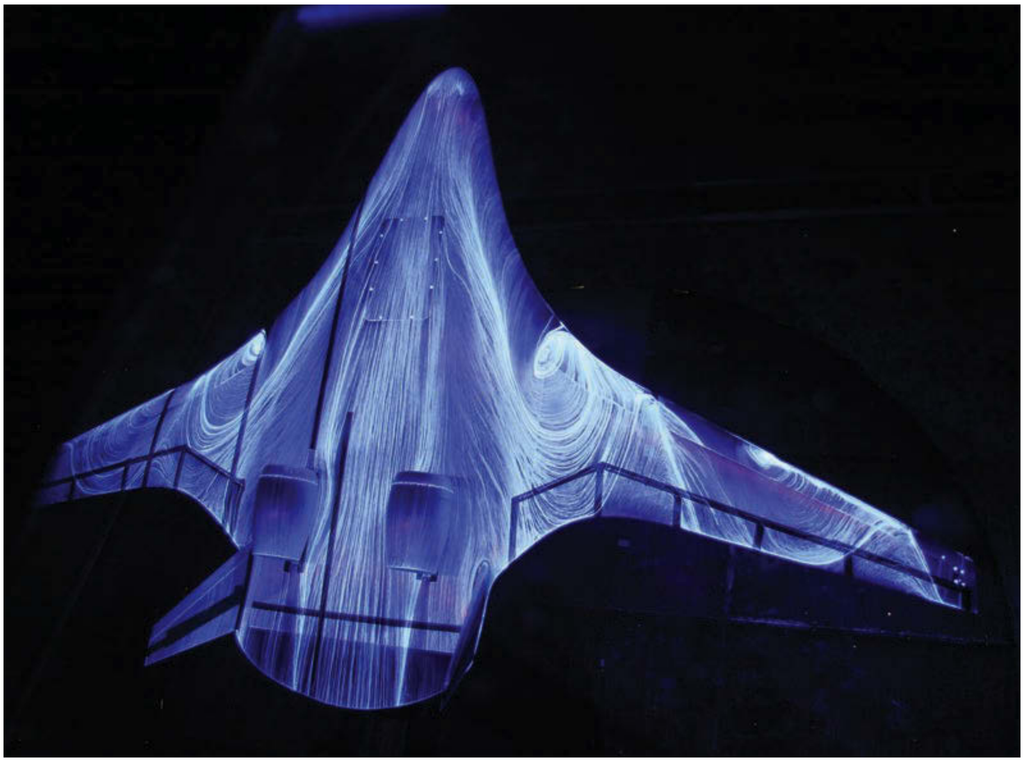
The NTF is a high-pressure, cryogenic, closed-circuit wind tunnel that uses supercold nitrogen gas at high pressure to duplicate true flight aerodynamics. The NTF can accommodate models as small as one-fiftieth the size of an actual aircraft. Notable vehicles tested in the NTF have included the Boeing 777; the Space Shuttle and Booster; the Boeing 767; and blended-wing-body designs such as the B-2 bomber, the A-6 Intruder and the F-18 Hornet.

Unlike conventional wind tunnels, this facility can adjust airflow to match model size. The test section has 12 slots and 14 re-entry flaps in the ceiling and floor to prevent any near-sonic flow 'choking' effect.

To ensure minimal energy consumption, the interior of the pressure shell is thermally insulated. The drive system consists of a fan with variable inlet guide vanes for responsive Mach-number control.

The NTF has two modes of cooling. In the first, variable temperature cryogenics, liquid nitrogen is sprayed into the circuit. The heat of vaporization and latent heat cools the tunnel structure and dissipates fan heat. In this mode, the NTF provides full-scale flight Reynolds numbers without an increase in model size. Ambient temperature air is the test gas in the second mode. Fan heat is removed by chilled water that flows through a cooling coil.

BELOW: Researchers at NASA's Langley Research Center in Hampton, Virginia, use all sorts of tools and techniques to learn more during the development of aircraft and spacecraft designs. Engineers, led by researcher Greg Gatlin, sprayed fluorescent oil on a 5.8% scale model of a futuristic hybrid wing body during tests in the 14 x 22ft Subsonic Wind Tunnel. The oil helps them "see" the flow patterns when air passes over and around the model. Those patterns are important in determining crucial aircraft characteristics such as lift and drag. (Image: NASA Langley/Preston Martin)



into existing tunnel systems of more efficient, environmentally safer, and less energy-consuming hardware and processes.

ATP continues to expand its capabilities necessary for current and future research. Newer, proven technologies are enhancing wind tunnel reliability and maintainability. In addition, the experience gained by NASA's workforce ensures the preservation of nationally relevant wind tunnel operational expertise in both defense and non-defense areas of aeronautical research.

TECHNOLOGY MOVING FORWARD

Test Technology supports ATP by keeping NASA's research test facilities and flight assets moving into the future. As the world's technologies continue to improve and research requirements become more demanding, Test Technology provides new and improved capabilities for measuring pressure, temperature, angle, strain and air flow.

It also improves research facility practices by perfecting processes and techniques and increasing the competence of research staff. Through building partnerships, harnessing small business innovations, and investing in NASA technologies, ATP test technology plays a key role in advancing cutting-edge capabilities.

Facility pressure measurements can indicate the vehicle speed and specific atmospheric conditions that correspond to a particular test environment. Pressure measurements on a model can indicate characteristics of vehicle performance for a given flight environment. Acoustic data measures pressure fluctuations and is used to measure the audible noise that a propulsion system or rotorcraft is producing.

These techniques address different types of instrumentation for carrying out pressure measurements. However, these techniques, as well as the information that is acquired, can then be applied in new ways to different situations to provide additional capabilities for research and design. These capabilities may provide new forms of information or improve a measurement system.

Pressure may be measured using a variety of different techniques, including placing sensors at finite locations, or taking measurements across a continuous smooth surface.

PRESSURE TECHNIQUES

There are a number of common techniques used for measuring pressure: pressure rakes use a rake- or grid-shaped structure of pressure probes, which are typically used to

“A NEW PRESSURE MEASUREMENT SYSTEM IS BEING EVALUATED TO REPLACE THE AGING SYSTEM THAT IS USED ACROSS NASA’S WIND TUNNEL FACILITIES”

measure flow quality within a test facility. Static pressure taps can be used in cases where the surface of the instrument is parallel to the flow it is measuring. Taps may be found on a vehicle/model surface or on facility walls to measure static pressure within a facility.

Pressure-sensitive paint (PSP) is applied to model surfaces; it contains luminescent molecules that fluoresce to different intensities depending on the air pressure. Unlike static taps, which only give measurements at very discrete locations, PSP allows for measurement of pressure over a continuous surface.

Pressure transducers are pressure sensors that turn a pressure value into a digital signal. This allows for better high-speed measurements, which are often used to measure the pressure fluctuations and noise of a system.

RIGHT: Boeing researcher Jeff Iman (left) shows NASA’s Jaiwon Shin (center) and Charlie Bolden (right) how coatings developed by NASA to prevent insect residue buildup will be applied to the leading edge of a Boeing 757 wing (Photo: The Boeing Company, Paul C Gordon)

DEVELOPING TECHNIQUES

NASA is continually seeking out ways to improve techniques for measuring flow variables. New instrumentation can provide fresh insight into flow characteristics and model performance, while improving existing techniques can increase measurement accuracy and give researchers greater detail about flow quality. This information also helps designers, who may use it to make greater improvements to model design.

A new pressure measurement system is being evaluated to replace the aging system that is used across NASA’s wind tunnel facilities. This project is being led by NASA’s Ames Research Center, but will eventually also take effect in NASA’s Glenn Research Center and NASA’s Langley Research Center.

The flow temperature of a facility must be properly maintained to achieve the desired atmospheric conditions. Temperature measurements are particularly important for studies in propulsion. Surface temperatures on a model may be measured to understand the heating levels a vehicle will undergo during flight. Surface temperatures are particularly important for hypersonic flow, including re-entry vehicles.

MEASUREMENT TYPES

Angle measurements focus on the angle of the model with respect to the facility test section and the flow around it. Since a small change in the model’s angle of attack may have a large impact on the forces acting on it, this angle must be accurately maintained. Typically, inflight or ‘wind-on’ instrumentation must also be frequently verified using additional instrumentation, which includes a more well-established reference system, but is less capable of handling flight dynamics.

Force measurement systems are the primary instruments used during aerodynamic and/or propulsion tests to measure the resulting forces and moments imparted on the test article. For an aerodynamic test, these forces include lift, drag and lateral forces, as well as yaw, roll and pitching moments. Knowledge of these forces is essential for knowing how a vehicle is going to perform in flight, and for evaluating potential aerodynamic test techniques.

Flow measurements are more focused on understanding the flow of the fluid (air, water, etc) rather than its effect on the model. These measurements may include shock shape, boundary layer measurements, or general calibration of an aeronautics test facility.

The development of a well-designed vehicle is not limited to measuring the pressures and forces that are induced on a model. Fundamentally, aerodynamic design requires an understanding of how the air moves around a given shape. Establishing greater knowledge of the fluid motion enables engineers to understand and account for flow effects in their vehicle design.

Flow measurement also includes calibration of facilities such as wind tunnels. Before a model is installed, it is essential to know the quality of the test-section flow in order to properly understand the vehicle’s response to the flow. ∎

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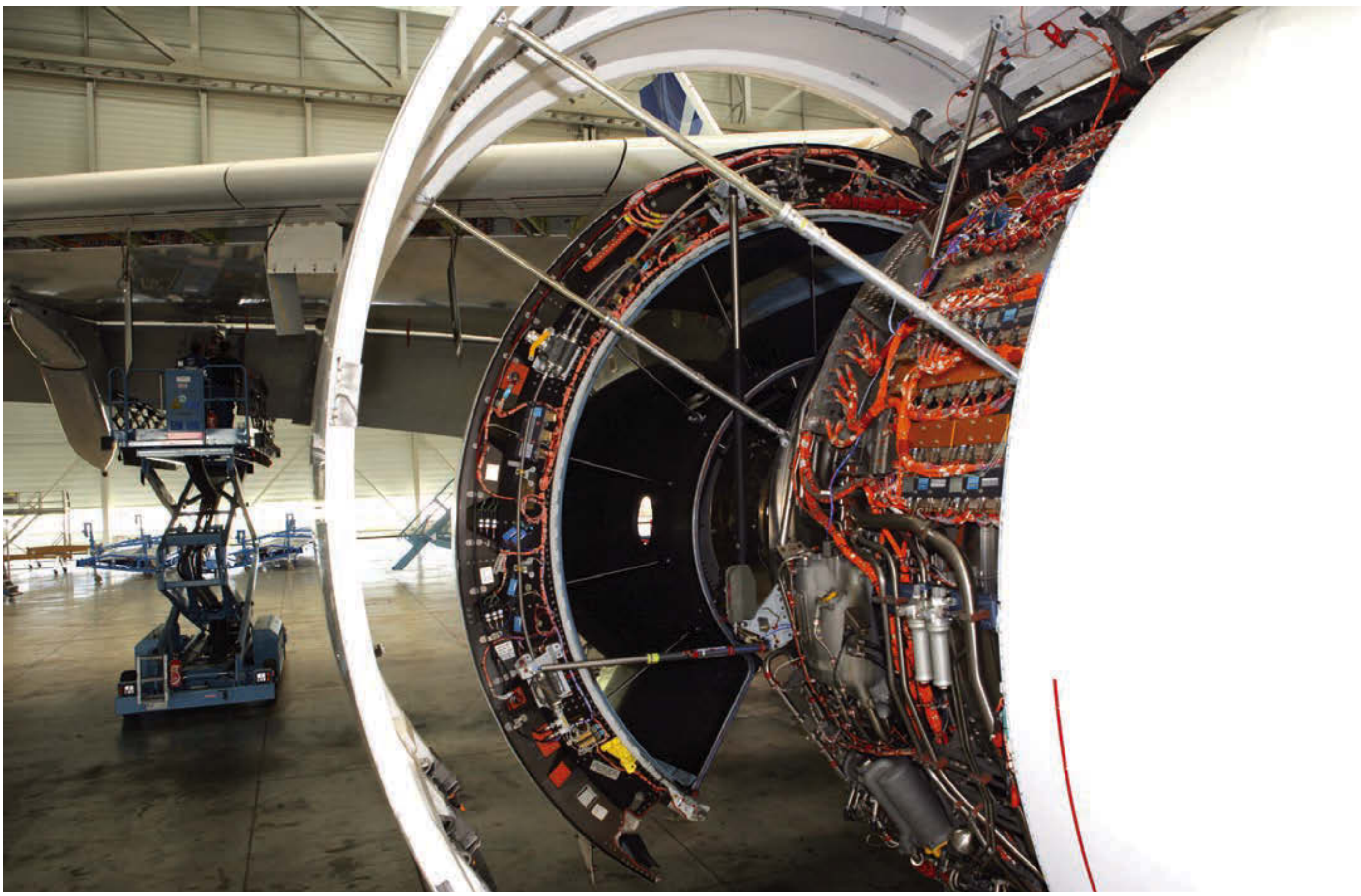
LIVING IN ETHERNET TIMES

More flight test instrument parameters with less SWaP-C: Ethernet-based data-acquisition units deliver flexibility

BY STEPHEN WILLIS



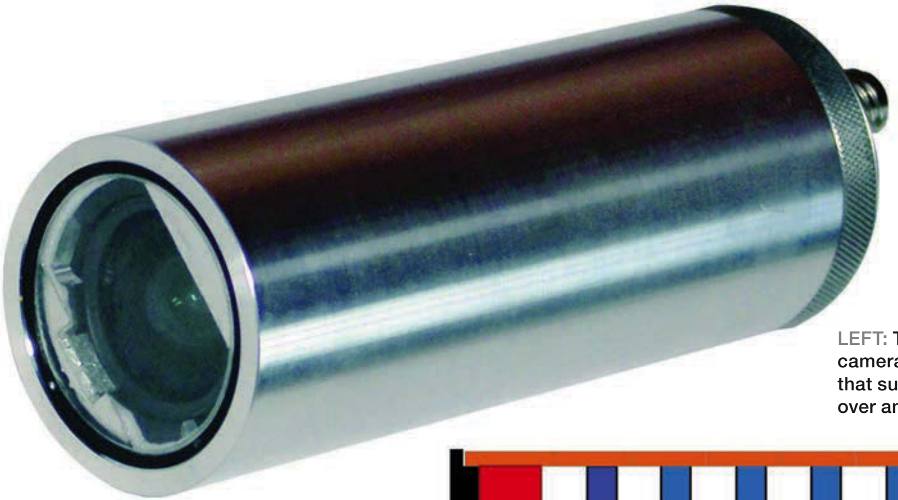
The task of flight test instrumentation (FTI) hardware today isn't simply to give flight test engineers the data they need. Rather, the challenge is to deliver access to the ever-increasing amounts of test data that customers want, which these days typically far exceeds the amount of data needed to meet certification and to prove flight models.

FTI equipment is used by flight test engineers to collect data from a platform during its flight test campaign, and usually consists of sensors, an airborne data acquisition system (collecting data from sensors, avionics interfaces, audio/video sources), monitoring equipment, network switches, consoles and data recorders. This specialized FTI equipment must be rugged enough to operate reliably under flight conditions in harsh environments such as high vibration, shock and temperature gradients. While using equipment designed for industrial data acquisition can save on initial purchase costs, such equipment can fail to produce reliable and complete data when subjected to flight test conditions. This bad or incomplete data results in repeating flights, delays in the program, and inefficiencies in the development and analysis teams. Any flight testing time lost due to equipment failure can be extremely expensive and can easily exceed the initial cost of purpose-designed equipment over the lifetime of a program.

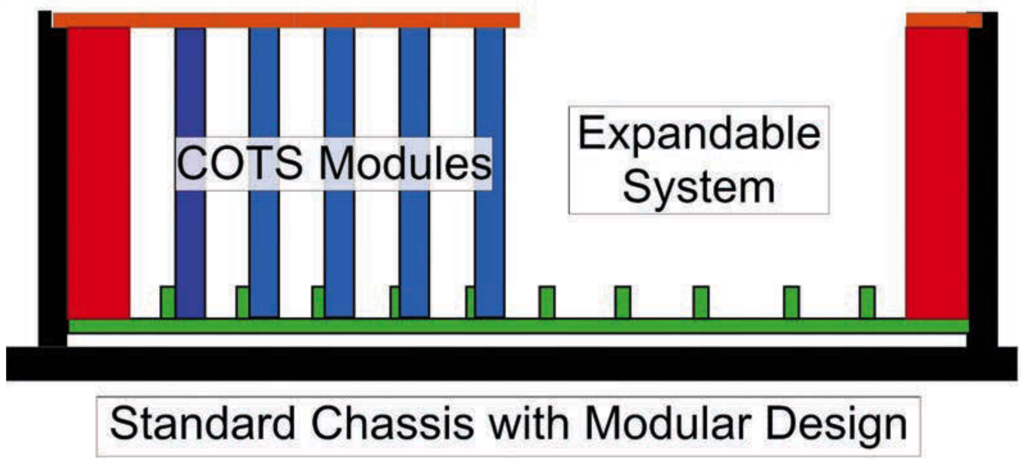
Today, the job of meeting the increasing demand for greater amounts of FTI data, while ensuring that FTI system SWaP-C is kept to an absolute minimum, is benefiting from a number of recent trends in data acquisition unit (DAU) and data acquisition system (DAS) design. These trends include higher levels of integration, the growth of Ethernet-based networks, modularization and the use of FTI metadata open standards.

DAUS AND ETHERNET NETWORKS

Today's FTI systems are moving away from traditional PCM-based architectures and increasingly embracing Ethernet networks. These networks use rugged Ethernet switches specifically designed for the unique requirements of aerospace networks. Deterministic, reliable and fast due to



LEFT: This standalone rugged HD camera integrates video compression that supports two channels of data over an Ethernet connection



ABOVE: Expandable and flexible data acquisition design makes it easier to add or replace modules

LEFT: Installation images are of the Acra KAM-500 4L chassis mounted on the engine of an Airbus A380

their hardwired switching design, FTI Ethernet switches are built with a sturdy compact form able to survive the extreme conditions of the aerospace environment. Every parameter can be synchronized using the IEEE 1588 Precision Time Protocol, ensuring coherency across even a massive system.

The use of rugged airborne Ethernet switches supports the development of distributed node architectures for FTI. This approach means that smaller DAUs can be located closer to the sensors on the aircraft. This increases the accuracy of the acquired data while potentially freeing up valuable space. With a single Ethernet cable being used to connect all the remote DAUs, the amount of wiring, and its associated weight, is greatly reduced. This results in a simpler installation process and, typically, as much as a 30% reduction in overall wiring. Ethernet also supports higher data acquisition and recording rates and helps to lower costs and ensure long system lifetime by easing integration with COTS equipment.

The Ethernet network architecture approach also directly supports users' desire for greater amounts of FTI data and parameters, because the Ethernet backbone significantly eases the expansion of the test system, making it possible to simply add the additional desired DAUs when required. To add more parameters only requires the addition of another DAU chassis to the network. This approach can be used to support FTI systems ranging from a single small chassis to relatively massive systems, as more DAU nodes can be easily integrated into the existing networked system.

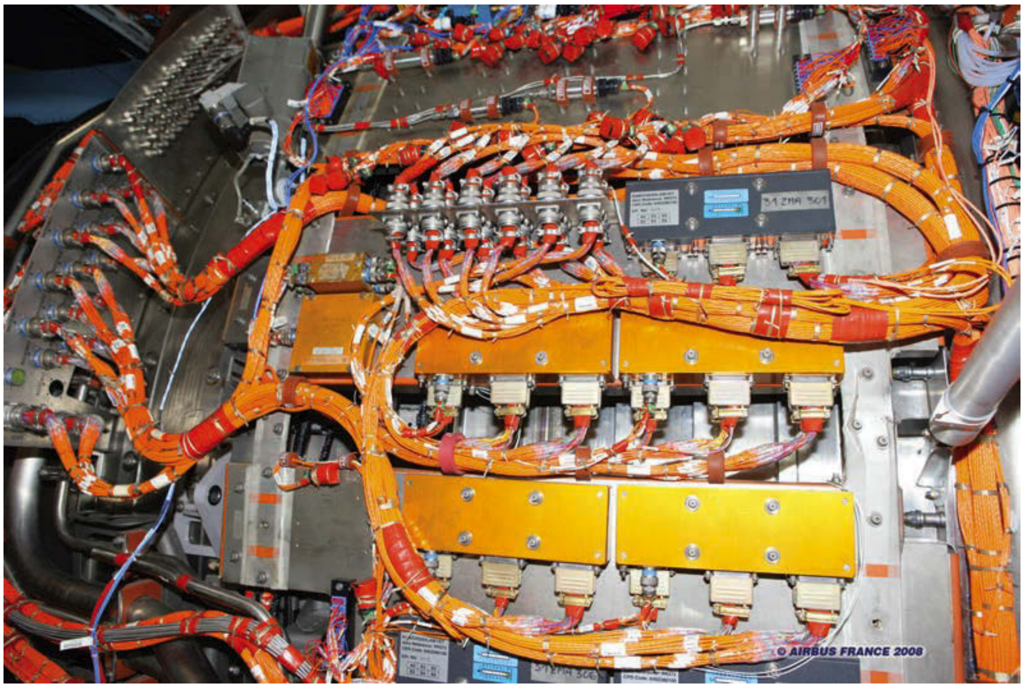
The trend toward higher levels of integration also helps provide access to more FTI data, because as modules used within the DAU chassis increase in channel density, they are able to support greater amounts of data input without adding additional overall weight to the platform.

ADDING CAMERAS WHILE REDUCING WEIGHT

Another trend that both provides greater amounts of FTI data while reducing SWaP-C overhead is the move from older video camera technologies toward modern HD digital video. Although this move brings with it greater amounts of video data that must be supported and moved around the FTI system, older cameras are typically much heavier than modern cameras, and because the former were not usually digital and network-ready, two separate systems and data networks were required.

Today, we are increasingly seeing designs that combine the video sensor and the DAU into one unit, which reduces overall weight and simplifies the process of piping the resulting video data around the aircraft. For example, Curtiss-Wright and Kappa Optronics recently announced plans to jointly develop a new family of highly rugged FTI airborne video cameras. These new HD cameras will feature built-in video compression and dual-channel Ethernet streaming. They are designed to seamlessly integrate with DAUs to reduce SWaP-C by eliminating the need for separate compression cards or video processing units.

"TODAY, WE ARE INCREASINGLY SEEING DESIGNS THAT COMBINE THE VIDEO SENSOR AND THE DAU INTO ONE UNIT, WHICH REDUCES OVERALL WEIGHT AND SIMPLIFIES THE PROCESS OF PIPING THE RESULTING VIDEO DATA AROUND THE AIRCRAFT"



ABOVE: Installation of the Acra KAM-500 4L chassis mounted on the engine of an Airbus A380

BELOW: More sensors, higher bandwidths and a 'capture-everything' philosophy have led to an explosion in the number of required channels

MODULARIZATION

Another trend for providing increasing amounts of data without adding unwanted weight and space is the growing use of modular FTI systems. The modular approach lowers installation, setup and maintenance requirements and extends system lifetime. In contrast with costly one-off custom designs or DAU architectures that lack backward compatibility, true open standard interface-based DAU designs enable the reuse of existing systems and ease the addition of more system nodes as the need arises.

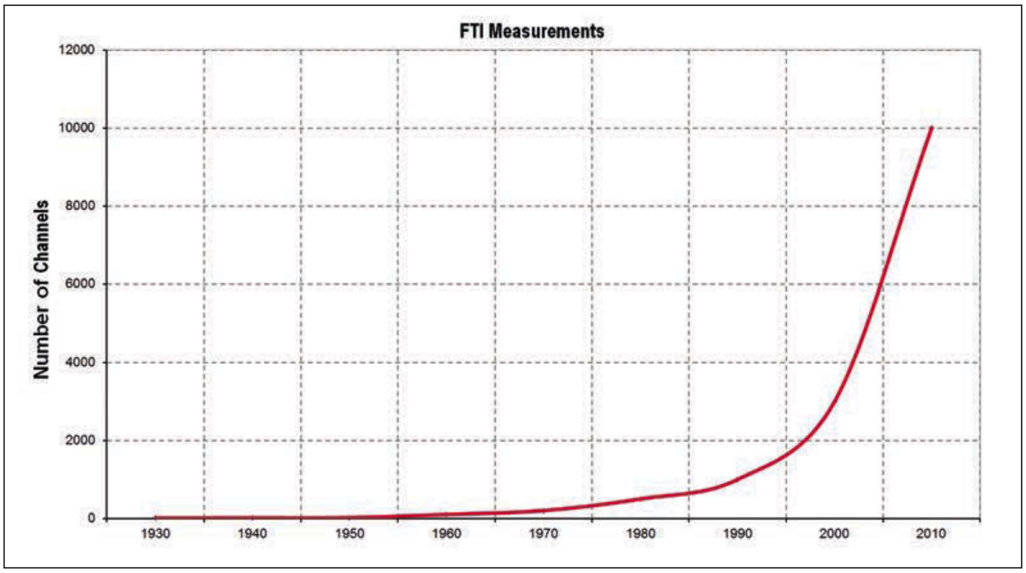
Even if the aircraft being tested has quite different requirements from the one for which the FTI system was originally designed, with the use of modular DAUs, adapting the existing system for use with the new platform often simply involves swapping out a module or two, enabling the reuse of the majority of the existing system. This approach reduces complexity, saves space and weight and essentially future-proofs the customer's initial investment. Even if the legacy and current DAU designs are heterogeneous, Ethernet connectivity ensures compatibility across product generations.

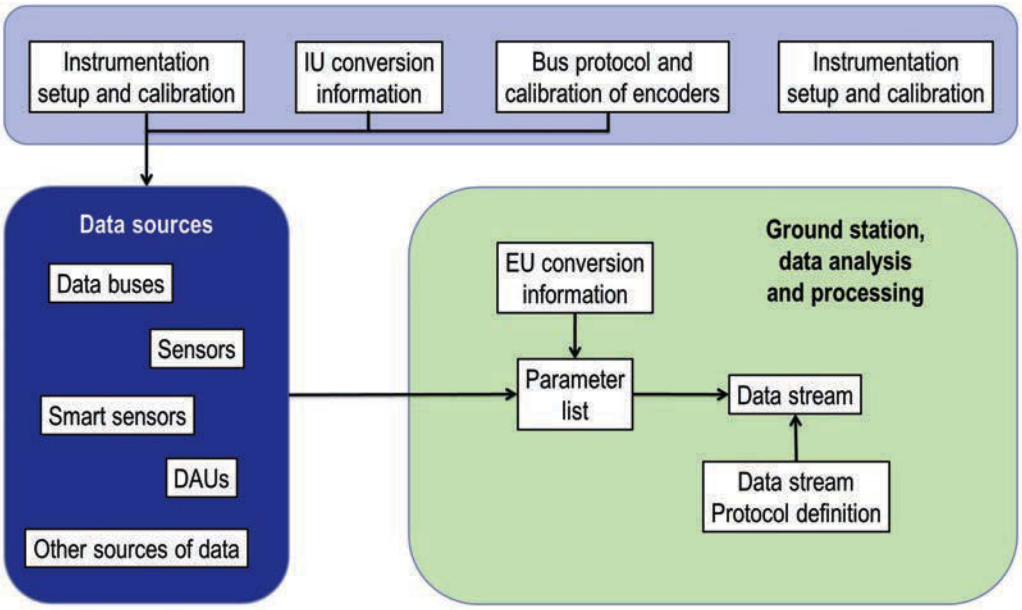
METADATA

Another approach for improving interoperability and increasing system flexibility is through the use of open standards and protocols for file storage and for system synchronization, management and configuration. Open standards help reduce FTI equipment costs and simplify the task of gathering thousands of data parameters. For example, current FTI metadata standards such as XidML, TMATS, iHAL, and MDL provide a vendor-neutral hardware configuration approach for acquiring, processing and packaging data for transmission, storage and reproduction. Designed specifically to meet the needs of the aerospace industry, metadata standards such as XidML ease the storing and exchange of FTI data between hardware from multiple vendors. By freeing users from proprietary formats, it makes it possible, for example, to select a DAU from one vendor and have the confidence that it will work well with a data recorder from another vendor. Today, while there are several competing metadata standards, which unfortunately hinder true interoperability, the trend is for the definition of a single standard that will be embraced across the industry in the not too distant future.

REDUCE TIME

Another element of an FTI system that is important not to overlook is its software interface. As greater amounts of data are being acquired by greater numbers of sensors, the ability to physically cope with the increased





RIGHT: An overview of a metadata standard that enables interoperability between hardware from different vendors

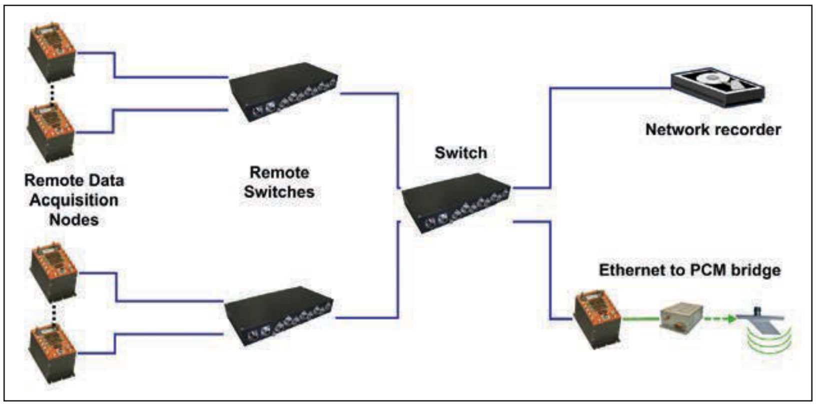
BELOW: In a distributed node architecture, smaller remote data acquisition units (DAUs) supply data via layers of switches

system complexity can become a big concern. Furthermore, the prospect of learning a new custom-designed system setup and management software package can be a daunting task. One of the key goals of an FTI test engineer is to reduce the amount of time involved in conducting flight tests. Setting up complex systems and dealing with masses of complicated wiring can add significant time and expense to an FTI program. This problem is compounded when a fault occurs, as it inevitably will in a complex system. Locating the source of the problem then becomes the challenge. The use of an Ethernet-based network makes troubleshooting easier. Even better, FTI setup software that makes full use of an integrated network architecture can be easier to use and more powerful. A good setup software package will save its users significant time in entering, reviewing and validating setup information and ensuring that instrumentation is correctly configured. The result is that system validation and programming can be performed in minutes or even seconds. Specially designed software tools can reduce the time required for commissioning and calibration and simplify flight line inspections, pre-flight checks and system reconfiguration.

EXAMPLE OF AN ETHERNET-BASED MODULAR DAU

Curtiss-Wright's Acra KAM-500 provides an example of a flexible, modular DAU for FTI that makes full use of the benefits of Ethernet connectivity. The KAM-500's data can be optimally packetized for Ethernet transmission and recording but can also be converted to many other industry standard protocols. This facilitates the integration of hybrid systems such as PCM DAUs into an Ethernet system and allows Ethernet data to be converted to PCM for telemetering. Curtiss-Wright currently offers more than 100 types of modules for use in the KAM-500, providing system developers exceptional flexibility to meet the specific needs of a program. This modular system also helps developers control costs. Systems can be easily modified or updated as the Acra KAM-500 is only one module away from any application.

To facilitate setup and management of FTI hardware, Curtiss-Wright has developed the DAS Studio 3 software package. It saves a considerable amount of time by integrating the process of entering, reviewing and validating setup information, ensuring that instrumentation is correctly configured. It also provides an easy-to-understand interface that lessens the usual complexity involved in setting up a data acquisition system. Integrated tools save time by automating time-consuming tasks such as building optimized PCM frames and importing data from proprietary bus descriptions. ∎



Stephen Willis is from Curtiss-Wright Avionics & Electronics, based in the USA

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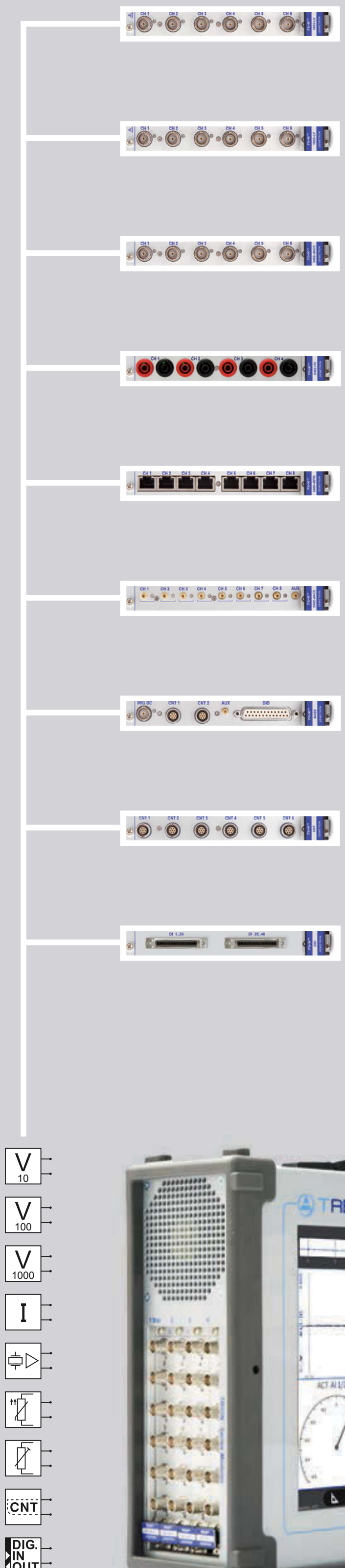

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SEE-ALL SIMULATION

The Sky Light Simulator is a next-generation lighting laboratory, in which engineers can ensure that cockpit crew can read essential information in any light

BY ALENIA AERMACCHI

With its 100+ years of history and successes, Alenia Aermacchi, a Finmeccanica company, is today a major international player in the aerospace industry. Its activities include end-to-end design, development, integration, ground and flight testing for qualification and certification, and through-life support for the most advanced systems, such as high-performance combat aircraft, advanced trainer aircraft, military and commercial transport aircraft, unmanned aircraft systems, mission systems aircraft and modern aerostructures for airliners.

The company has R&D and test laboratories focused on testing structures, systems and structure/system integration, for development and aerostructure certification.

The Alenia Aermacchi's system testing facilities range from the wind tunnel at its Turin and Venegono plants, to the general system laboratories at the Venegono and Pomigliano d'Arco plants, up to the electromagnetic laboratories at the Caselle and Vengono plants where equipment, systems and aircraft are tested and qualified.

In Alenia Aermacchi's Turin/Caselle and Venegono Plants, two state-of-the-art facilities – the Sky Light Simulator and the anechoic chamber – have reinforced the range of testing facilities of the System Laboratories, a department in Design Organization.

THE SKY LIGHT SIMULATOR

The Sky Light Simulator is a lighting laboratory – a patented Alenia design – for the artificial reproduction of natural ambient lighting conditions. It is capable of reproducing the entire range of ambient light, from darkest night to full daylight.

State-of-the-art aircraft cockpits are equipped with a high number of light-emitting and passive displays to provide the crew with essential information for flight and mission execution. A specific design and a set of careful tests are required to ensure that all instruments are easily visible in any lighting conditions to prevent the crew from any loss of information. In

"THE SKY LIGHT SIMULATOR IS A 12M DIAMETER SPHERICAL DOME CONSISTING OF METAL STRUCTURE SUPPORTED BY A CYLINDRICAL BASE, 2.8M HIGH"

ABOVE: Sky light simulator testing inside cockpit

LEFT: Tornado canopy in Skylight Simulator

addition, cockpit instruments must not interfere with the crew's view of the outside world, in specific conditions such as night flight with the use of night vision imaging systems.

Environmental lighting conditions are highly variable, presenting extreme conditions, such as very high ambient lighting when flying at high altitude over a cloud layer, or very low ambient lighting when flying during a dark night with no moon over unpopulated terrain. There are a few ambient lighting conditions that can be considered worst cases for the purposes of cockpit lighting system testing and qualification. They include critical combinations of direct sunlight (rear sun, forward sun) and diffused light (full day, dawn/dusk and night).

Cockpit lighting requires specific ground and flight tests or ground tests in an environment capable of reproducing all light conditions. This requires simulation with an adequate level of fidelity of various combinations of direct sun light, sky-diffused light, light reflected by clouds and, for night flight situations, moonlight and starlight.

The Sky Light Simulator can reproduce all day and night conditions in a highly realistic, controlled and reproducible way. Such capabilities can result in cost savings, allowing a reduction in the number of test flights.

Furthermore, with respect to in-flight testing, the Sky Light Simulator ensures the repeatability of the lighting conditions and the objectivity of the tests.

The Sky Light Simulator is based in Alenia Aermacchi's Ground Test Centre at Turin-Caselle. Aircraft can easily reach the facility, which is directly connected to the runway at Turin International Airport.

The Sky Light Simulator is a 12m diameter spherical dome consisting of a metal structure supported by a cylindrical base, 2.8m high. A wide door enables the fore-body of an aircraft to enter the dome, which is subsequently sealed with special curtains to isolate the system under test from external light.

As an alternative, it is possible to use a mock-up cockpit. The dome's internal surface is covered with 191 panels, 79 active and the rest reflective, to generate the day-diffused light, while a powerful lamp specifically designed for this purpose and mounted on a movable arm simulates the sun. Whenever needed, a set of internal matte black curtains makes the Sky Light Simulator a dark room where an internal source produces the light of the moon and stars to simulate night. Several other ancillary instruments and measurement tools complete the equipment.

The major use of the Sky Light Simulator is in the assessment of new aircraft cockpit configurations as well as modified cockpit layouts. The foreseen class of tests include subjective tests, where a qualified assessor (test pilot) evaluates cockpit equipment under different lighting

ABOVE: M346 outdoor electromagnetic test

conditions, and objective tests, where cockpit and lighting engineersand specialists perform measurements on dedicated equipment.

The Sky Light Simulator, optimized for airplane and helicopter testing, also has potential applications in non-aeronautical sectors, such as those of automotive, architectural, luminance panel for road infrastructure, medical and human physiology.

ELECTROMAGNETIC TEST CENTRE

The Electromagnetic Test Centre is made up of open-area test sites dedicated to fighter aircraft and medium-size air vehicles, and indoor facilities for testing at the equipment and the aircraft level. The facilities were developed to reach the desired degree of confidence in providing required aircraft flight clearances according to military and civil international standards.

An aircraft represents a complex system of high-speed and low-level logic integrated circuits that operate in an increasingly hostile electromagnetic environment. The combination of these two factors is potentially increased aircraft electromagnetic vulnerability.

Evaluating the aircraft's ability to operate without malfunctions in the presence of electromagnetic threats is therefore of paramount importance. Ensuring electromagnetic compatibility is the role of the Electromagnetic Test Centre.The Electromagnetic Test Centre is mainly involved in electromagnetic compatibility/ high intensity radiated field (EMC/HIRF) qualification and certification of products that Alenia Aermacchi designs and qualifies.

The most recent aircraft, including the C-27J Spartan, the Eurofighter Typhoon and the Alenia Aermacchi M346, have been tested and certified by Electromagnetic Test Centre engineers and specialists.

An anechoic shielded chamber, the largest in Europe for aeronautical use, is at Caselle South plant. It was designed to perform electromagnetic tests, assess sensitivity to radio frequencies, and evaluate the performance of equipment installed on aircraft, both transmitting and receiving, within an environment protected against external electromagnetic disturbances and meteorological conditions, without any impact on civil infrastructure.

This facility has a 900m^2 base, is 20m in height has an internal volume of 18,000m^3. Built of welded panels of zinc-coated steel to guarantee a high level of protection from internal and external electromagnetic interference, it is completely covered with 11,000 pyramids of radio-absorbing material, ensuring an echo-less environment like the one in which airplanes and helicopters normally operate.

The anechoic shielded chamber has a double moving system for the test object – a turntable that can rotate aircraft or devices weighing up to 30 tons with 0.02° precision, and a hoist system capable of lifting, by means of Kevlar ropes, aircraft up to 25 tons to

ABOVE: EFA electromagnetic testing

"THE ELECTROMAGNETIC TEST CENTRE ENGINEERS ARE SPECIALISTS WITH EXTENSIVE EXPERIENCE CARRIED RADIO FREQUENCY TESTS ON COMPLEX SYSTEMS AND IN RESOLVING ELECTROMAGNETIC PROBLEMS RELATED TO ELECTRONIC AND ELECTRICAL INTERFERENCE"

LEFT: Head-up display testing sky light simulator

BELOW: Electromagnetic test on missile launcher (Picture: Thales)

a maximum height of 16m, to perform tests with landing gear up and aircraft irradiated from the bottom – a typical flight condition.

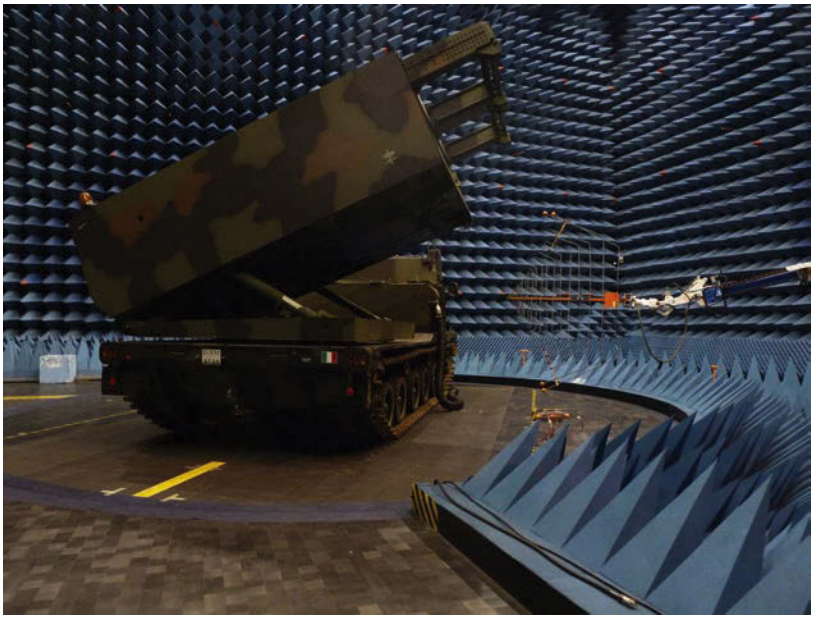
Moreover, the anechoic shielded chamber is equipped with dedicated provisions, including 28V DC and 115V AC filtered electrical power supply, hydraulic power supply, engine exhaust extraction (for automotive and transport applications), fiber optic links to the control room for system monitoring, and a CCTV system, including an infrared camera.

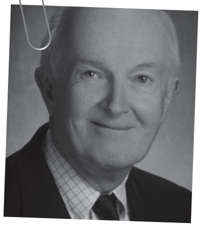
The anechoic chamber's operating frequency range is from a few kilohertz to 18GHz, depending on the test methodology, compliant with the requirements of civil and military international standards. Radiated and conducted susceptibility, radiated and conducted emission, voltage/transient spikes, ESD tests and antenna noise/desensitization and coupling tests are performed at equipment, subsystem and system level. Remote management of the anechoic chamber to conduct tests and drive RF and acquisition instrumentations is possible inside the Shielded Control Room.

The testing facility is completed by the reverberating chamber, which consists of a rectangular chamber and a mode-stirrer paddle that disrupts RF fields inside the enclosure. The chamber is used for testing equipment and material, providing field uniformity above 100MHz and assuring radiated emission and susceptibility testing repeatability. The Electromagnetic Test Centre engineers are specialists with extensive experience carried radio frequency tests on complex systems and in resolving electromagnetic problems related to electronic and electrical interference. The team also carries out the electro-explosive device spurious energy pick-up test, required by military standards on electro-explosive devices.

The test facilities and instrumentation, starting from RF high-power amplifiers to the RF high-sensitive receiver, enable the Electromagnetic Test Centre engineers to carry out tests on airplanes, rotorcraft, special ground equipment and vehicles and complex systems. ∎

The author was a senior member of the design team with Alenia Aermacchi based in Italy





TIM NICHOLS

RIGHT FIRST TIME

A slightly different angle on how aircraft development within the current sector will develop

BY TIM NICHOLS

ABOVE: Two Williams FJ44-4A engines on the PC-24 have take-off thrust of 3,400 lb each

LEFT: Utilizing the 1600 shp PT6A-68B engine from Pratt & Whitney Canada, the PC-21 pushes the speed and climb rate of the turboprop into an area that, until now, was exclusively jet territory

The aerospace industry is expected to experience continued growth for the foreseeable future. This year the global market for business and private jets is showing signs of a comeback – the market for deliveries, which has a year or two delay from when orders are placed, is expected to rise 3% this year to US$23bn, and then 10% the following year, according to Teal Group, the US aerospace consultancy. This is undoubtedly the result of an improvement in global business confidence and the luxury goods sector.

However, with this rapid growth come associated challenges. Aerospace program managers are increasingly faced with pressures of budget, scope, risk and scheduling supply chain processes across global partnerships. One of the biggest issues for business and private jet OEMs is to deliver a new aircraft model that meets all the technical and performance requirements at a competitive cost. As a result, OEMs are increasingly finding that they can best meet these challenges through the use of a well-planned and implemented product lifecycle management (PLM) software system.

GROWING COMPLEXITIES

Given the growing complexities of today's aircraft designs, an urgent paradigm shift is needed in order to reduce risks and costs, while speeding up time to market. Too often, today's initiatives experience high design change rates as the aircraft progresses through the various stages of certification, and then enters production – then again when the aircraft enters test and finally when the aircraft enters service. It may seem obvious but many companies forget that investing in delivering the right aircraft model the first time can provide a competitive edge that is crucial to a program's success or failure.

To address these challenges, some aircraft manufacturers have created virtual enterprises consisting of globally distributed design teams and operating sites. These virtual enterprises leverage collaboration with global partners and suppliers to accelerate innovation, reduce time-to-market and optimize resources. But managing a virtual enterprise to function as a highly disciplined, integrated and synchronized value chain presents enormous challenges, especially with aircraft lifetimes

spanning 30 years or more due to the aerospace industry's historical and growing focus on sustainability.

As a result, extended enterprise performance has emerged as the crucial issue for sustained profitability. This applies to all phases of the protracted product lifetime: design, development, certification, manufacturing, assembly, functional test, fight test, certification – and then throughout the complete operating and service cycle. The isolated and often autonomous operational silos of the past must now be aligned and synchronized across the extended enterprise, from the initial requirements until the final aircraft or engine is retired.

> "THE ISOLATED AND OFTEN AUTONOMOUS OPERATIONAL SILOS OF THE PAST MUST NOW BE ALIGNED AND SYNCHRONIZED ACROSS THE EXTENDED ENTERPRISE, FROM THE INITIAL REQUIREMENTS UNTIL THE FINAL AIRCRAFT OR ENGINE IS RETIRED"

NEW REALITIES

It's therefore no surprise that aviation OEMs struggle with legacy methods and processes to develop aircraft, which are clearly not ready for the new realities and challenges of global collaboration and total lifetime knowledge management from start to finish.

KEY CASE: PILATUS

Pilatus, a global aerospace leader specializing in the supply of single-engine training aircraft for the Air Force as well as business and work aircraft, deployed Siemens NX and Teamcenter PLM software offerings in the development of its PC-21 and PC-24 models.

For its PC-21, a military training jet performing better than other turboprop aircraft while being more economical and quieter, Pilatus used PLM to transform its testing processes and increase the integration between the design, manufacturing and engineering functions. This enabled the company to embed concurrent engineering into design from the very beginning, and to carry out the design, development and manufacturing of the aircraft in parallel. "We performed all processes in parallel, and carried out the digital modeling according to the master model concept using only a single model," says Bruno Cervia, VP R&D at Pilatus, summarizing one of the most important factors for success. "We never worked on different versions of the model." Concurrent engineering only works when design and data management systems are tightly integrated. The depth of data provided by the software also enabled the company to look at the entire lifetime of the aircraft, not just in terms of development and production, but all the way through to maintenance costs many years down the line. Ultimately, development time for the PC-21 was significantly reduced, with return on investment seen before the project was even completed.

For its PC-24, Pilatus needed to deploy PLM in order to solve the kinematics issues surrounding the creation of the world's first 'super versatile jet' being able to land on almost any type of surface. The jet required a new state-of-the-art wing design with a powerful high-lift device in order to succeed. Pilatus used PLM to develop and design all the moving parts of the aircraft in order to ensure the technical requirements were met, and to work out detailed kinematics analysis of all areas of the aircraft. "PLM software was absolutely needed in the development of the PC-24," continues Cervia. "It's the ideal tool that allowed us to share data securely across teams both within the company, and globally with partners, which guarantees that everyone is working with the latest data in real time. As a result, configuration is constantly kept fully under control." Without PLM, Cervia says that the company would have needed to wait until a prototype was produced before testing could take place. However, by using PLM software, the company could perform all interference checks virtually on the digital model, significantly shortening the time to market.

BELOW: The Pilatus PC-21 is a single-turboprop, low wing swept monoplane advanced trainer with a stepped tandem cockpit

ADAPTING TO UNIQUE AEROSPACE CHALLENGES

Aerospace prime contractors often compete on new programs that require them to accept lifecycle performance agreements, which place a premium on logistics support planning. In addition, even though they participate in a complex global supply chain comprised of diverse suppliers and partners, aerospace and defense manufacturers are required to respond quickly to changing program and production schedules.

Operators must be able to adapt to these challenges in order to realize sustainable profit and growth. This requires program management solutions that provide:

- Integrated program management
- Virtual environments to synchronize global design and development, and speed development cycles
- Supply chain management capabilities to deliver the development and production phases on schedule
- Faster production ramp-up
- Virtual prototyping which is capable of minimizing physical models, assembly error and design rework.

A collaborative business enterprise means product lifecycle management software providers can act as technology partners, creating a seamless, collaborative business enterprise that allows OEMs to:

- Create information once and maintain it at its source while enabling all users to access and utilize the data throughout its lifecycle
- Manage systems that ensure timely and accurate configuration control
- Comply with import and export control regulations ensuring adherence to security processes and procedures
- Have a method for contract data requirements list (CDRL) and subcontractor data requirements list (SDRL) delivery
- Manage and ensure environmental compliance
- Assure adherence to government infrastructure and data standards.

Product lifecycle management solutions can provide a full range of capabilities for not only regulatory compliance but consistent program execution excellence, resulting in increased competitive advantage, revenue and profits.

There is a clear opportunity to create an enterprise-wide knowledge management foundation that organizes and manages the complete aircraft product structure and all related technical information throughout all phases of the complete product lifetime and the extended enterprise. PLM has emerged as a key software platform that provides the total extended enterprise with instantaneous and concurrent access to the complete technical definition of the most complex product. Aerospace companies can have the control, access, discipline and facilitated processes they require in order to manage the complete lifetime of their developments to which they did not previously have access.

LOOKING AHEAD

The aerospace industry will continue to face new and greater challenges than ever before. These challenges include building even more complex, affordable aircraft in less time with greater reliability and durability, developing new global air traffic management systems, and coordinating counterterrorism activities around the world. This will exert even greater pressure on global enterprises to work seamlessly and efficiently across the protracted lifetime of most programs.

PLM can help to meet and more effectively manage these challenges by providing a synchronized foundation to align and harmonize the extended enterprise. PLM is more than a new software technology or acronym; it is a transformational business imperative that, when embraced and supported by all levels of the leadership team in the extended enterprise, can enable a significant leap forward in total enterprise productivity, efficiency, cost reduction and time-to-market. ■

Tim Nichols is managing director of global aerospace at Siemens Industry Software, based in the USA

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JÖRN HAASE

TESTING OF CAN SIGNALS

Highlighting the technical development, troubleshooting and maintenance of CAN applications in the aviation industry

GAVIN ROGERS

BY JÖRN HAASE AND GAVIN C ROGERS

The CAN (controller area network) serial bus has already been deployed in numerous aviation applications. Extensive activities in CAN standard working committees such as ARINC 825 and ARINC 812 indicate that aircraft manufacturers, suppliers and airlines are increasingly relying on CAN systems in future aircraft programs. To meet the stringent requirements for robustness, reliability and long service life, there is an increasing demand for efficient measurement and test methods, which also cover the CAN physical transmission layer.

Although the CAN bus was originally developed for automobiles, properties such as its robustness, reliable time behavior and good cost/benefit ratio have quickly lead to its deployment in numerous other sectors and applications. Aviation poses many challenges for robust CAN communication, including long cables, extreme environmental conditions (heat, cold and moisture), stringent lightning protection requirements and long service life. While commercial vehicles are expected to have a bus length of no more than 40m, according to SAE J1939 a bus cable on a large airliner such as an Airbus A380 can be 200m or longer. A further challenge is the long service life of aircraft, of at least 30 years. Electrical installation is typically subject to gradual deterioration of its electrical parameters. Corrosion- and wear-induced aging quickly leave their mark, in particular on plug-in connections.

CAN is currently used in aircraft for systems such as environmental control, doors, galleys, smoke detection, potable water and de-icing. Due to the specific challenges in aviation and the long service life, adequate electrical reserves must be included in the design and layout of networks, to counteract the expected aging phenomena. However, the fact that a new system passes logical function tests says nothing about the quality and robustness of the physical communication. Such information can only be obtained by testing and measuring the CAN physical layer.

THE CAN PHYSICAL LAYER

The CAN protocol recommended for civil aviation is standardized in ARINC 825. Even in the CAN 2.0A/B standards originally published by Bosch, only the tasks of layer 2 (datalink layer) of the ISO/OSI layer model have a binding definition. In practice the physical parameters actually used depend heavily on the system developer and the specific conditions. This relates in particular to the bus length and the bit rate, which are related in that the longer the bus cable, the greater the signal propagation delay. ARINC 825 supports data transmission rates of 83.333kbps, 125kbps, 250kbps, 500kbps, and 1,000kbps. High-speed CAN buses use a twisted-pair cable and operate with a differential voltage of 0-2V. The bus cable is implemented in a line topology and requires termination at both ends with a terminating resistor. Bus nodes are connected using short stubs.

On a CAN bus, each sender expects bit-synchronous acknowledgments from one or more receivers. This is one of the reasons for the great robustness

ABOVE: **Targeted and reproducible disturbance of the CAN bus, its physical properties, and the logic state with CANstressDR and CANoe**

of CAN. The instantaneous bus access method is also based on a (bit-synchronous) synchronization of the high-low signal state. All bus drivers are equipped with open-collector outputs, and a switched-through (low-resistance) output always prevails, because it pulls the high signal generated via pull-up resistors to low state. Low is thus always dominant and high is recessive.

PHYSICAL LAYER ERRORS

Each CAN bit is subdivided into multiple phases and the developer specifies a uniform sampling point – a kind of common denominator for the bus nodes. Physical layer problems in CAN networks are often caused by phase errors due to oscillator tolerances, bit asymmetries caused by transceiver delays and wire delays. Depending on the specifications of the physical layer components, the optimum for this time window can be shifted slightly forward or backward. Usually the aircraft manufacturer is responsible for specifying the bit timing as part of the physical specification of its CAN networks. It should therefore be checked that the bit timings are correctly configured in the individual CAN controllers for each bus node.

Physical layer errors can be caused by overly long bus cables, too many or too long stubs or a faulty termination. Due to cable lengths of 200m, signal propagation delays play an increasingly important role in aviation CAN networks. The position of the bit diverges with increasing cable length, making it more and more difficult to find a robust sampling point for all bus nodes; the use of a lower bit rate should help. An alternative approach is to divide the system into two faster separate networks.

The network stubs for each node can also cause ripple effects such as reflections. They occur at cable ends and transition points, including junctions and plug-in connections, and superimpose interference voltages on the CAN bus signal. As a rule of thumb the sum of all stubs should not exceed 10% of the total cable length. Finally, electromagnetic compatibility problems must always be considered if the bus cable is installed near sources of interference, such as strong electric motors and converters.

SYNCHRONOUS ANALYSIS

Developing a robust CAN network and detecting potential communication errors before they occur requires the synchronous analysis of both physical and logical CAN layers. Developers need bit-accurate insights into signal variations in the physical layer. On the other hand, measurements without any reference to the logical CAN events

“DEVELOPING A ROBUST CAN NETWORK AND DETECTING POTENTIAL COMMUNICATION ERRORS BEFORE THEY OCCUR REQUIRES THE SYNCHRONOUS ANALYSIS OF BOTH PHYSICAL AND LOGICAL CAN LAYERS. DEVELOPERS NEED BIT-ACCURATE INSIGHTS INTO SIGNAL VARIATIONS IN THE PHYSICAL LAYERS”

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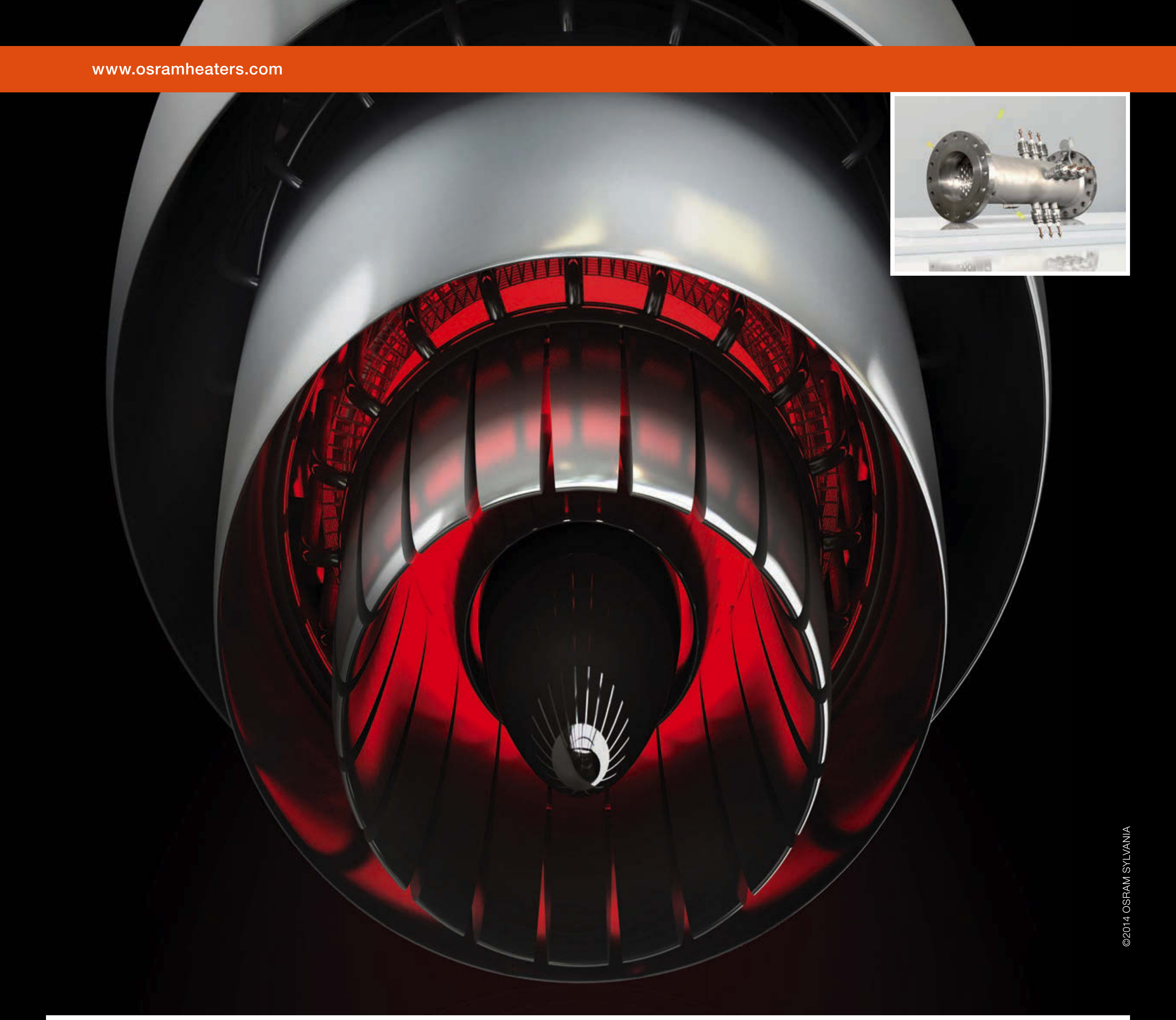

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ABOVE: USB oscilloscope hardware for bit-accurate analysis of CAN communication

are difficult to configure, interpret and evaluate. For this reason, Vector has added powerful oscilloscope functions to its CANoe and CANalyzer test and analysis tools for CAN. The Scope option uses a common time base for oscilloscope data and CAN event data, which gives a completely synchronized display of the recorded CAN frames and the corresponding CAN bus signal. CANoe/CANalyzer.Scope is based on USB oscilloscope hardware (Figure above) and supports four- and two-channel solutions with bandwidths of 200MHz and 60MHz; the sampling rate is up to 500MS/s in each case. A sync cable between the oscilloscope hardware and the CAN bus interface establishes the exact time reference.

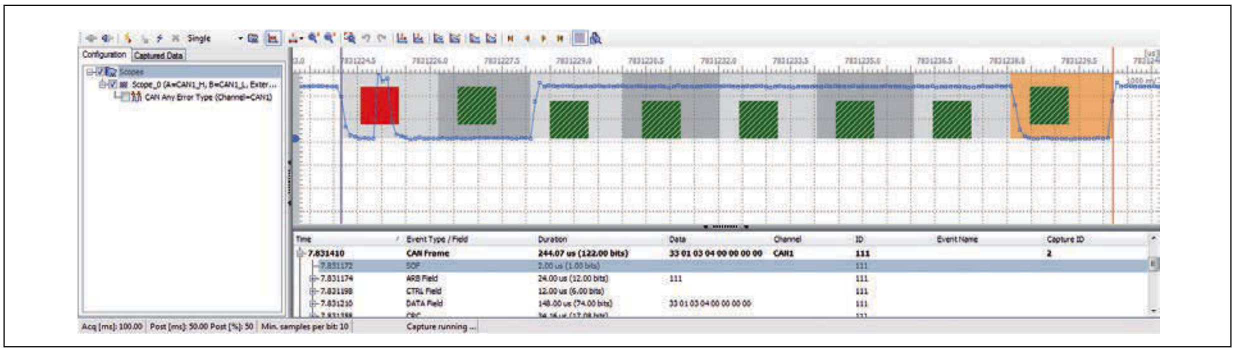
An extensive set of trigger conditions are available to allow fast pinpointing of physical layer problems. Individual CAN frames, entire ID areas, and special events such as error frames can be configured as trigger types. Programmable triggers can be configured and combined to define more complex trigger conditions. Bit timing violations can be explicitly visualized by means of user-definable bit masks in the voltage-time diagram. If the voltage level of the CAN signal passes through the bit mask, it indicates a possible violation of the physical specification and/or the system reserve. CANoe.Scope displays violated bit masks in red, while untouched masks are displayed in green (Figure top, next page).

> "IF A NETWORK IS OPERATING ERROR-FREE, THERE IS STILL A DESIRE TO KNOW WHETHER IT IS JUST BARELY FUNCTIONING OR IF SUFFICIENT SYSTEM RESERVES ARE STILL AVAILABLE"

TROUBLESHOOTING AND ROBUSTNESS

Such oscilloscope analysis functions provide developers and test engineers with a fast and targeted analysis of the CAN physical layer. As a test strategy, Vector recommends individual testing of all Line Replaceable Units (LRU) to begin with, in order to filter out possible problem candidates. The location of identified errors can be narrowed down in subsequent steps and actions taken to eliminate them.

For sporadically occurring errors, endurance tests on the same frames or identifiers are useful. If a network is operating error-free, there is still a desire to know whether it is just barely functioning or if sufficient system reserves are still available. This can be determined using stricter violation criteria. The position and shape of the bit masks are changed incrementally until the first errors occur again. The LRUs responsible for the violations would be the first to fail in regular operation and represent potential error sources. Test reports of documented errors or exported data can easily be exchanged between aircraft



ABOVE: Bit mask test of a CAN differential signal in order to evaluate the signal quality of a CAN node in the area of the sampling point

manufacturers and suppliers (Figure below). Ideally the supplier uses the same analysis and test tools and is therefore easily able to find and eliminate errors.

A further typical test strategy involves stressing the CAN network with artificial physical and logical errors. A suitable method is to use the CANstressDR hardware module (Right opening page).

Vector has been a CAN pioneer from the outset and can look back on 25 years of experience in the automotive, commercial vehicle, agricultural engineering, aviation and marine sectors. Its hardware and software solutions are supplemented by numerous training courses on subjects such as design, analysis, and testing of CAN systems and other networks such as CAN FD, AFDX and Ethernet. With the free e-learning module 'Introduction to CAN (including CAN FD)', interested parties can introduce themselves to CAN communication technology.

CONCLUSION AND OUTLOOK

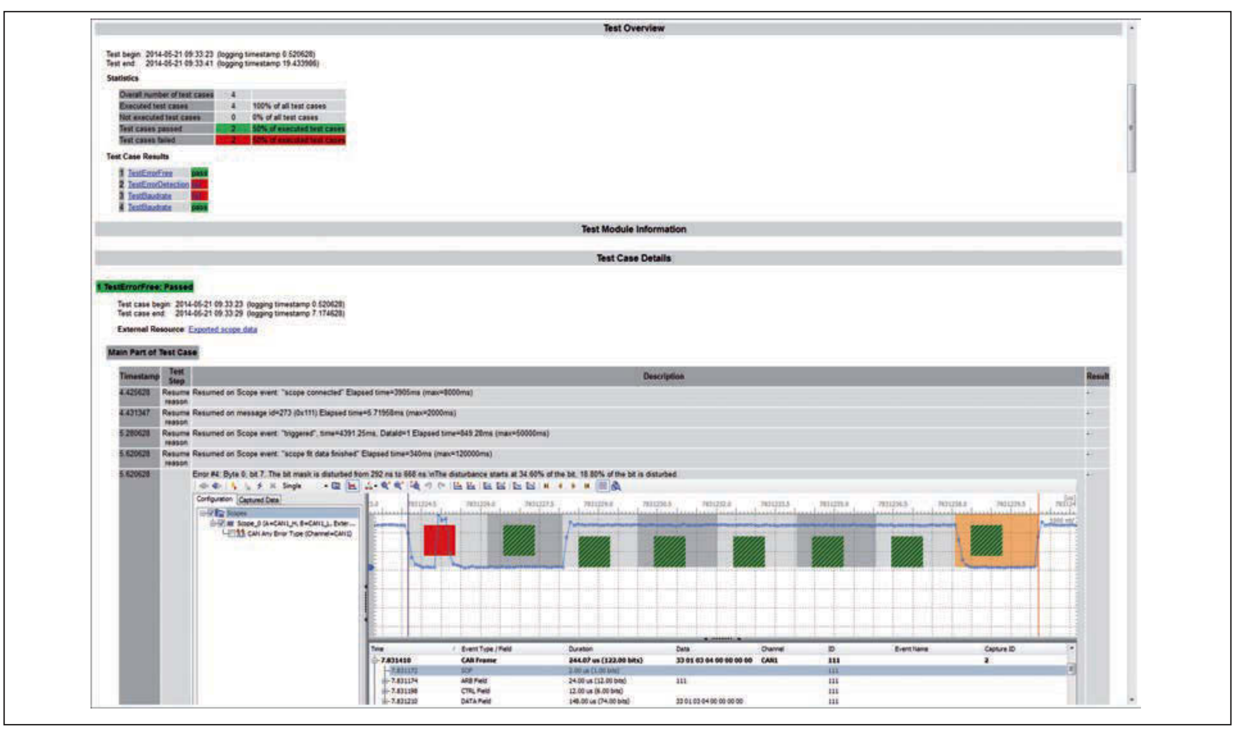
Due to the several hundred CAN systems in current and future aircraft generations, manufacturers and suppliers alike are increasingly dependent on the availability of powerful analysis and test tools. Bit-accurate and time-synchronous analysis of logical and physical events on CAN buses with the described oscilloscope solution not only speeds up primary troubleshooting, but also enables evaluation of the signal quality and robustness. Extensive triggering and programming options combined with high-performance test automation, support developers during troubleshooting and optimization of their CAN networks.

For the various manufacturers and development departments in the aviation industry, a dedicated product based on the Vector Scope solution can also be useful. A product development that combines an oscilloscope with a suitable CAN interface in a single housing is already planned at Vector.

The company is also open to customer-specific requests such as special signal-analysis functions and manufacturer-specific user interfaces so that its test solutions can be used as efficiently and widely as possible. This enables the development of automated test tools capable of quickly performing routine production tests on every aircraft according to defined manufacturer specifications. Vector also plans to extend its oscilloscope solution with innovative measurement and analysis functions for checking CAN cables and terminations. Since the CAN cables in aircraft are often very long and difficult to access, the goal is to pinpoint the location of a damaged or broken cable to minimize troubleshooting costs. ∎

Jörn Haase (graduate engineer) is a global technical aerospace engineer at Vector Informatik GmbH aviation office in Hamburg, Germany. Gavin Rogers (B Eng MSc) is product manager for the CAN and Scope options of CANoe/CANalyzer at Vector's headquarter in Stuttgart, Germany.

BELOW: During automated tests, a detailed test report is created



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TAKE THE STRAIN

The National Aerospace Laboratory in the Netherlands has conducted a damage enhancement test on the wing of the F-16 of the Royal Netherlands Air Force and the Chilean Air Force, leading to an estimated saving of US$39m

BY MARCEL BOS

To verify the current estimates for the service life and maintenance requirements of the F-16 of the Royal Netherlands Air Force (RNLAF) and the Chilean Air Force (FACh), the National Aerospace Laboratory (NLR) in the Netherlands has conducted a so-called damage enhancement test on the left-hand wing of a decommissioned F-16 Block 15 aircraft. This durability test aimed to grow in-service fatigue cracks of sub-detectable size to a size at which they could readily be detected.

The main objective was to determine whether the ex-service wing, which had logged more than 4,000 RNLAF flight hours, contained damage not accounted for in the initial General Dynamics durability test program of the 1970s or in later analyses by Lockheed Martin.

Other objectives were to generate data that can be used for an assessment of the current maintenance program and to establish the most likely fail scenario. For this purpose, the ex-service wing was installed in a test rig and connected to 23 hydraulic actuators, which were independently controlled by means of a servohydraulic load control system. The rig's stiffness was designed and tuned such that the reaction forces encountered in the test rig and the internal loads in the test article closely matched the expected in-service loads for a wide range of operational flight conditions.

NON-DESTRUCTIVE AND VISUAL INSPECTION

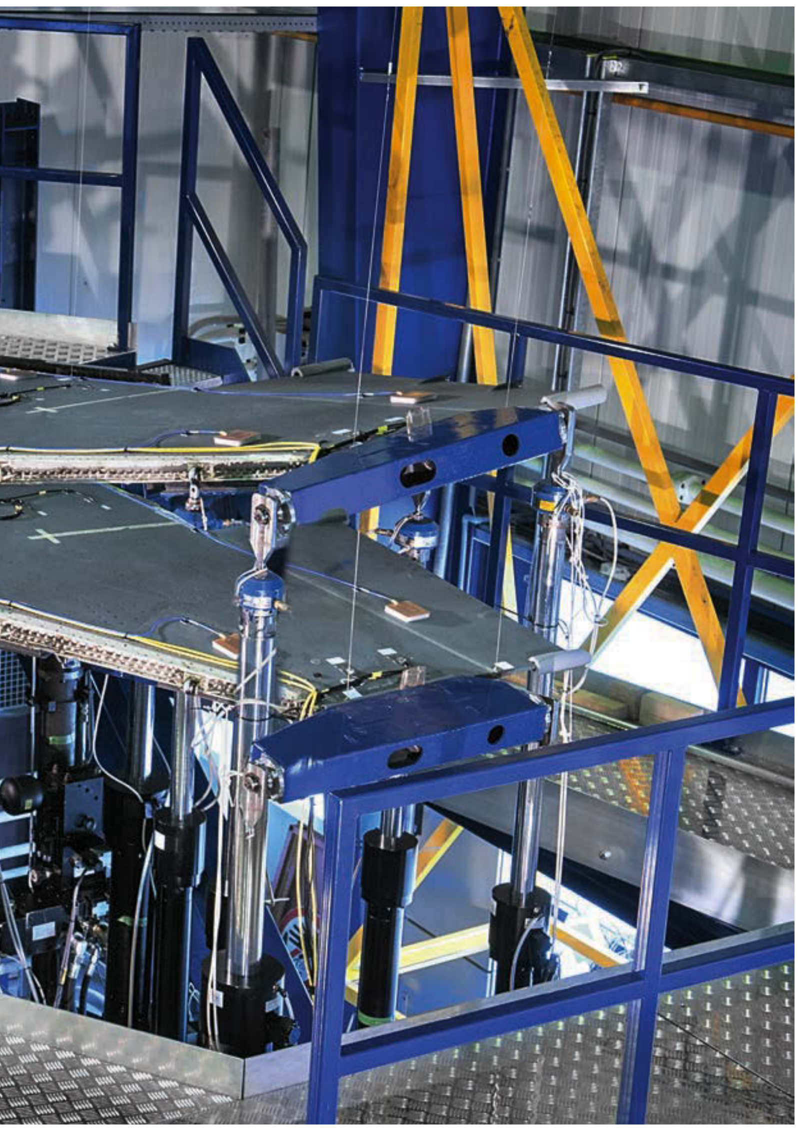
Prior to installation in the test rig, a detailed non-destructive and visual inspection of the left-hand wing was carried out. In parallel, a teardown inspection of the right-hand wing was conducted to establish the baseline damage condition. Instrumentation in the form of conventional and optical fiber strain gauges was applied for the measurement of the local strain responses in the wing skins and spars. The vertical displacements due to up and down bending were measured using a novel technique that utilized a radio transceiver mounted at a fixed point above the wing and a number of patch antennas that were bonded to the upper wing skin.

After commissioning of the test setup, the wing was subjected to a load spectrum representative of Netherlands operational usage. The spectrum was enhanced with marker loads to improve the 'readability' of the fatigue fracture surfaces during post-mortem fractography.

Throughout the test, the wing was regularly inspected for the formation and growth of fatigue damage. For this purpose, standard eddy current technology was used, as well as an acoustic emission system and a comparative vacuum monitoring system. Strain surveys were performed at preset intervals to verify the proper loading conditions.

FATIGUE ANALYSIS

Upon completion of the damage enhancement test, the left-hand wing had been subjected to a load spectrum



that was equivalent to more than twice the certified service life. During the test, a number of fatigue cracks had initiated and grown, some of them to a significant size. The wing was able to sustain the three limit load cases that were applied after the durability test, however.

In the subsequent teardown analysis of the left-hand wing, the lead cracks were investigated using optical and scanning electron microscopes. Quantitative fractography, enabled by the application of marker loads in the test spectrum, yielded valuable information that was used to calibrate the available fatigue crack growth models and to update the current estimates for the service life and maintenance requirements of the F-16 Block 15 wings of the Netherlands and Chilean air forces. The inspection and test results enabled the RNLAF and the FACh to reassess the need for their planned modification programs and the acquisition of new wings for subsets of their fleets to ensure the required operational availability up to the phasing-out of the last F-16s in their fleets. Based on the test results and the ensuing analyses, the RNLAF has decided to cancel plans to acquire 30 new wing sets, which led to a saving of approximately €30m (US$39m). ∎

Marcel Bos is an R&D engineer at National Aerospace Laboratory (NLR), based in the Netherlands

ABOVE: **Composite photograph showing the F-16 Block 15 wing deflections as encountered during the applied limit load cases**

RIGHT: **Eddy current inspection of the fatigue critical areas in the F-16 Block 15 left-hand wing during teardown**

JARED VAN BAREN

TRUE OR FALSE?

Can test engineers really see what is going on behind the scenes by doing random testing during ramp-up?

BY JARED VAN BAREN

In today's testing world, test professionals want to see a nice, smooth line on their random PSD plots when ramping up a random test. These tests look accurate on a report and do not raise any questions about the test. It seems everyone is happy because the report looks good. But in these graphs, can test engineers see what is really going on behind the scenes during ramp-up? A nice smooth ramp-up line on a random graph is an indication that the actual data is not being presented. This is a major concern. Ramp-up is a critical time when drive could possibly overshoot low-level tolerances before settling into control. When a test steps up from one level to the next, a resonance can easily shift. This can be critical information that test professionals need to see.

THE RAMP-UP PERIOD

To put it simply, ramp-up is a term used to describe the period between when the test begins and when it reaches level. The random test takes a large block of data over time and averages the signal over that time. A random signal requires averaging for a certain amount of time to get a response line that has some smoothness. At the beginning of a test, only a short amount of time has been spent collecting and averaging data. Therefore authentic random graphs will always be choppy initially. The more time spent averaging, the smoother the line will be.

There are three ways for control software to address this concern:

• Present the reality. This method displays real-time data during ramp-up. As testing progresses, the line will average out and become smoother.

• Mask real-time data through delay. This method multiplies the low-level data by the ramp-up factor and displays the result. The problem is that this method does not present the true noisy signal; it is a calculated average and not what is really happening during ramp-up.

• Mask real-time data through prediction. This method also uses averaging but instead predicts the

ABOVE: In satellite launch applications, ramp-up periods could be dangerous to ignore

BELOW: A satellite launch without proper testing could be a costly mistake

demand level and precedes it with the averages, factoring in new averages as time goes on. The graph only displays the response at the beginning and as sufficient data is accumulated, the line will finally be updated to show real-time random data. Here the problem is that real results are not displayed during ramp-up. The display shows what is expected (low-level results multiplied by the step amplification factor). Although this is what customers like to see, it is not actual data; it is presenting something that didn't happen as if it were actually there.

Consider this analogy. A car, per test specification, is supposed to go from 0 to 60mph in 1 second. This is probably not possible. Controllers are not able to show similar test data. No controller is able to ramp-up that quickly while meeting the demand level. It is too short a time period. The test either has to display real-time data or has to mask it so that the graph fits customer expectations.

Continuing with this analogy, what some controllers will do is display a reading of 0-60mph on a speedometer during that 1 second. That is to say, after 0.001 seconds the speedometer reads 60mph and never changes. However, the car is really still accelerating and may only be at 6mph in this first second, 20mph after 2 seconds, 45mph after 3 seconds, and 62mph after 4 seconds. Anyone would recognize that if a speedometer did this, something would not be working properly. It is not true data; it is masked data that displays an expectation, but is not accurate.

THE DATA AND RESULTS

Historically, controllers have not shown the important real data during ramp-up, and therefore test professionals are not accustomed to seeing this on the graphs. Seeing

LEFT: A ramp-up period during a rocket launch should be replicated in the lab before launching

"WHEN AN OUTPUT IS MULTIPLIED BY 10, THE INPUT IS ALSO EXPECTED TO MULTIPLY BY A FACTOR OF 10. ALL THE READINGS IN THE INITIAL RAMP-UP STAGE ARE USED, TO SHOW WHAT THE INPUT IS EXPECTED TO BE"

this ramp-up data, which sometimes exceeds tolerance and abort lines, can be concerning to test professionals. Many controller manufacturers attempt to meet expectations by masking real-time ramp-up data through prediction. This is done by running a low-level signal, maybe 10% of the desired level, then multiplying the output by a factor of 10. When an output is multiplied by 10, the input is also expected to multiply by a factor of 10. All the readings in the initial ramp-up stage are used, to show what the input is expected to be.

There is a downside to this practice. When stepping up in level, results can change and resonances can shift. With this masking technique, as the test progresses, more frames of data are added to the calculation but are weighted insignificantly. What if the product fails at that point? What if the product hits a resonance during ramp-up that users should know about, but the resonance is not seen because the product is undertested due to weighted averaging? If something this extreme is happening, the data should not be hidden. In a satellite launch application, for example, this could be important information and dangerous to ignore.

Nobody wants to see a product fail during ramp-up. But what if that is the perfect time for it to happen? What if the resonances that the product sees during ramp up are never seen again during the random test? Yet, the product may see these resonances during real-life customer applications. This may leave test professionals scratching their heads when the product 'meets' testing requirements yet continues to fail in the field.

A more realistic approach is to present the reality as it occurs during ramp-up, even if the graphs appear choppy and possibly temporarily exceed tolerance and abort lines. ∎

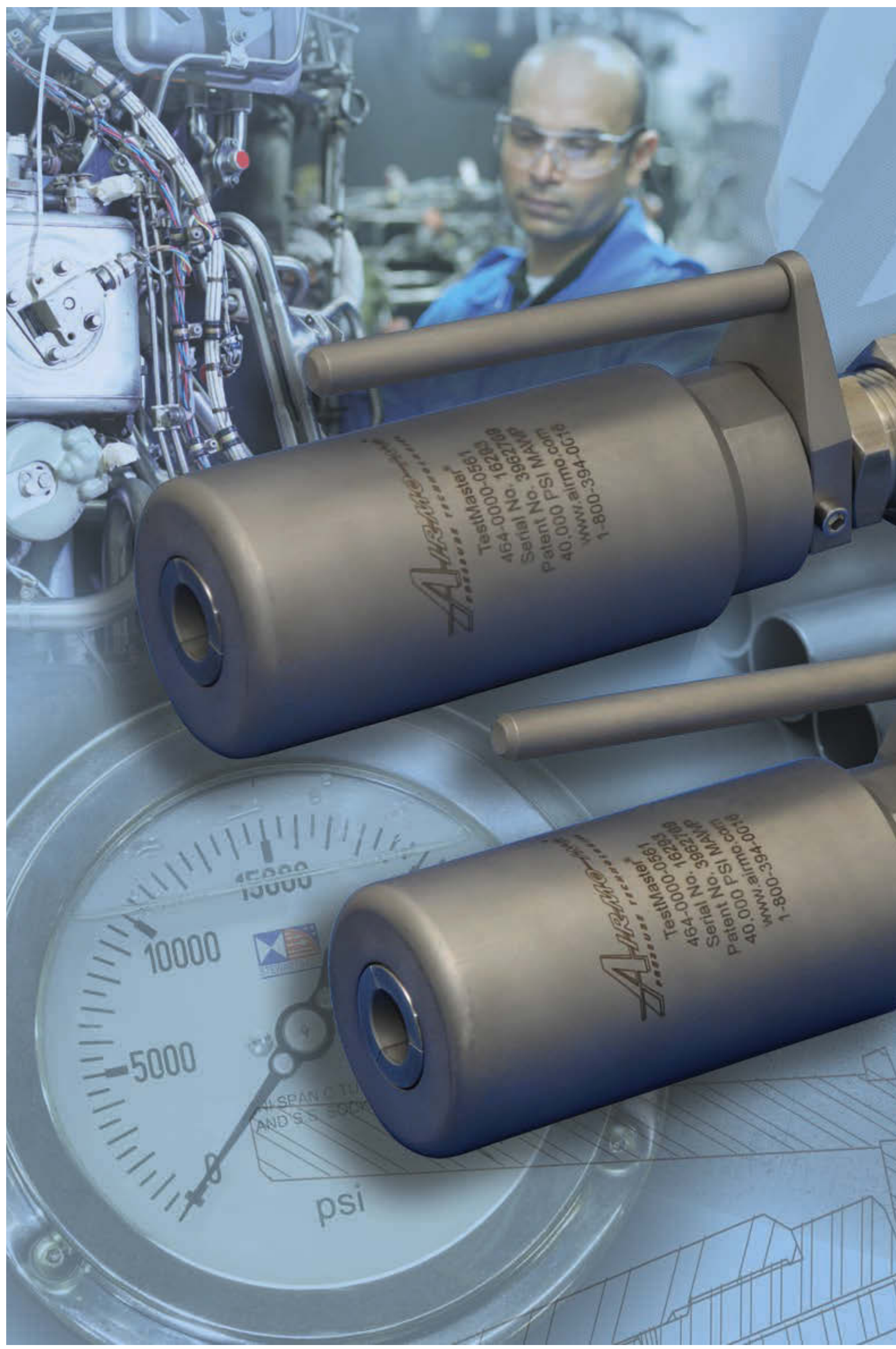
Jared Van Baren, sales and marketing at Vibration Research, based in the USA

JOHN VUKELICH

UNDER PRESSURE

The aerospace industry continues to seek solutions for testing at higher pressures. To meet this demand, a patented multi-use hydrostatic test tool has been developed

BY JOHN VUKELICH



Use of high-strength tubing in commercial and military aircraft is increasing as a result of industry demands for products that perform in challenging and harsh environments. Titanium alloys in various grades and heavy wall thicknesses have been specified for hydraulic systems in military aircraft. This accommodates working pressures upward of 8,000psi (552 bar). For applications such as this, proof and burst tests of these tubes and tube assemblies have become necessary at pressures exceeding 30,000psi (2,068 bar).

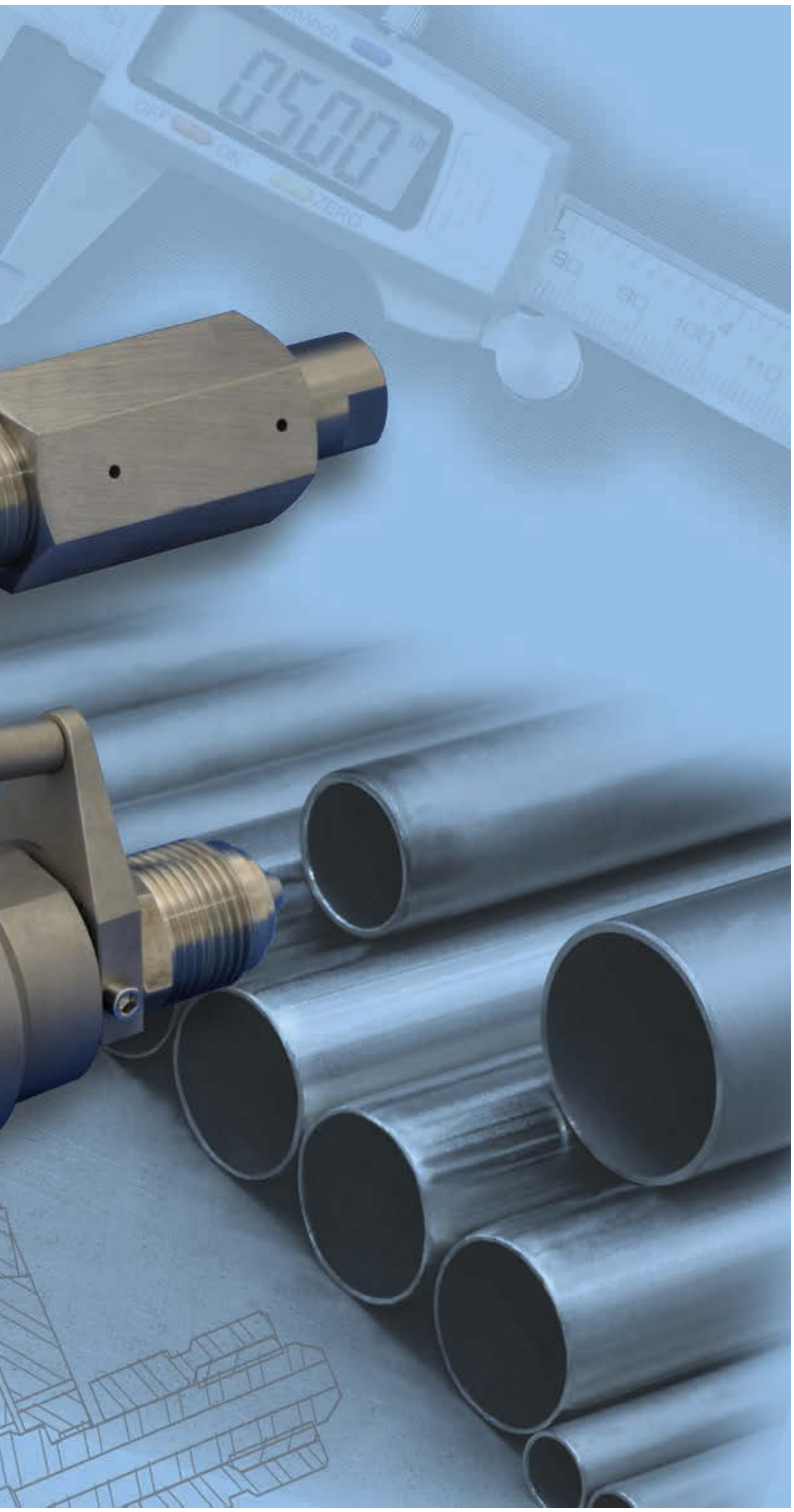
Airmo has developed a tool that will grip and seal on the outside diameter of a tube while fluid is pumped through the tube or assembly during a pressurization cycle. It can safely perform a variety of proof and burst tests from 0-40,000psi (0-2,758 bar).

HOW IT WORKS

The hydrostatic test tool is a hand-operated device that is easily placed on the end of a plain round tube. Normally this type of tool is used in pairs, with one on each end of the tube or tube assembly being tested. The tube end where fluid is introduced is called the 'fill' side and the end where air is expelled is called the 'air bleed' side. Bleeding the air is a common practice when testing tubes. A hydrostatic test is safer than a test with pressurized gas because of the tremendous stored energy in compressed gas. In the event of rupture during a hydrostatic test, the small amount of stored energy released from compressed fluid is easier to manage.

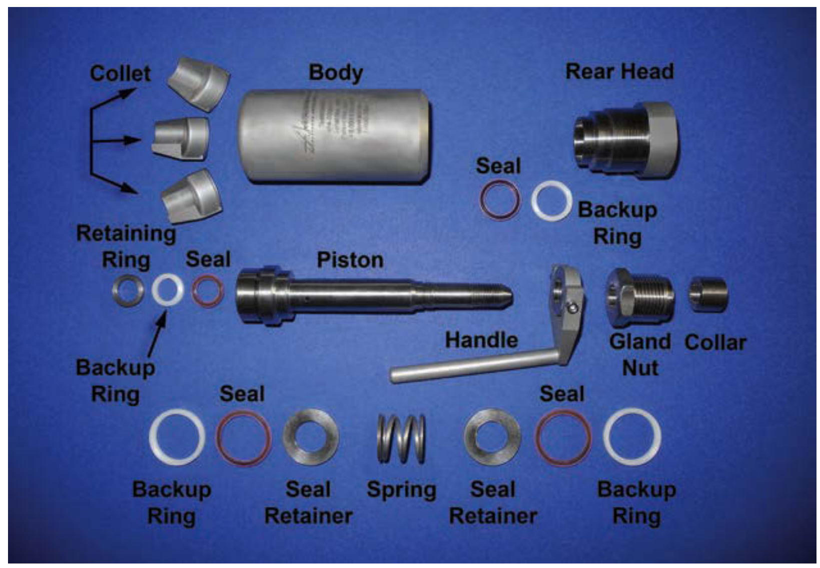
Squeezing the handle on the tool retracts the collet segments, allowing insertion of a tube. Once a tube is seated against the tool's internal shoulder, the handle can be released. A spring then moves the collet segments to an initial gripping position. At this point, the operator no longer needs to hold onto the tool.

With a hose connected to the fill side tool's high-pressure port, pressurization may begin. As fluid is pumped through the line, it flows



LEFT: Hydrostatic test tool with and without air bleed assembly

BELOW: Exploded view of hydrostatic test tool



through the tube and internal chambers of the tool while forcing the air out. Once all air is evacuated from the assembly, a valve closes to allow pressure to build. As test pressure rises, growing pressure in a tool's internal chamber will produce increasing force on the backside of collet segments. This force moves the collet down the angled surface of the body and produces a normal force on the tube surface. The resulting friction is what keeps the tube safely held inside the tool.

GRIP AND SEAL SOLUTIONS

While the collet must provide sufficient gripping force, it is desirable to do this without permanently distorting or marking the tubes. If no marking occurs during the test procedure, reworking the end will not be necessary prior to use in a final assembly. Several unique features of this tool's collet prevent tube distortion and marking. First is the collet angle. It is designed to provide sufficient gripping force, but not so much that it crushes the tube. Second is collet bore finish. It optimizes friction, but leaves little or no marking on the tube. Third is collet contact area with tube. This surface area is made as large as possible to distribute the gripping force, further reducing marking. Finally, the collet is split into three or four segments using a small diameter wire in an electrical discharge machine. The small resulting gaps do not allow tube material to flow between the collet segments during pressurization, which reduces distortion.

Obtaining adequate seal performance was a challenge faced during development of the hydrostatic test tool. The seals must provide leak-free sealing at any test pressure up to 40,000psi (2,758 bar) and must not extrude or wear rapidly. This tool uses lip-type seals with O-ring energizers. The shell portion of the seal is made from high tensile strength elastomer, while the softer O-ring promotes low-pressure sealing by pushing the shell's lips against mating components. Backup rings are special-geometry

ABOVE: Inserting tube into fill side of hydrostatic test tool

RIGHT: Inserting hydrostatic test tool air bleed side onto tube

parts made from a hard plastic that deforms enough to fill any gaps through which the seal would otherwise extrude when at high pressure. Gaps between metal components are kept to a minimum, while still allowing the motion necessary for tool function. Surface finish on metal components is controlled to minimize abrasive wear of seals.

The seal in contact with the tube may be most susceptible to extrusion and wear. Tube size and condition play a big part in determining the life of this seal. If the tube diameter measures within a 0.004in (0.1mm) range, the seal is unlikely to extrude. A tube end free of burrs and sharp corners will contribute to long seal life and avoid cuts during insertion or removal of the tube.

OTHER FEATURES

While gripping and sealing are critical functions of the hydrostatic test tool, it is also important that the tool be easy to use and maintain. Every tool is designed to be dedicated to a specific tube diameter, making the tool as lightweight and compact as possible. The small size allows the tool to fit into tight spaces, which is advantageous when testing tube assemblies already installed on the aircraft. Ergonomics are addressed with a rounded handle and body to avoid pressure points, which lead to hand fatigue. The rounded surfaces also reduce the risk of damaging fragile components that may be contacted during the testing process.

The design simplicity of these tools means little training is required to become proficient in their use. New users typically learn to operate the tool properly within minutes, which leads to good repeatability in the testing process.

Tool simplicity is also beneficial from a maintenance standpoint. The tool can be disassembled and reassembled in the field, with no special wrenches or expertise needed. Components of the hydrostatic test tool are made from hardened stainless steel, making them robust and corrosion-resistant. This results in a long service life and reduces the amount of maintenance needed.

TOOL OPTIONS

To accommodate a wide variety of applications, the hydrostatic test tool is offered with different sizes and types of ports, as well as different surface finishes on the collet bore. Port types are limited because of the 40,000psi (2,758 bar) working pressure, but include cone-and-thread type connections such as 'High-Pressure' and 'Type M'. Collets are available with bore finishes in different roughness levels, which provide optimal gripping while minimizing marking on the tubes.

As higher-performing aircraft systems are developed, an upward trend toward higher-pressure burst and proof tests is expected. With its 40,000psi (2,758 bar) maximum working pressure, Airmo's new hydrostatic test tool is positioned to meet current and future testing needs. It does this while providing the ease of use and simplicity that have come to be expected in this type of tool. ∎

John Vukelich is a mechanical engineer with Airmo Inc. Pressure Technologies, based in the USA

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LITTLE BIRD LIVES ON

Boeing Mesa tests the latest branch in the Little Bird family tree, the International AH-6i

BY FRANK COLUCCI

Boeing Vertical Lift in Mesa, Arizona, is conducting airworthiness qualification testing on the latest version of the combat-proven Little Bird scout/attack helicopter. The new AH-6i will be built for international customers but qualified by the US Army Aviation Engineering Directorate on behalf of the army's Non-Standard Rotary Wing Aircraft Project Management Office (NSRWA PMO). "I think we're about a third of the way there," says Boeing's chief engineer for attack helicopter programs, John Schibler. "We talk about it in the number of flight hours, but we really track test points and where we are in getting the test points for qualification." The first production-configured AH-6i flew in May, and Boeing plans to fill its Mesa production line in 2016.

Although it has little in common with the Vietnam-era OH-6A, today's AH-6i builds on the Hughes Cayuse heritage and dynamic improvements already qualified in the MH-6M Mission Enhanced Little Birds (MELBs) of US Army Special Operations Forces. The AH-6i test program consequently uses only a single instrumented aircraft. "It's not as extensive as a brand-new aircraft would be because this whole qualification is based on the strong lineage of the MELB," acknowledges Schibler. The AH-6i mission suite, meanwhile, leverages hardware and software in the highly integrated, digitally connected AH-64E Apache. "We've redesigned the mission processor based on the design in the Echo-model Apache, using some of the same avionics boxes already qualified on the E-model Apache," says Schibler. "We call that engineering reuse in a good way."

Boeing Mesa has four Little Birds configured for various test duties, including the Model 530F Unmanned Little Bird (see *Aerospace Testing, International, Testing Talk*, May-June 2009, p12-16) and two AH-6X demonstrators. Most AH-6i flight testing is done around the Mesa factory, but company testers took their AH-6X Armed Aerial Scout contender to Yuma Proving Ground in 2012 for US Army voluntary flight

The instrumented test aircraft has a tail boom 'bike rack' to keep sensor wires away from the high-lift tail rotor (Photo: Boeing Mesa)

LITTLE BIRD EVOLUTION

The AH-6i traces its size, survivability and performance back to the Hughes OH-6A light observation helicopter first flown in 1963 and ordered into production by the US Army in 1965. The agile, crashworthy OH-6A had four-blades with only a 317 shp Allison engine. The T63-A-5A had a design gross weight of 2,100 lb and saw extensive combat in Vietnam. In preparation for a second Iranian Embassy rescue attempt in 1980, the army evaluated both the Bell OH-58C and McDonnell Douglas OH-6A as small, deployable attack and utility helicopters. The OH-6 proved easier to load into a C-130 transport, and the first Special Operations Little Birds were drawn from the Oklahoma National Guard.

Task Force 160 received new-build AH-6 attack and MH-6 utility helicopters based on the T-tailed McDonnell Douglas MD500D starting in 1981 under the code name 'Seaspray'. The five-bladed AH/MH-6C with 420 shp Allison (now Rolls-Royce) 250-C20 had a take-off gross weight of 3,200 lb. Six AH-6Cs were deployed by C-130 to fight for the first time in Operation Urgent Fury on Grenada in 1983. Little Birds attacked the minelayer Iran Ajr in the Persian Gulf in 1987; and strafed the headquarters of the Panamanian Defense Forces in December 1989. An MH-6 pulled wounded Black Hawk crew members from a firefight in Mogadishu, Somalia in 1993. Although used extensively, the Little Bird never completed formal army airworthiness qualification until years after it joined what is today the 160^{th} Special Operations Aviation Regiment. Little Birds were used in Operation Iraqi Freedom and elsewhere. The A/MH-6J, with 650 shp maximum take-off power, has a gross weight of 3,950 lb. However, two MH-6Ns with the NOTAR (no tail rotor) anti-torque system were rejected for Special Operations Missions.

The Special Operations Little Bird was ultimately qualified with 7- or 19-shot rocket pods, 7.62mm M134, and 50 caliber M2 guns, and the laser-designated AGM-114 Hellfire missile mounted on a removable fuselage plank. They have acquired a succession of reconnaissance and targeting sensors, and integrated cockpit avionics. The current, convertible A/MH-6M Mission Enhanced Little Bird with six-bladed main rotor, four-bladed tail rotor, and integrated cockpit, has a gross weight of 4,700 lb. The 160^{th} SOAR received the last of 51 A/MH-6M conversions in 2008.

The high-density altitudes encountered in Afghanistan drove the US Army to evaluate various Armed Aerial Scout alternatives to replace the OH-58D Kiowa Warrior. The optionally manned AH-6S flown in 2007 was stretched by 15in to carry more fuel and leveraged avionics from the Apache Longbow Block III. The first AH-6i demonstrator for the international market flew in 2007, and the production configuration now in test flew in 2014.

demonstrations. Yuma will probably be the site of AH-6i weapons tests. "That's one of the reasons Boeing is in Arizona for rotorcraft," observes Schibler. "We can get to so many places where we can do certification testing."

Given data collected by government and industry testers, the US Army Aviation Engineering Directorate (AED) at Redstone Arsenal, Alabama, oversees the airworthiness of all US Army aircraft, and those bought for allied countries by the NSRWA PMO in Huntsville, Alabama. AED, for example, qualified the civil-certified Bell 407 armed and integrated for Iraqi forces. Boeing will not name its first AH-6i customer, although both the US Defense Security Cooperation Agency and the NSRWA PMO acknowledge aircraft on order for Saudi Arabia.

Middle Eastern operators need helicopters with exceptional hot-day/high-altitude performance. The AH-6i has a 600hp drivetrain, six-bladed main rotor, canted tail rotor, Rolls-Royce Series 250 C30/3M engine with dual-channel full authority digital electronic control (FADEC), and other performance enhancements. With two pilots, full internal fuel and four Hellfire missiles, the new Little Bird at 95°F (35°C) promises to hover out of ground effect at 7,500ft (2,286m).

The six-bladed main rotor derived from that on the MD600 commercial helicopter, noise-reducing four-bladed tail rotor, and various engine and transmission improvements were previously qualified for the MH-6Ms of the 160^{th} Special Operations Aviation Regiment. The Army Aviation Technical Test Center (now the Aviation Flight Test Directorate) began a full Airworthiness and Flying Characteristics program for the MH-6M in 2001.

The AH-6i will be offered with the same civil-certified metal main rotor blades now on the MELB. Small composite rotor blades developed by Kaman, and other configurations studied by Boeing, have yet to be qualified. Schibler says, "The only performance difference from the MELB stems from the fact that this aircraft we're qualifying right now for our international customer base will actually have a dual-channel FADEC – electronic controls. Rolls-Royce was developing that for some other aircraft out there. We won't be offering the AH-6i with the electromechanical version of the past."

The Special Operations helicopter with weapons, auxiliary fuel and external bench seats was tested to 4,700 lb gross weight. "The Special Forces guys fly these things fully loaded and very heavy," says Schibler.

RIGHT: The production configuration AH-6i with 600hp drivetrain, six-bladed main rotor, canted tail rotor, and avionics 'beak' is under test for international customers

We've done an awful lot of testing with them in years past to take them to weights the -6i will never need." Current plans test the new Little Bird at gross weights up to 3,850 lb. Given the structural lineage of the AH-6i, the test program does not include a static test article. "From a static test standpoint, we know all the margins," explains Schibler. "We know where we can grow and can't grow. That paves the way for you if you want the airframe to grow in the future."

LITTLE BIRD'S BEAK

Boeing sold the rights to the commercial MD500 series helicopters in 1999 to what is now MD Helicopters Inc (MDHI). Boeing and MDHI continue to work on production agreements for the AH-6i airframe. Independent of Boeing, MDHI and the NSRWA have delivered MD530F helicopters to Saudi Arabia. MDHI now markets its armed, integrated, six-bladed MD530G II around the world. The competitive global marketplace wants armed aircraft with integrated navigation/communications/targeting avionics. Although the US Army killed hopes for a stretched AH-6S Armed Aerial Scout, Boeing continues to sell the advantages of a light scout/attack helicopter with Apache commonality and connectivity.

Saudi Arabia is an AH-64D operator and in line for new AH-64E Apache Guardians (formerly AH-64D Block III Apache Longbows). Tommy Filler, Boeing's director of international Apache and AH-6 programs, notes, "If you look at the legacy of the Apache program, when you look at the AH-6i you can easily see things we've done in the avionics architecture, software and pilot workload. All the taskings certainly give us differentiation when it comes to putting those capabilities in a smaller aircraft."

The AH-6i cockpit enables either crew member to access electro-optic/infrared video, engine and systems, moving map, armament and other information on dual 10.4in flat-panel multifunction displays, a vertical engine display and a caution-warning up-front display. The avionics architecture reuses select line replaceable units and significant software from the AH-64E. Flight and weapons symbology and digital map pages, for example, are based on those now in the Apache. The AH-6i mission computer is likewise based on AH-64E-based open system architecture and commercial off-the-shelf hardware.

Unlike the Apache, the AH-6i has no full systems integration hot-bench. Schibler explains, "We have a 'hot bench lite', if you will, for the -6i software and mission processor work. Because the aircraft is so small and easy to operate, it's more economical to configure the aircraft and do the testing on the aircraft."

The current AH-6i targeting sensor is the WESCAM MX-15D gimbal with thermal imager, day and low-light television cameras, and laser rangefinder, designator, illuminator and spot tracker. The package provides aiming symbology and designation for laser-guided missiles and rockets, and 7.62 or 50 caliber guns on four external stations.

The mixed sensors occupy a chin turret, but integrating the other AH-6i avionics into the small airframe posed packaging challenges. Where the Technology Applications Program Office of the US Special Operations Command opted for Little Birds with round noses to maximize visibility, AH-6i engineers put a distinctive beak on the already-pointed windshield of the commercial MD500E/520/530. "The beak is a variant of the pointy-nose model with air intakes to cool the boxes up in the front," says Schibler. "There's no air-conditioning on the aircraft like we have on the Apache. Cooling avionics is a lot trickier than on an Apache where you have a huge air flow to cool the boxes."

Flight tests have examined the impact of the beak on Little Bird flying

"THE FIRST AIRCRAFT IN TEST TODAY IS A FULLY INSTRUMENTED AIRCRAFT. WE'RE FINDING THAT THE NOSE IS TYING INTO THE EXISTING DATABASE OF THE ORIGINAL ROUND, BULBOUS NOSE. WE'RE FINDING NO DELETERIOUS EFFECTS"

qualities. "We greatly affected, in a positive fashion, the CG of the aircraft by putting the pointy nose on it. We put some structural reinforcement in to put the mission processor and some other boxes up there." Flight tests have so far validated the new nose design. "We're going through a complex flight strain survey and handling qualities," says Schibler. "The first aircraft in test today is a fully instrumented aircraft. We're finding that the nose is tying into the existing database of the original round, bulbous nose. We're finding no deleterious effects."

The instrumented AH-6i also has torque sensors and accelerometers on the canted tail rotor assembly. An external 'bike rack' keeps the sensor slipring assembly from free-spinning with the rotor and provides a way to run the wires away from the rotor. The AH-6i avionics suite records some standard flight parameters. Data from add-on sensors is collected by dedicated recorders, and the cumulative data stream is telemetered to Boeing ground control. "We telemeter almost everything," notes Schibler. "We're monitoring key points where we don't want our aircrews to get in harm's way.

"It's nothing compared with what we did with the E-model telemetry when we were up to our ears in data," he adds.

Boeing vertical lift engineers are teamed with Boeing Test & Evaluation (BT&E) on the AH-6i. "BT&E has a very strong presence here in Mesa," says Schibler. "It is an extension of my integrated product team structure. You can't tell the difference between my engineering and BT& E… we benefit from Big Boeing. They do a lot of testing." ■

Frank Colucci specializes in writing about rotorcraft design, civil and military operations, test programs and material and avionics integration. He is based in the USA

BELOW AND INSET OPPOSITE: The AH-6i integrated cockpit builds on hardware and software qualified in the latest AH-64E Apache

JEFF VANLANGENDON

STRUCTURALLY SOUND

The National Research Council of Canada (NRC) and National Institute for Aviation Research (NIAR) use MTS cross-coupling compensation to improve structural test speed and efficiency

BY JEFF VANLANGENDON

Complex test configurations are a constant challenge for full-scale structural testing. In these highly coupled loading schemes, multiple actuators exert different forces on the same portion of a test article simultaneously, generating errors that can compromise aggressive test schedules.

One solution for reducing error rates, and thus improving test efficiency and accuracy, involves fully compensating for all of the cross-coupled actuators in the rig. Offered as a feature of MTS AeroPro control and data acquisition software, this cross-coupling compensation utility (known as C^3 Performance, or C-cubed) enables test teams to manage highly coupled schemes without building extra time in the test schedule to account for resolving an abundance of stops and interlocks.

The cross-coupling compensation technique was co-developed by experts from the National Research Council of Canada (NRC) and MTS Systems Corporation. Today, it is a standard part of the testing protocol at NRC Canada's full-scale structural test lab, where Andre Beltempo works as a structural test engineer.

"We never consider not using it," Beltempo says. "Typically, we use C-cubed on all tests. With full-scale fatigue tests, you see very complex actuator interaction. That's exactly why we need it."

TECHNOLOGY DEMONSTRATION

Recently, Beltempo's team used the cross-coupling feature during a technology demonstration for a major helicopter manufacturer. The full fatigue and static test program focused on a tail boom made from composite material using advanced manufacturing techniques. The tests were identical to those that would be used to certify the part for safe life tolerance FAA requirements.

"If you look at the tail rotor gear box interface fitting, the two rear actuators are both loading on the same fitting," Beltempo says. "Cross-coupling compensation helps minimize the fighting [between actutators]."

The test involved six actuators and four million endpoints, running overnight for approximately 125 days, with an average frequency of 0.5Hz. This test speed would have been impossible without C3 Performance, according to Beltempo.

"We could not have done it as quickly without cross-coupling compensation," he said. "For an overnight test, we would have had to run the end levels at half the speed to not have to worry about unattended shutdowns. Our standard approach for any fatigue test is to tune the test, apply C-cubed, and tune it again right away. I've never seen a speed increase of less than a factor of two for a rigid article. Our customers always want fatigue tests to be done as quickly as possible, which makes it an essential tool for us."

Another aspect that Beltempo appreciates about C^3 Performance is its overall ease of use for everyone on the test team. Because test operators can set it up on their own, C^3 Performance helps labs gain even more time.

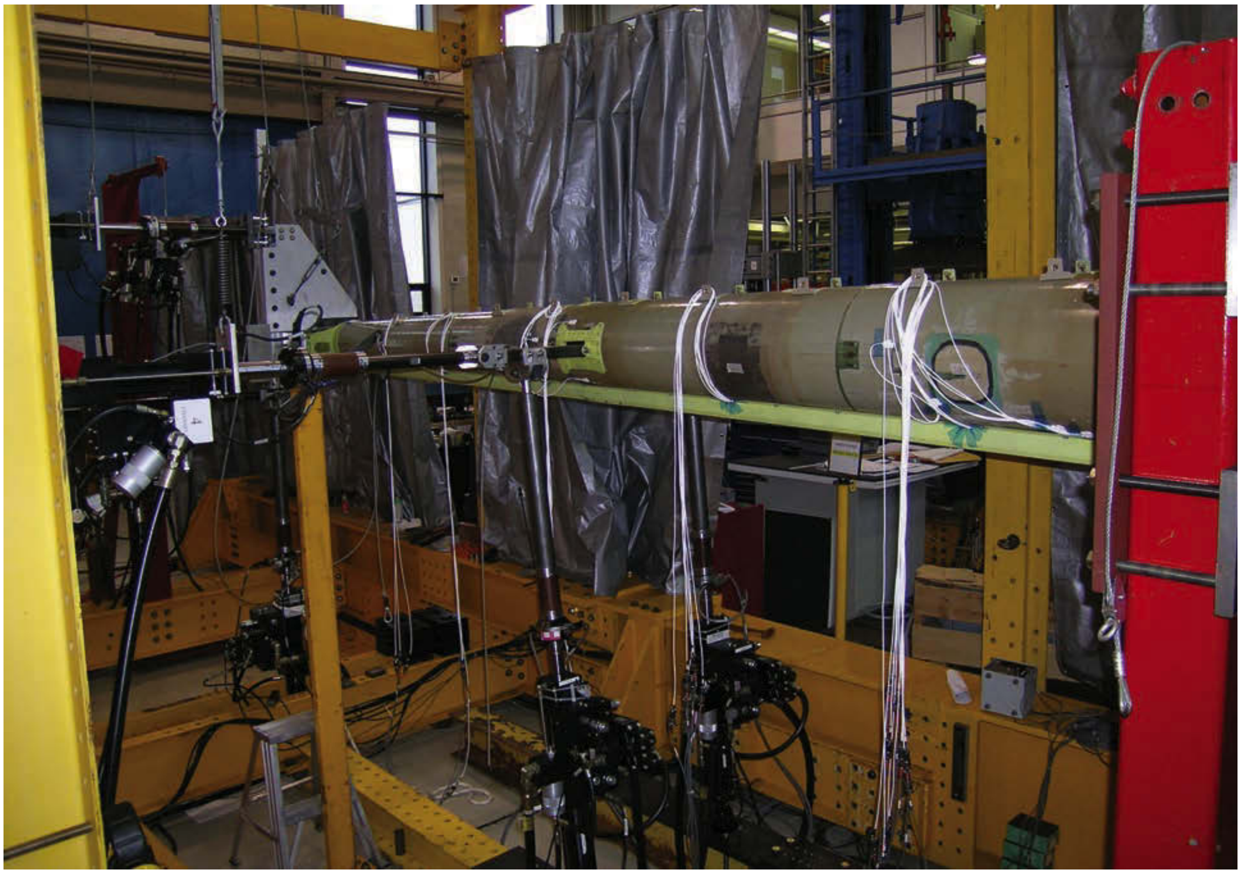
"The fact that it's so hands-free gives me the ability to focus on more important tasks," Beltempo says. "If you had to sit there and figure out all the coefficients on your own, it would be different. But you just click a button and it happens. It's a real productivity improvement."

While it is natural for the organization that helped develop C^3 Performance to apply it to every fatigue test as a matter of protocol, other test labs are also discovering the problem-solving potential of this powerful AeroPro software feature.

RESEARCH

For Dr Waruna Seneviratne, a technical director in the Composites and Advanced Materials lab at Wichita State University's National Institute for Aviation Research (NIAR), the largest university aviation research and development institution in the USA, the problem was sleep deprivation.

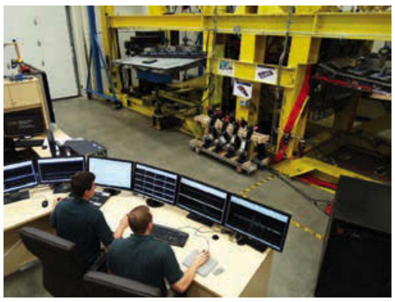
"We were running a fatigue test with a very distinctive combination of custom fixturing and actuation, and we had a very aggressive test schedule," Seneviratne says. "The test ran overnight and we were experiencing a large number of nuisance error limit triggers. Our team had to come down to the lab in the middle of the night to see what was



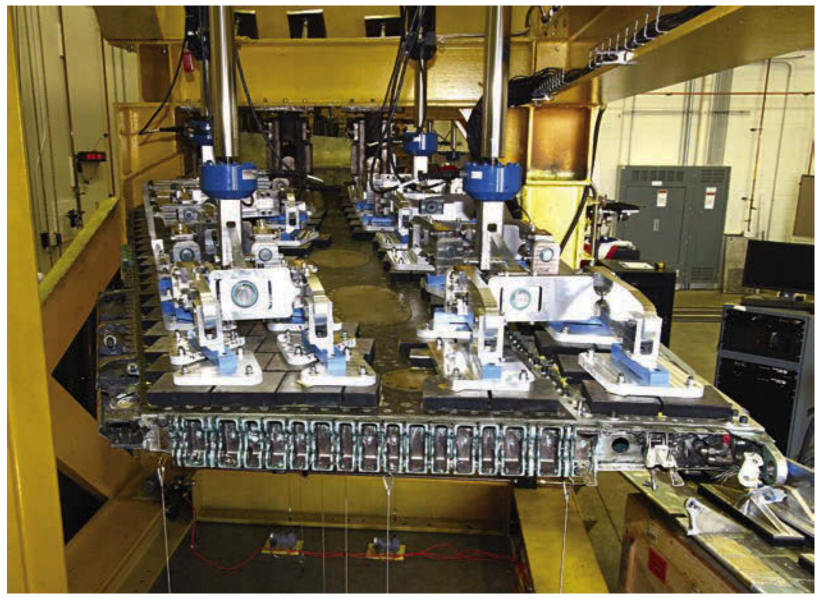
ABOVE: Applying C^3 Performance enabled NIAR to run this complex fatigue test of an F/A-18 Hornet composite wing structure 20% faster

RIGHT: Using C^3 Performance, NRC Canada was able to maintain an average frequency of 0.5Hz on this six-actuator fatigue test of a helicopter tail boom

"TO STREAMLINE STRUCTURAL TEST SETUP, C^3 PERFORMANCE ELIMINATES THE TIME-INTENSIVE TASK OF MANUALLY INPUTTING CROSS-COUPLING DATA BY EMPLOYING UNIT LOAD CASES TO GENERATE AUTOMATED CROSS-COUPLING COMPENSATION COEFFICIENTS"



BELOW: By reducing unintended test stops by two-thirds, C^3 Performance enabled the NIAR team to run tests overnight with greater confidence and operate on a more predictable schedule



RIGHT: With the F/A-18 Hornet composite wing structure, no mechanical modifications were made to the test rig

causing test shutdowns and to restart the test. We were falling behind."

The test in question was focused on evaluating fatigue life of composite structures of the F/A-18 Hornet, many of which are approaching retirement. The aircraft's replacement, however, will not be ready until 2019, which means the US Navy needs to safely prolong the service life of the aircraft's aging composite components and structures.

Seneviratne's research successfully determined that the composite-to-titanium bonded joints at the wing root had a great deal of life left in them. The new test expanded the study to include the entire inner wing, which has a composite skin. The test article includes the inner wing, trailing-edge flap and center barrel, as well as simulated leading-edge flap and outer wing. NIAR's research team had to construct an elaborate high-strength steel rig with custom-designed fixturing and apply significant loads to recreate aggressive maneuvers.

"There were significant differences between stroke and loads across the actuators, which was a likely source of the errors," he says. "We needed a way to minimize the false shutdowns, so we started looking into it."

Research engineer Travis Cravens, a member of Seneviratne's team, handled the setup and configuration of C^3 Performance. System and application engineers from MTS completed the installation and training in less than a day, and the lab saw results almost immediately.

"We were running 20% faster by the end of the first day with no mechanical modifications to the test rig," Cravens says. "C^3 Performance was very easy to learn and set up; it all occurs within the software. You simply create a cross-coupling matrix by applying a unit load on each load channel, which represents just one extra step for each actuator."

To streamline structural test setup, C^3 Performance eliminates the time-intensive task of manually inputting cross-coupling data by employing unit load cases to generate automated cross-coupling compensation coefficients. Seneviratne characterized this process with an apt analogy.

"It's like having a team of 20 people who don't know each other working on the same project," he says. "The unit loads are simply a way of introducing those people to each other so they can collaborate and work more efficiently."

With some extra tuning, Seneviratne and Cravens were able to increase the test rate by 24% and cut the number of stops significantly.

"It has greatly improved the performance of our test," Cravens says. "With the improved load tracking, small perturbations in feedback are much less likely to trigger error limits, resulting in fewer test stoppages. The reduction in error has also enabled us to run more segments per hour."

Before using C^3 Performance, NIAR was only able to achieve a maximum of 375 segments per hour, with an average of 97 stops and 55 interlocks per test block. With C^3 Performance, this has improved to 480 segments per hour, with an average of 51 stops and 15 interlocks.

"The number of stops was a third of what they were, which was a huge gain for us," Seneviratne says. "That enabled us to run the test overnight, some nights without a single interruption. That's up to 10 hours of testing we didn't have before, which helped tremendously with our schedule."

C^3 Performance saved weeks, enabling Seneviratne's team to provide the test results on time. In addition, lab productivity was enhanced: the team was able to operate on a more predictable schedule and had more time to devote to other projects. In any lab with finite resources, that is an important advantage.

"Knowing that we could run the test overnight and be confident we could do inspection and repair during the day allowed us to increase the efficiency of our test path," Seneviratne says. "We were able to plan better and coordinate our activities knowing that the test ran overnight unattended with minimal interruptions." ▮

Jeff VanLangendon is an aerospace application engineer at MTS Systems Corporation, based in the USA

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DR WOLFGANG STARK

KARSTON LANGE

DR WERNER BOHMEYER

ULTRASONIC DIAGNOSTICS

Monitoring by sound wave propagation is becoming an essential tool in the curing of aerospace composites in prepreg autoclave and resin transfer molding injection technology

BY DR WOLFGANG STARK, DR WERNER BOHMEYER AND KARSTON LANGE

Lightweight structures are characterized by a combination of a reinforcing fiber and a polymer matrix. An advantage of using thermosetting polymers is the source state liquids, which can easily impregnate fiber braids.

Prepregs are composite materials where the reinforcement fiber is pre-impregnated with a thermosetting resin. Often they are cured in autoclaves. The RTM (resin transfer molding) process is characterized by using a rigid two-sided mold. The reinforcement material is placed into the mold cavity. The preheated epoxy is then injected into the hot mold, which remains closed until the specified degree of curing is reached.

This is a critical parameter for a thermosetting material and must be continuously monitored – contrary to the offline use of analytical methods (DMA, DSC, FTIR). For demanding components, online monitoring of the whole curing process is required. In the past, dielectric sensors that recorded the change in mobility of impurity ions were used. Some years ago an alternative method using propagation of sound waves was developed and applied in serial production of composite parts.

TECHNICAL BACKGROUND

Cure monitoring using sound waves is based on continuously measuring the change in sound velocity caused by crosslinking. The velocity of sound increases until it is constant.

Sound velocity (v_s) is calculated from the signal traveling time (t_t) and material thickness (d):

$$v_s = \frac{d}{t_t}$$

Commonly a through transmission measurement setup with a sender and a receiver sensor in opposite positions in the tool is used (Figure 1).

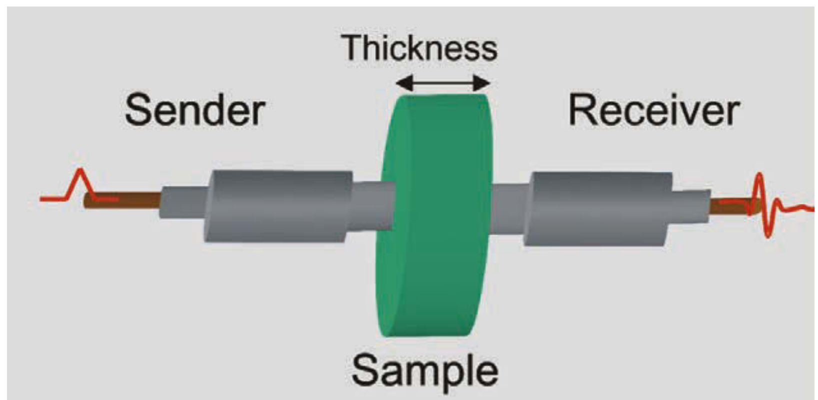


FIGURE 1: Through transmission measuring arrangement

FIGURE 2: Ultrasound transducers

The relatively small sensors can be used up to 180°C. Two kinds of sensors are available – flat on the tool surface with direct contact or mounted behind the cavity wall to avoid an imprint and contamination.

MEASURING EQUIPMENT

The computer-controlled measuring device US-Plus generates the excitation pulse for the sender and manages the acquisition of the received signal, including automatic control of the input amplifier. All signal acquisition is time optimized to achieve up to five measurements per second. Variants for one, eight and 16 measuring channels are available.

AUTOCLAVE PROCESS

To control the autoclave curing process, sensors can be positioned in direct contact with the component part inside the autoclave. An alternative is to use a small temperature-controlled test rig parallel to the autoclave, with two sensors to trace the actual autoclave temperature. Figure 3, below, shows a measuring assembly with sensors inside the autoclave.

The graphs for temperature (T) and sound velocity (v_s) are shown in Figure 4, together with the calculated degree of conversion (α). Curing starts at 120°C. In the two hour isothermal segment no final curing state can be reached.

RTM PROCESS

In Figure 5, an example of an RTM-tool for a high-volume fiberglass reinforced composite part is depicted.

Five measuring lines were allocated to the critical regions – beside the injection nozzle and close to the vents

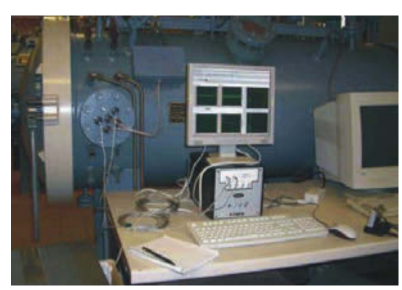
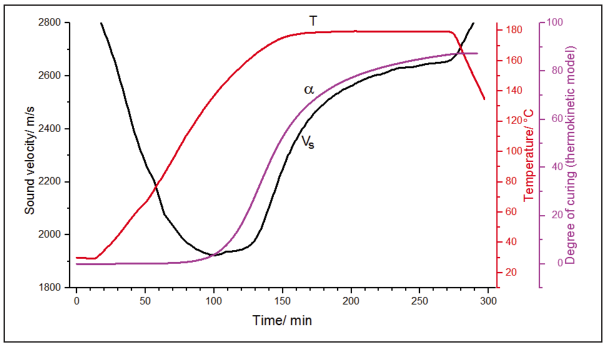
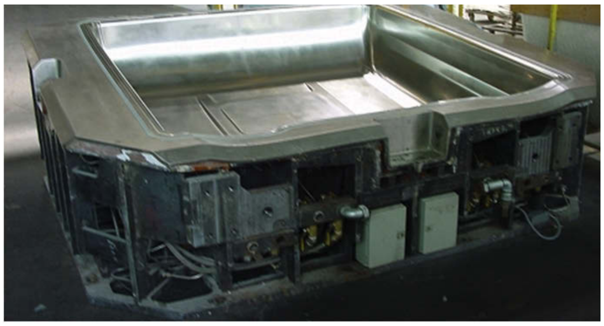


FIGURE 3: Cure monitoring inside the autoclave



LEFT, FIGURE 4: **Sound velocity signal and degree of conversion**

RIGHT, FIGURE 5: **Lower part of the RTM tool**



at the four edges. The first signal is an indication that the flow front has reached the sensor position (Figure 6). The mold is preheated to a constant temperature of 160°C. The resin is injected at 80°C. At first the reduction in sound velocity indicates a reduction in viscosity because of warming before the crosslinking process takes effect. The longer the flow path, the more time the resin has to heat and the lower the sound velocity at first contact with the sensors. The whole process, including crosslinking, is shown in Figure 7. At the termination of the process, the final conversion is not reached but the degree of curing has been found to be sufficient for this application.

INCOMING GOODS CONTROL AND TECHNOLOGY

A small two-plate mold (Figure 8) with integrated sensors and PC-controlled heaters offers the possibility of low material consumption (1ml is sufficient) to understand and control incoming goods and even optimize process parameters. Operation is very similar to using a rheometer but much easier to handle. The measured curing curves can be automatically compared with deposited reference curves. Figure 9 summarizes results for RTM6, an epoxy resin for aircraft use. Curves for curing temperatures between 120°C and 180°C are shown.

BELOW LEFT, FIGURE 6: **RTM process flow front detection**

BELOW RIGHT, FIGURE 7: **RTM change of sound velocity through the crosslinking process**

RIGHT, FIGURE 8: **Small two-plate mold with integrated sensors**

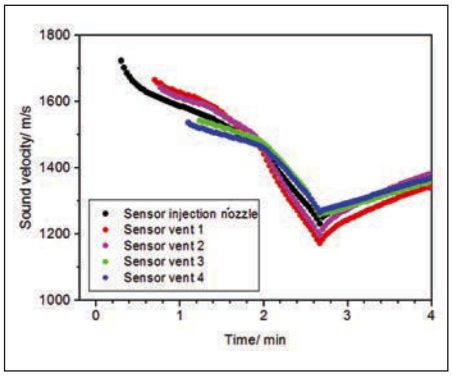
BELOW FAR RIGHT, FIGURE 9: **RTM6 influence of temperature on crosslinking reaction**

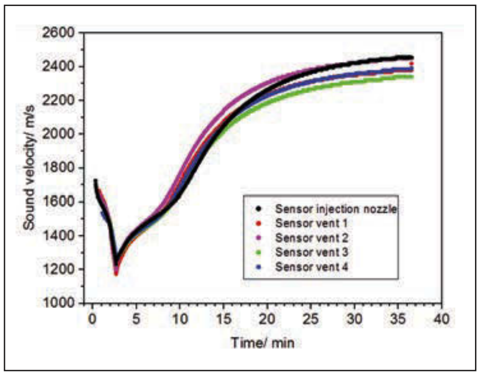
SUMMARY AND OUTLOOK

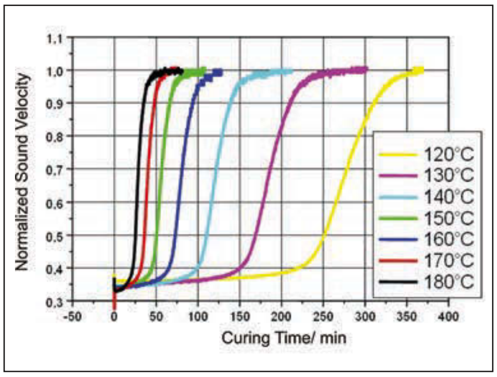
Cure monitoring by sound wave propagation offers the advantage of measuring a mechanical parameter directly related to the compression and shear modulus. In contrast to dielectric ion viscosity, an absolute value is measured. The difficulties for dielectric measurements stemming from the use of conductive carbon fiber composites have been overcome. Hidden sensors can be used, giving no imprint and being protected against contamination with adhesive resins. Tool protective foils can be used because they do not disturb sound wave propagation.

Based on information for the progress of the curing reaction, high quality can be realized and directly controlled. An example is the halting of the process when a specified value of conversion is reached, so as to overcome rate fluctuations from batch to batch. ▮

Dr Wolfgang Stark is senior scientist and material researcher, Dr W Bohmeyer is CEO and Karsten Lange is part of the research and development team, from Sensors-Und Lasertechnik based in Germany







ULRICH EISEMANN

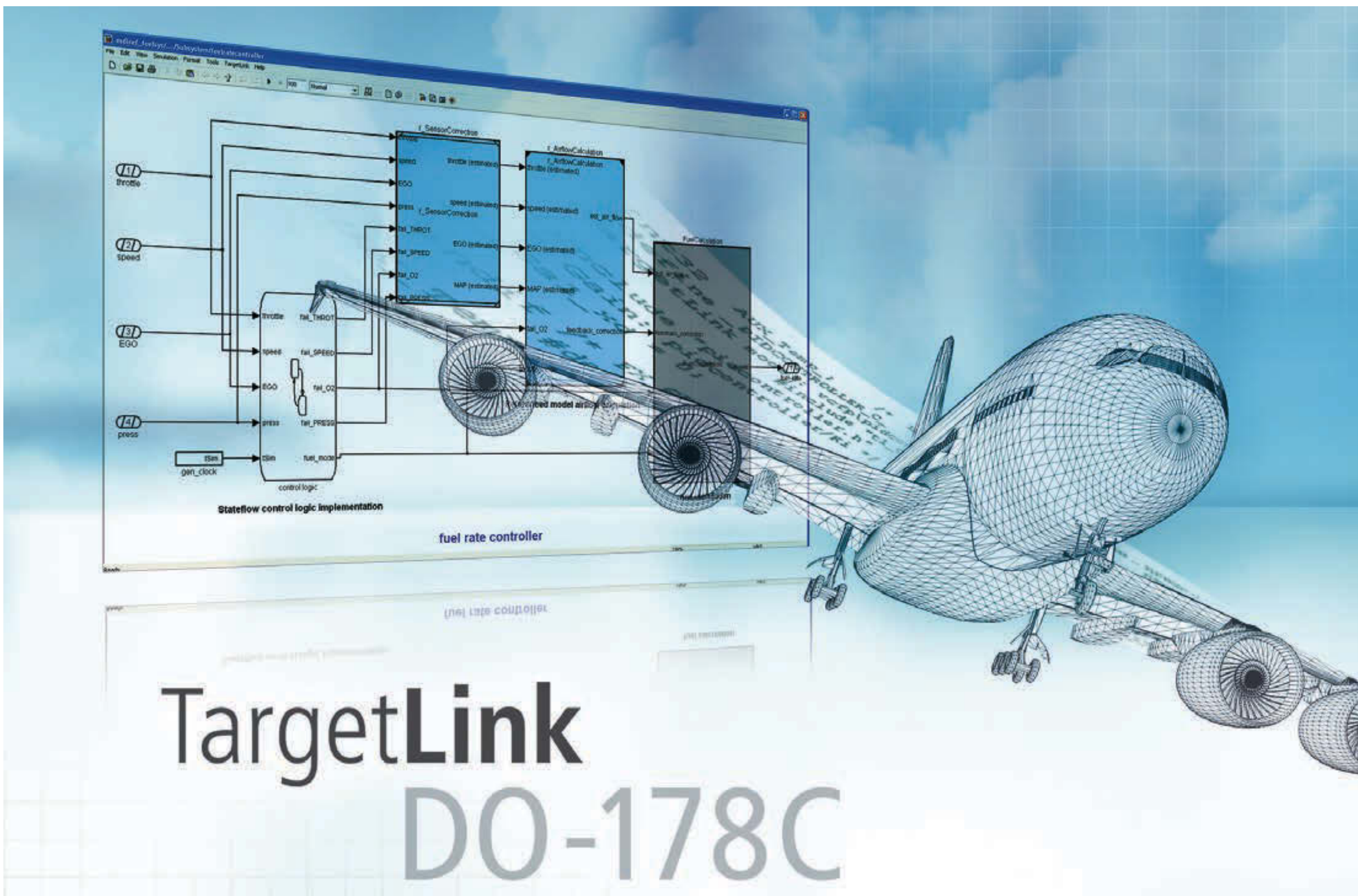
MARKUS GROS

HANS J HOLBERG

SOFT APPROACH

Model-based development and model-based verification are two key software design techniques that offer enormous potential for achieving highly efficient software development in the aerospace sector

BY ULRICH EISEMANN, MARKUS GROS AND HANS J HOLBERG



Published at the end of 2011, the DO-178C standard mainly differs from its predecessor DO-178B in that it has supplements to provide greater scope for using new software development methods. The supplements include a document on the methods of model-based development and model-based verification (D0-331), and another on the use of formal methods (DO-333). These two key software design techniques offer enormous potential for achieving highly efficient software development in the aerospace sector, while not only maintaining the high quality and safety requirements for software, but actually improving them. A model-based tool chain with Simulink, TargetLink and verification tools from BTC can be used to develop software right up to DO-178C Level A – the highest safety level. The methods used include model-based design, automatic production code generation, and model-based and formal verification, as described in DO-331 and DD-333 respectively.

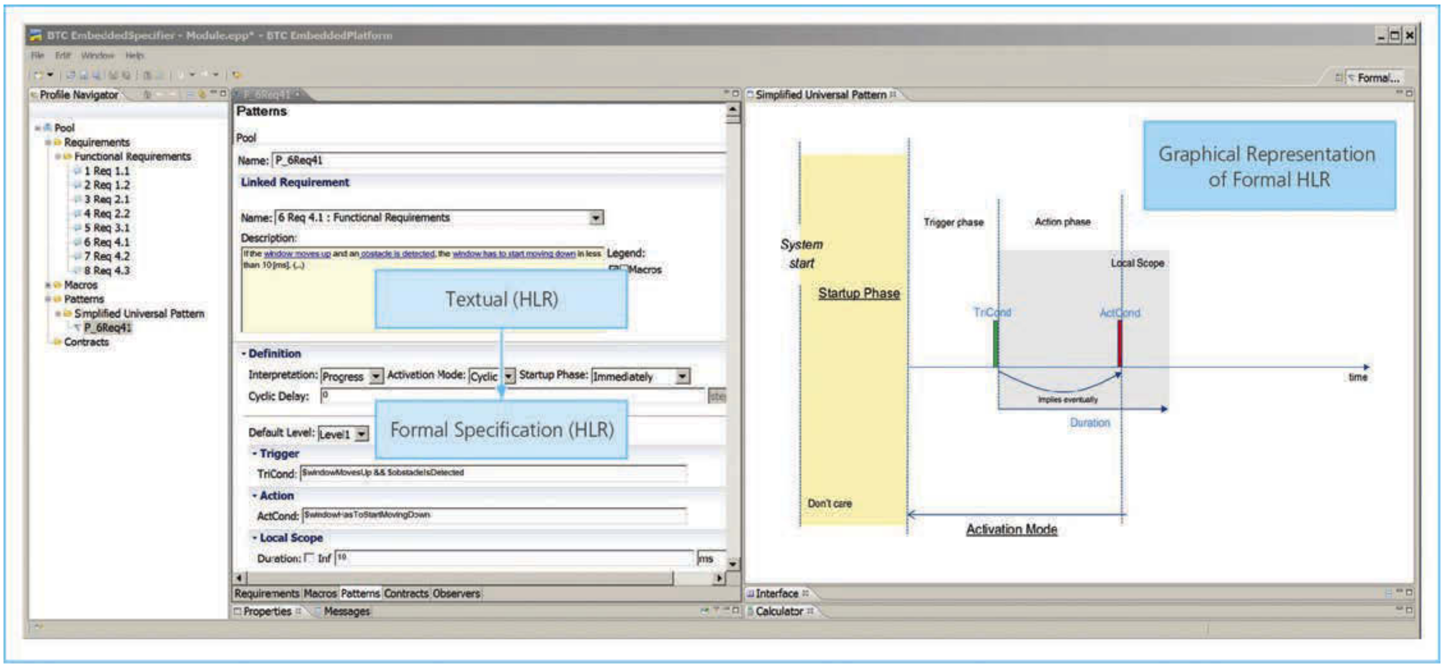
OPENING THE DOOR TO INNOVATIVE METHODS

The ability to represent requirements by models in accordance with DO-331, the modeling supplement to DO-178C, is a decisive advance in efficient and quality-oriented software development. The move from purely textual requirements to formalized requirements expressed as models opens up numerous new options for automated analysis, source code generation, and verification.

There are two different types of software requirements according to DO-178B/C:

• High-level requirements (HLRs): These describe, in a simplified form, what the software has to do, but not how it has to do it (i.e. the software is treated as a black box). HLRs are derived from the requirements for the actual overall system that are defined in the system process (see ARP 4754).

• Low-level requirements (LLRs): These describe the internal workings of the software (viewed as a white box), i.e. how it has to do what it does. These are naturally derived from the HLRs and must implement them exactly. The form of the LLRs must allow the actual



ABOVE: **Using BTC EmbeddedSpecifier to convert informal textual requirements into finite state machines**

source code to be generated straight from them and then translated into an executable object code.

Gapless, bidirectional traceability between the requirements levels (LLR and HLR) is an essential element in DO-178C. Models can now be used to represent requirements on these levels.

For example, specialized methods and tools for formal representation such as those offered by BTC EmbeddedSpecifier are suitable for functional HLRs. This tool is designed for translating textual requirements into machine-readable formal requirements step-by-step and intuitively (see figure above). BTC EmbeddedSpecifier helps users create a formal notation in a process that uses graphical representations. The tool then automatically generates a description that can be used for automatic software verification. This smooths the transition from informal to formal requirements, which clearly pays off in subsequent verification steps. HLRs can also be expressed as block-based and state chart-based representations in the form of specification models (Simulink/TargetLink models). This is particularly useful if such models are already available in the system process. Models that represent LLRs are particularly popular, as source code can be generated from them automatically in subsequent steps. These so-called design models not only describe the actual functionality, but also contain the necessary details on the software, such as internal data structures, distribution across different components and functions, control flow information, fixed-point representations, and other relevant information (see figure overleaf).

FROM DESIGN MODEL TO SOURCE CODE AT A CLICK

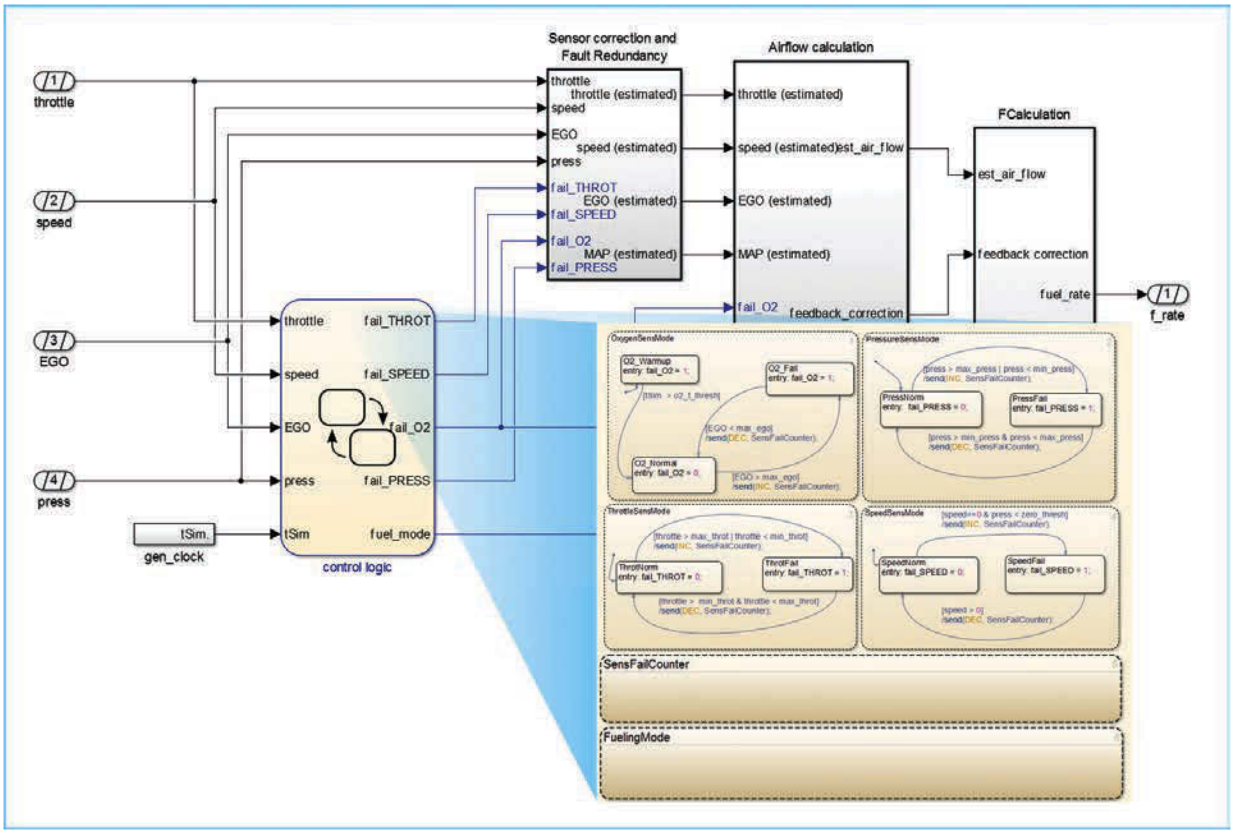
Obviously, design models representing low-level requirements also offer a direct route to creating the software source code. Automatic code generation with dSPACE TargetLink translates specification models from Simulink/TargetLink directly into C code, and can bring great benefit in terms of quality and reliability. At a click, the code generator completely deterministically produces source code that:

- Is very readable and suitable for reviews. This is ensured by extensive source code commenting and easy-to-understand symbol names, and by using a subset of the C language;
- Can be traced straight back to the design model. This provides direct traceability between the source code and the associated model from which it was generated; and
- References the requirements that it has to implement. This supports traceability of requirements, the cornerstone of any software development process.

The code generated by TargetLink is also extremely configurable. This ensures compliance with coding guidelines, be they general or company-specific, and optimum code integration into the software architecture and structure.

In addition to the actual source code, TargetLink simultaneously generates other artifacts or configuration items, thereby ensuring that they are always consistent with the source code – for example:

- Automatic documentation on the software and its interfaces;
- Files that facilitate the review process and traceability between models and their associated source code; and



LEFT: Simulink/TargetLink design models are used directly for automatic source code generation with TargetLink

• Information (used to build up a requirements traceability matrix) on the requirements that are implemented by the source code.

Automatic code generation from Simulink/TargetLink has been an established method for many years, used successfully not only in the aerospace sector, but also particularly in the automobile industry. A point to note is that the TargetLink production code generator is directly integrated in MATLAB/Simulink, but it is also independent. This makes it easier to prove the independence of software tools required for DO-178C Level A and Level B.

THE KEY TO EASIER CERTIFICATION

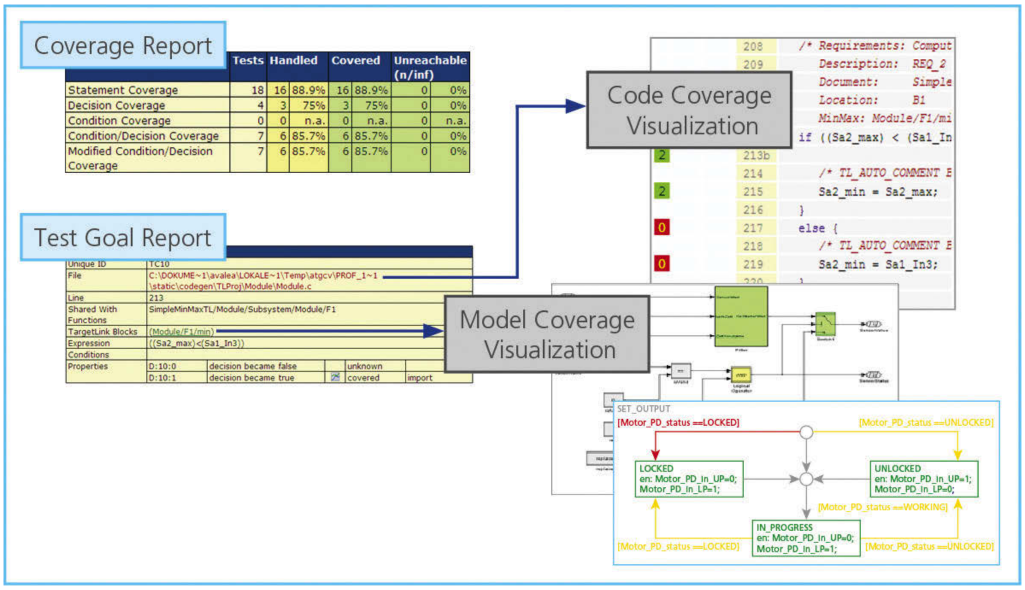
The great advantages of using models to specify requirements (HLRs and LLRs) are evident not only in automatic production code generation, but also in other areas such as verification steps. These have to be performed in parallel with the development process to verify the resulting artifacts, such as models, source code, and object code, in each individual development step. The following activities are particularly important: verifying that the models for HLRs or LLRs implement only the requirements that they were derived from and nothing else; verifying that the models and source code comply with specific modeling guidelines and coding guidelines; also verifying that the source code implements the requirements contained in the design model and nothing else, and finally verifying that the executable object code (EOC) implements the HLRs and LLRs. The model-based approach, combined with formalized requirements, provides very powerful mechanisms to simplify these verification steps.

A combination of model simulations, coverage analysis and test case generation is an obvious choice for proving that models comply with requirements according to item 1 on the above list. DO-178B and C state that test cases have to be created solely on the basis of requirements whose definitions directly include the required result. If a requirement is itself expressed as a model (for example, a specification model in Simulink/TargetLink), techniques for automatic test vector generation such as those provided by BTC EmbeddedTester can be used to automatically generate test cases from the specification model. Formal requirements specifications also facilitate the manual creation of test cases because special tools can build on the formal interface descriptions of the software; one such tool is BTC EmbeddedTester. To verify that a model complies with the requirements from which it was developed, the previously generated test cases are executed with the model by means of model simulation. Model coverage analysis is used to investigate whether the various model elements are all covered completely.

To verify that models comply with modeling style guides (item 2 above), style checkers like MXAM from Model Engineering Solutions or the Simulink Model Advisor are used. The automatic checks made by these tools support the reviewing of models. Dedicated C code tools are used for the generated C code.

To verify that the code complies with the models (item 3 above), an obvious choice is to perform reviews and analyses with tool support. For example, TargetLink supports code reviews by easy linking between the model elements in the design model and the code passages generated from them. Other analyses can be performed automatically or semi-automatically.

A typical way to verify that the executable object code is consistent with the HLRs and LLRs (item 4 above) is to execute it on the target platform. TargetLink provides extremely powerful mechanisms for this in the form of so-called processor-in-the-loop simulation, in which the automatically generated code is translated directly by the target compiler and executed on an evaluation board with the target processor (see figure bottom of following page). These tests run directly in the Simulink/TargetLink environment and allow all previously defined test cases to be reused completely. BTC EmbeddedTester provides a powerful environment for performing the necessary tests, including options for code coverage analysis – MC/DC code coverage for Level A, condition coverage for Level B,



LEFT: Code coverage report in BTC embedded tester

etc (see Figure above). The associated test reports are also created completely automatically.

If requirements are specified formally with BTC EmbeddedSpecifier, there is yet another innovative way to verify that the models and code comply with their requirements (items 1 and 4 above): generate so-called requirement observers. This is done by generating C code from the formal BTC EmbeddedSpecifier requirements and running it alongside all the simulations of models and executable object code to automatically check that all the test cases performed comply. This way, compliance with requirements is tested not just with individual test cases, but for the entire set of all test cases.

100% CERTAINTY WITH MATHEMATICAL PROOF

In a conventional test, a single test case describes only one possible way in which the system under test could run. Because reactive systems in the field of embedded software can potentially run endlessly, it is not possible to create a set of test cases that covers all the possible system behaviors. Testing is therefore always incomplete and possible errors can remain undetected.

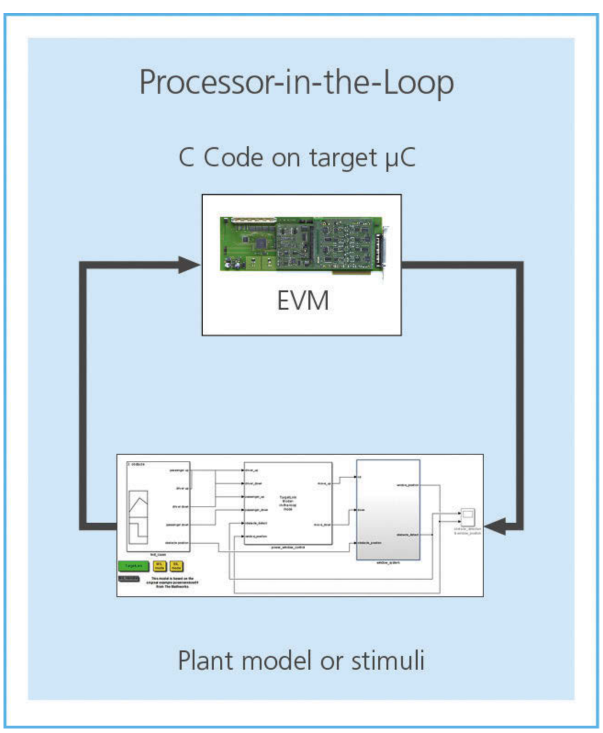
The BTC EmbeddedValidator tool uses model checking technology for mathematically complete checks of both the models and the source code against the requirements formally specified with BTC EmbeddedSpecifier. Because these are formal methods that use mathematical symbols, complete verification represents 100% test case coverage. At the end of the process, there is absolute proof that the model or the code implements the specified requirements under all possible circumstances.

CONCLUSION AND SUMMARY

The methods, technologies and tools described in this report, which are used in the model-based development process, make it possible to fulfill a very large proportion of the objectives described in DO-178C and its supplements DO-331 and DO-333.

The focus is also on an important objective in addition to those defined in DO-178C: substantially increasing the efficiency in the development process, while maintaining a high quality standard.

What is being stated here is an outline of highly integrated tools for completely automated testing and formal verification that work hand in hand with dSPACE's functionality for automatically generating code from Simulink/TargetLink models. For many years now, this tool chain has been very successfully used for production-level testing by all the OEMs and Tier 1 suppliers in the worldwide automotive industry. Now the aerospace sector and industry is increasingly turning to it for DO-178C-driven software system development. ■



LEFT: Running the executable object code in processor-in-the-loop simulations

Ulrich Eisemann is the senior product manager TargetLink, dSPACE; Markus Gros is the director product sales Europe, BTC Embedded Systems; Hans J Holberg is senior vice president of marketing and sales representative director BTC Japan; co-auther, Doreen Krob is product engineer TargetLink, dSPACE based in Germany

MARK VALENTINO

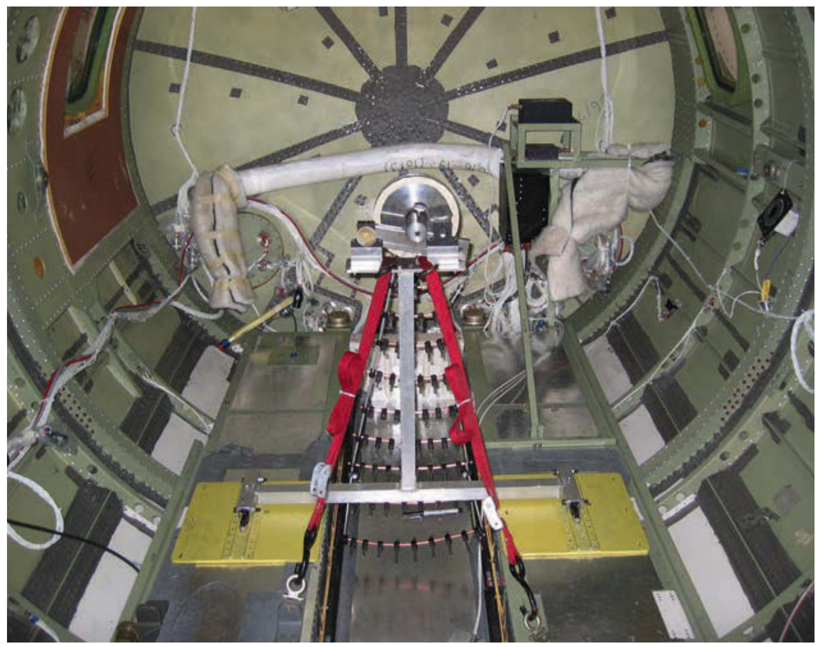
QUIET REVOLUTION

Excess cabin noise can greatly affect passenger comfort, so what can the industry do to improve this problem?

BY MARK VALENTINO

Directives to assess and minimize cabin noise have become a top priority for the aerospace industry. From large commercial jets, to helicopters, to small propeller aircraft, the aim is the same: to reduce cabin noise. This is critical to the commercial success and competitiveness of the aerospace manufacturing industry and is also desirable for passenger comfort.

High-amplitude acoustic signals, whether in the audible ranges of the human ear (20Hz to 20kHz) or beyond human hearing capability (infrasounds and ultrasounds), can range from being noisy and causing mild discomfort, to resonating human body components and inducing headaches or nausea. This is why there is an increasing demand to reduce noise levels inside the aircraft to improve passenger comfort.



DERIVING THE NOISE SOURCE

The noise source location and source strength must be established before acoustic engineers can improve conditions. Some preliminary tests can be achieved in wind tunnels, but for maximum noise and the best characterization, an inflight study is preferred. Noise can be derived from many sources; some of the most common are from fuselage structural vibrations, exterior wind noise leaking through windows and structures, gearbox noise, turbo propellers, engine noise, and general squeak and rattle. Knowledge of the acoustic field inside the fuselage can direct the noise abatement procedures for lighter and more efficient damping/insulation solutions. Noise generated from the passengers also needs to be accounted for in order to predict and control interior cabin noise.

Detecting the noise can be difficult when measuring sound power entering the cabin at different locations from multiple external sources, which tend to become polluted due to hard wall surfaces and reverberant components within the cabin. Early noise source identification methods included accelerometer measurements and intensity measurements using two 'phase matched' microphones spaced closely apart. Although easy to use, they were time consuming, lacking in resolution, and provided limited information.

Modern methods using a large array of microphones, strategically placed, along with complex software, enable a greater amount of information to be obtained in a fraction of the time. Spherical beamforming, the HELS (Helmholtz equation least squares) method and other acoustic holography methods have been implemented for improved sound pressure mapping, acoustic pressure, surface velocity, acoustic power and intensity measurements.

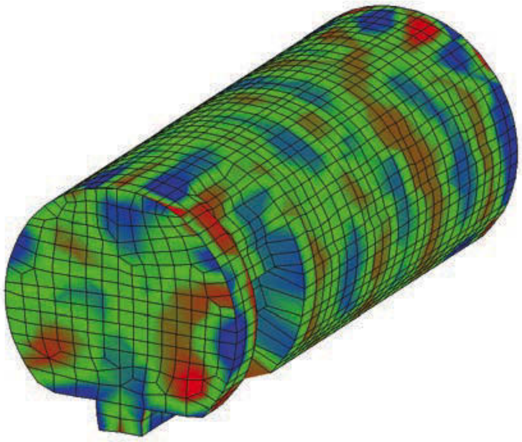
THE HELS METHOD

HELS is based on nearfield acoustical holography (NAH) and enables the visualization of acoustic pressure, normal intensity and normal surface velocity mappings. It differs from the Fourier transform NAH method by analyzing the acoustic field through an expansion of spherical wave functions, which greatly simplifies reconstruction and enables complex problem-solving on arbitrarily shaped surfaces with fewer measurement points, saving both setup time and material costs.

According to Manmohan S Moondra of SenSound LLC, with HELS, "The acoustic pressures are expressed as an expansion of the particular solutions to the Helmholtz equation. The coefficients that are associated with the expansion functions are then determined by solving an over-determined linear system of equations obtained by matching the assumed form solution to the measured acoustic pressures, and the errors incurred in this process are minimized by least squares."

TEST AND SETUP

A medium-sized business jet was used in the test, with all interior panels in the passenger cabin removed. Inflight testing was conducted at a flight level of 30,000ft and Mach 0.73. The closed surface included the forward cabin skin and floor, aft cabin skin and floor, and two closing surfaces (between the cockpit and the forward cabin and at the aft divider location). A conformal circular microphone array of 60 microphones was built to cover the circumferential measurements, and a planar microphone array of



ABOVE: Distribution of surface velocity at 155Hz

FIGURE 1 (FAR RIGHT): Circular microphone array, PCB, microphone model: T130D21

50 microphones was built for the closing surfaces measurements. The circumferential measurements were taken every 2cm in the longitudinal direction, located 2cm from the skin.

Figure 1 shows the grid with measurement points. Placement areas of the highest interest and likely location of passengers should be assessed, and the reconstructed location of the fuselage skin and the closing surfaces then derived. The interior acoustic pressure field was reconstructed in seven interior planes, including setup of custom microphone arrays and fixtures for circumferential and longitudinal measurements of acoustic pressures along the fuselage body. Identification of 'hot spots' in the cabin skin where noise is more likely to be transmitted into the cabin can then be determined.

CONTROL STRATEGIES

Once the noise is identified, engineers can take appropriate steps to minimize them. There are active and passive methods to combat the noise sources, and each method has its advantages. An example of an active method would be to place speakers in strategic areas and broadcast counteractive noise signals to cause destructive interference. When performing passive methods, consideration should be made to weight reduction, which also reduces fuel cost and travel time. Some examples of passive methods include special panels, coupling between exterior and interior transmission of sound so it is impaired before it enters the cabin, and other dampening materials.

CONCLUSION

HELS and other NAH-based methods can provide noise source locations in order to improve the sound inside today's aircraft and helicopters, enabling manufacturers to reduce noise for their passengers. ∎

Mark Valentino is the acoustic product manager at PCB Piezotronics, based in the USA

STEPHAN TROST

EYE ON THE JOB

Data delivered by network-ready, next-generation and customizable cameras is a crucial part of the development stage of an aircraft

BY STEPHAN TROST

High-speed cameras that record store separation or other events during tests flights are used routinely as measurement systems in development processes. The data delivers important feedback to design and test engineers for system improvement and validation. The need to use high-speed cameras in more 'hot spots' demands new features of next-generation cameras. These new cameras must be network-ready for COTS-standard network systems or work reliably in standalone operation. This demand for fit-the-aircraft cameras has driven the development of a semi-customized camera system.

DESIGN OF THE CAMERA

In a complex system, it is vital that the camera adapts to the aircraft, not vice versa, for the electrical and control interface and mechanical outline. An application may require that a camera's connectors are at the back, sideways for a 90° view, or in space-limited positions with recessed lens mounting. Aircraft-specific connectors for ease of integration are necessary, and the design must meet environmental and EMI and MIL 810 environmental specifications.

One solution is a semi-customizable camera platform where the functionality and identical operation of cameras is guaranteed, the camera performs reliably under given environmental conditions, and it is economically attractive. The design must meet a high degree of flexibility in terms of electronic and mechanical design in order to fit the space required, and interface parts must be easy to adapt to the connectors and the power requirements of the aircraft. As the camera is always equipped with the same sensor, the same optical performance is given for all views, making image analysis more efficient.

ABOVE: The Q-MIZE FH (FlatHead) is a semi-customized high-speed camera with a recessed head for fitting into the tightest spot

RIGHT: For in-flight image data acquisition, semi-customized cameras offer the perfect fit

> **"THE GigE VISION STANDARD IS AN EASY AND VERSATILE COMMUNICATION PROTOCOL THAT ALLOWS ENHANCEMENT OF VIDEO DATA COLLECTION DURING FLIGHT"**

LEFT: S-EM mounted in an instrumentation pod

What does this camera design mean for the operation of systems under various conditions? Smart features in the camera, pre-programmed on the ground by flight engineers, can be used to give the camera a standalone operation that does not interfere with flight operations.

NETWORKING AND COMMUNICATION STANDARD

In a network environment it is important that communication is standardized. A recent idea is to network cameras via a central control unit. The captured sequences are downloaded to the unit and new commands are sent to the camera for the next take.

The GigE Vision standard is an easy and versatile communication protocol that allows enhancement of video data collection during flight. For instance, a live stream at a standard 30 frames per second is recorded directly in the control unit. If the test requires a high-speed recording, the data is buffered in the camera and sent to the control unit on demand or transferred to the internal non-volatile camera memory. This memory can be accessed later on the ground or in-flight by the control unit.

DATA FORMAT

Easy correlation between video and other data is important for test data analysis. Until recently, users had to cope with many data formats.

The IRIG-106 format is a viable base for all data gathering and analysis. A common data format simplifies the use of analysis tools and ensures a secure correlation of measurements. It is an economical method and makes any comparison between measurement data for testing much simpler.

Stephan Trost is the managing director of AOS Technologies AG, based in Switzerland


MARKUS NAGL

PUMP ACTION

A test bench for main fuel pumps, hydromechanical units and fuel metering units

BY MARKUS NAGL

Test Fuchs, a leading Austrian designer and manufacturer of test systems in the aerospace industry, is always happy to be able to work within its core discipline: the design and manufacture of tailored test systems.

In the past, the company has produced test systems for fuel pumps, hydromechanical units (HMUs) and fuel metering units (FMUs). Leading MROs in Europe have been using these test systems for the past decade with great success.

An important European MRO facility, which knows and trusts Test Fuchs, needed a new system to test main fuel accessories but was restricted by its infrastructure. This new development had to comply both with the customer's wide range of technical requirements and the local conditions of the customer's test facility. Test Fuchs engineers were challenged with several space issues and in the end came up with the ideal solution for the customer.

This new test stand for Main Fuel Accessories (MFAT) is capable of testing most of the main fuel pumps, HMUs and FMUs currently used in civil aviation. It is possible to test 11 different main fuel pumps and 13 different HMUs and FMUs on one single test system. Developing it was quite a challenge, considering that normally just one main fuel pump and one or two HMUs and FMUs can be tested on a single test stand. The new MFAT is divided into two independent test systems, one for testing main fuel pumps, and the other for testing FMUs and HMUs. This separation was an important step toward developing a future modular concept. The test stands can test pumps and FMUs/HMUs both independently and at the same time, using a common power unit, which is placed at a greater distance than usual. The challenge here was to successfully compensate for the loss of power due to the 15m distance between the power unit and the individual test stands. A cooling water unit is also located at a distance. With 500kW power, this completes the MFAT test system.

The highlights on the HMU and FMU test unit are the multicoupling adaptors with lever mechanisms. Since the units under test undergo various pressure measurements, it is time-consuming to change the adaptors for the different measurements. With this multicoupling adaptor, all adaptors can be connected before the test run. Up to 24 adaptors are at the user's disposal and preparation time is therefore reduced to a minimum, saving both time and costs for the operator. Once the multicoupling is fixed, the tests run automatically. HMUs and FMUs can be tested on the MFAT without the corresponding pump, because the test system uses its own pump, supplying the necessary pressure and flow. The UUT is driven by an engine with a capacity of 0-8,500rpm. The corresponding main fuel pump can be tested itself at the same time on the pump test unit. This technique gives the operator great flexibility, and makes him particularly time-efficient.

The handling of the UUTs is designed to be operator-friendly. According to the customer's requirements, both testing units feature either a crane or a telescopic crane, so that a single operator can install the units under test. The pump test unit has a spacious test chamber where the operator can adapt the pumps without space restrictions. The HMU and FMU test unit is protected by a two-door protecting cap that ensures the operator a maximum degree of access to the components, it being sometimes necessary to perform adjustments during testing. The doors on both test units can be locked, thus providing a maximum level of security for the operating personnel. A telescopic swivelling arm on the HMU and FMU unit completes the user-friendly and fully flexible design.

The accessibility of the hydraulic chambers for the maintenance of filters and other components of the test stand add to its user friendliness. Lockable

"THE MFAT, LIKE ALL OTHER TEST FUCHS TEST SYSTEMS WITH SIMILAR NEEDS, IS DESIGNED FOR UNIVERSAL USE, AND CAN EASILY BE ADAPTED TO SUIT FURTHER REQUIREMENTS"

doors permit easy entrance to the respective components.

Among the technical highlights are the 1,400-liter tank volume for the calibration fluid MIL-C-7024E Type II, the low pressure supply for the pump test unit that performs a capacity of 70,000pph at 50psi, and a high-pressure supply for the HMU and FMU test unit with a capacity of 70,000pph at 2,200psi.

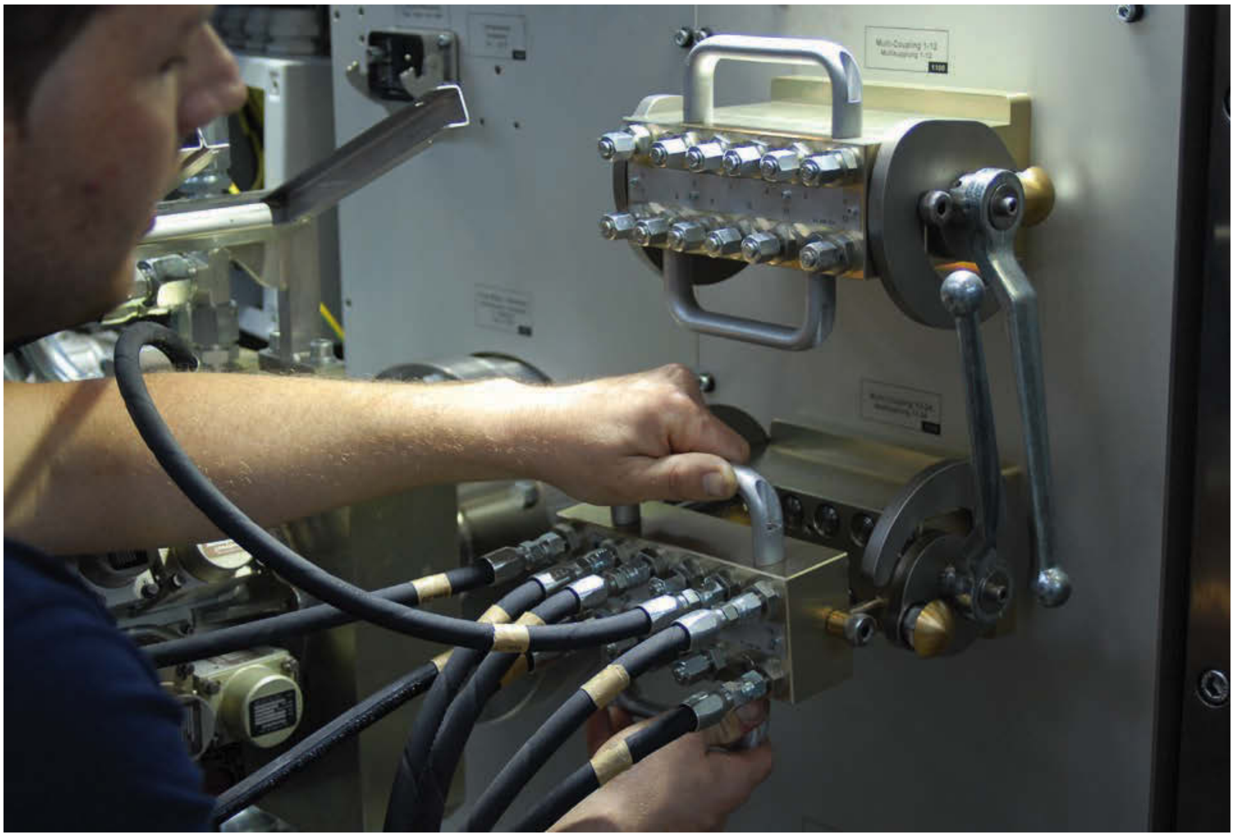
Another important feature is the extremely low noise level of the test bench. It is manufactured using an excellent noise proof design, reaching a maximum noise level of only 75dB(A) at 1m distance.

The MFAT, like all other Test Fuchs test systems with similar needs, is designed for universal use, and can easily be adapted to suit further requirements. "One feature our customers always ask for is the flexibility for future adaptions and modifications," says Benjamin Deimel, the head of the engineering team working on the MFAT. The Test Fuchs software, therefore, has to be similarly flexible, with the potential to accommodate possible adaptions in the years to come, something the software engineers always take into consideration. The user-friendly software for fully automatic test runs drastically shortens the testing time, it evaluates and controls test procedures, and records data such as flow, pressure or temperature. The integrated modem allows trouble-shooting and updating of the test stand software or test procedures directly from the headquarters, so there is no risk of losing time or money through the displacement of software specialists. The calibration of the whole test system is done via the Test Fuchs software, quickly and easily. The economic implications of such a test system are increasingly important to the operator.

There is also an element of danger in the handling of fuel components. The temperature of the test medium is therefore controlled below flash point, and a gas warning system, as well as technical ventilation, are integrated into the test system, to avoid any explosive atmosphere. The whole test system complies with the standards of ATEX directives.

This test bench for main fuel pumps, HMUs and FMUs has been tailored to the requirements of a specific customer. Since costs are a crucial factor in the maintenance industry nowadays, Test Fuchs engineers have also thought of a modular concept of bigger test benches like this one. With modular hydraulic test benches already available, modular test benches for main fuel pumps, HMUs and FMUs will be the next development. ∎

Dr Markus Nagl is technical director at Test Fuchs based in Austria



ABOVE: A test stand under construction

RIGHT: Multicoupling adaptors

BERND MATTNER

DEVELOPMENT COMPANIONSHIP

Modern aircraft equipment development has to be supported by tests tailored to the needs of specific development phases

BY BERND MATTNER

Today it is unusual to start testing and integration only at aircraft level. In the latest programs, the commercial aircraft manufacturers took some measures to increase interaction between equipment, system and aircraft level. This was accomplished by configurable test systems with the capability to cover adjacent testing levels, for example equipment and subsystem level, and model-based incremental integration. The test and verification effort is still increasing by more and more complex aircraft systems, caused, for example, by requirements for more functionality and comfort, especially in the cockpit. Additionally, these systems have to be developed and integrated in short time-to-market.

Any essential effect can only be reached by starting test and integration activities in the early phases of development. TechSAT, a company specialized in system test benches and large-scale integration facilities for the aerospace sector, has extended its product range to meet the requirements for this type of application. Test and integration solutions to support the development process have to be available on time, and be customizable and convenient. With cost-efficient test system approaches, it is possible to use multiple systems for parallel development and acceleration of results.

DEVELOPMENT TEST SYSTEM PLATFORM

Model-based development and integration in early aircraft system development phases are supported by high performance ADS2-based PC systems, so-called Model Development and Verification Systems (MDVS). Just like the larger test systems, they support the TechSAT ADS2 tool chain (such as Test Process Management ADS2/TPM, ICD importer) and provide interfaces to modeling tools, such as MATLAB and the SCADE Suite.

To support equipment development, TechSAT picked up and reinterpreted the previous approach of its cADS test system, building a new compact test system platform, the Single Device Integration Bench (SDIB). This consequently uses proven COTS products and components of TechSAT's technology platform for large test systems. Thereby the same high-performance real-time PC platform and I/O components (such as AFDX, A429, and CAN boards, FAST family) are available for the SDIB. At the same time, the entire ADS2 tool chain with the ADS2 Generic Simulation Framework (GSF) is provided for HIL test and integration. The SDIB is built into a desktop case of variable height to meet the varying customer requirements. Customer specific components are the rear side connection panel as well as a front side breakout and interface panel (see Figure 1), both tailored to the development use case for a specific unit under test. The UUT interface in the connection panel is realized with a generic connector to allow an external small harness adaption to the UUT.

In spite of custom-tailored equipment and user interface, the SDIB platform concept is modular, to ensure fast realization and early support in the equipment development process. With the use of TechSAT's technology platform for larger test systems, it is also possible to connect multiple SDIB for different equipment to smaller subsystems under test.

Below, the validity of the test system portfolio will be explained using the example of the C919 Cockpit Display System development.

ABOVE: A customized SDIB breakout panel for a C919 multifunction display

CDS DEVELOPMENT SUPPORT

Multifunction displays (MFD) are the main components of a modern flight deck. They provide the capability to display several aircraft systems and safety information on one single device. With an intuitive human machine interface according to ARINC 661, the primary flight management, navigation, and engine management parameters can be shown in real time. For example, on an MFD with moving map, additional information of navigation, terrain and radar can be overlaid, as well as data from TCAS, proximity warning and anti-collision systems.

Avionics equipment suppliers providing this kind of cockpit display system have the chance to offer flexible and interoperable equipment to the market. In this way, they enable the airframe manufacturer to standardize the CDS interface for different aircraft implementations. On the other hand, the CDS supplier has to ensure interoperability with various systems of different criticality. As most of the advantages are achieved by software in embedded systems, it is important to win confidence in HMI design and CDS functionality at an early stage of the aircraft development process.

SAVIC was chosen as the supplier for the Cockpit Display System for the COMAC C919 aircraft program. SAVIC in turn selected TechSAT as a partner for a broad development and qualification support. The collaboration is intended to provide the qualified C919 Cockpit Display System in short time. The display system development has to follow the ARP 4754A at system level. The derived software requirements have to be implemented under guidance of DO-178B. Both guidelines have a direct impact on the required validation, integration and verification steps on multiple levels.

The first step is the model-based validation and verification of the derived software requirements at T4 level. One level below, the software implementation is integrated into the target hardware, and formal verification on equipment level can be performed. Also on T4 level, the lowest level of system integration and verification is performed for all software requirements using only one multifunction display. The display system integration and verification is performed on system level (T3) utilizing all equipment of the CDS as well as the equipment with direct interface to the CDS (for example RDIU, AFDX/A664 switches).

CDS DEVELOPMENT SYSTEMS

The test and integration means to execute the validation, integration and verification steps at the described levels are provided by TechSAT, a company with long-term experience in system test technology and integration facilities for the aerospace sector.

The Model Development and Verification System (MDVS) supports test and verification of models created with SCADE Suite and SCADE Display. Equipped with the TechSAT ADS2 and ADS2/TPM, the MDVS provides the capability to generate automatic tests and to interface the SCADE logic model to run tests on model level. Multiple MDVS are used from the beginning of the CDS development phase to speed up development and to ensure model verification and requirement validation early in the development phase.

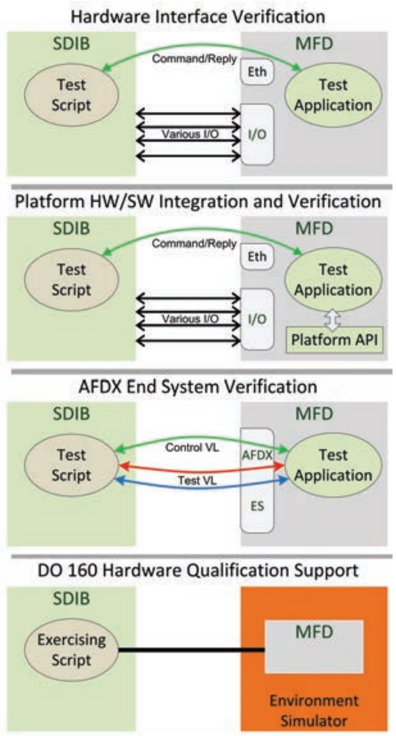
DEVELOPMENT BENEFITS

To minimize the cost of aircraft equipment development, it is important to find effective ways for equipment and system development, integration, and verification. Model-based engineering and development is a promising approach to handle complexity and prevent breakage between the development layers. In agile development, in particular, this will only be effective if testing and integration follow this approach. Test means tailored to a specific development phase are therefore required. They have to be available in sufficient numbers for parallel work to achieve reasonable results.

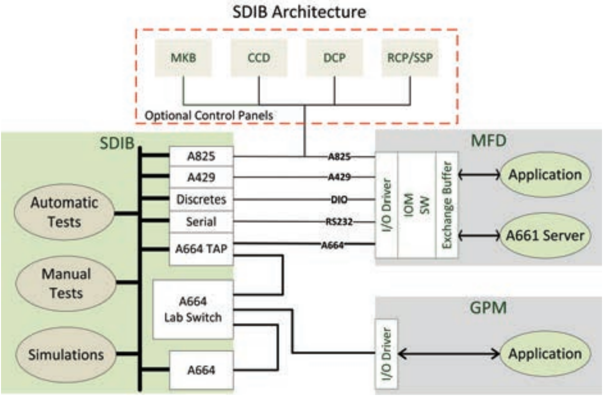
One of the most efficient test systems in the CDS development process is the Single Display Integration Bench, based on the TechSAT SDIB platform. For the specific needs of CDS development, the SDIB is extended with a UUT power supply, a TechSAT AFDX/A664 TAP and an AFDX/A664 lab switch. The TechSAT ADS2 platform with ADS2/TPM supports monitoring, control and stimulation of I/O, simulation of equipment, and automated and manual tests. The generic UUT connector in the rear side panel of the SDIB allows connecting MFD laboratory prototypes and real MFD by simply changing the connection cable. The breakout panel on the front side allows direct access to the equipment signal for measurement with external equipment.

The SDIB is used for equipment level hardware tests of a multifunction display like I/O interface verification for AFDX/A664, CAN/A825, A429, discrete, serial and Ethernet plus AFDX/A664 end system verification, including the Boeing EDE protocol. With the same equipment, the HW/SW integration for the MFD can be performed. Subsequent formal verification of the MFD platform software and the display system application software is achieved with the SDIB. The SDIB can also be used for the MFD hardware qualification according to DO 160.

The connection to the IMA cabinet-hosted Graphic Processing Modules (GPM) can be realized via the SDIB internal AFDX/A664 lab switch. With this setup – GPM and single MFD – initial system level verification can be performed as well as robustness and performance tests. The entire AFDX/A664 traffic from and to the MFD is monitored with a dedicated TechSAT AFDX Test Access Port (TAP) with high precision time stamping.



RIGHT: SDIB use cases for C919 multifunction display



BELOW: SDIB architecture for C919 multifunction display

The benefits of a companionship over the entire development process with test means adapted from a continuous technology platform are manifold. Test and integration activities start early at the beginning of the development. Users have to familiarize themselves with the test environment at a time when the SUT is less complex. During the development process, with the increasing complexity of the SUT, the test of one system level can be reused on the next integration level with modifications only applied where test requirements have changed. The reuse of test procedures will improve quality and reliability. Moreover, there is no need to spend additional familiarization effort on completely different development support and test means. ∎

Bernd Mattner is project manager at TechSAT GmbH, based in Germany

MOVERS AND SHAKERS

Strict standards have been established to ensure electronic systems can withstand high levels of vibration

BY THOMAS REILLY AND KEVIN MCINTOSH

Aerospace electronic systems must be designed to withstand high levels of vibration. As a result, strict vibration standards have been established to qualify these systems. Standards include DO 160 for commercial aircraft and MIL-STD-810G for military aircraft.

Vibration qualification testing is typically performed using shaker systems to produce single-axis vibration. Sequential single-axis tests are run in each of three orthogonal axes to fully characterize the vibration. In flight, however, vibration is actually experienced in multiple axes simultaneously.

Until recently, multiple degree of freedom (DOF) vibration testing was limited by actuator and control system technology. Advances in technology have made it possible to more accurately simulate the multi-DOF vibration environment.

Tables using multiple electrodynamic shakers driving through hydrostatic bearings have enabled multi-DOF vibration testing at much higher frequencies. The SignalStar Matrix multishaker vibration controller offers the sophisticated control algorithms and high-speed digital signal processing necessary to control complex multi-DOF vibration.

VIBRATION RESEARCH

The US Army is conducting research at the Center for Advanced Life Cycle Engineering (CALCE) at the University of Maryland on multi-DOF vibration. Ed Habtour is the principal investigator on a project at the US Army Research Laboratory at the Vehicle Technology Directorate (ARL/VTD) working to develop high-fidelity Physics of Failure (PoF) based reliability models. Recent tests at CALCE have shown that traditional sequential single-axial testing is inadequate, expensive, time consuming and can provide misleading reliability predictions in comparison with simultaneous 6DOF testing. Habtour went on to announce that discoveries from this breakthrough study could lead to changes in the way industry conducts vibration testing for cars, trucks and aircraft.

The multi-DOF vibration tests at CALCE were conducted using a Data Physics Matrix system to control a Team Corporation Tensor 900 6DOF table. This table comprises 12 electrodynamic shakers driving a table that is capable of vibration in all six rigid body degrees of freedom.

MDOF CONTROL

Multi-DOF vibration is typically characterized by the six rigid body degrees of freedom – three translations in orthogonal axes and three rotations about each axis. If a structure is flexible within the frequency range of interest, there will be considerably more degrees of freedom.

When controlling an MDOF table, it is important to consider that all unconstrained degrees of freedom must be controlled. If there are no bearings in the table to constrain translation or rotation, the table must be instrumented to measure this vibration and the control system must actively control it. For example, if a six DOF table is used for a three axis test, the control system must control the translational vibration in each axis. It is equally important that it also actively constrains any rotations that may be induced by asymmetric loading or table and test article resonances.

The SignalStar Matrix multishaker vibration controller uses an array of triaxial accelerometers to measure the MDOF vibration of the table. The Matrix controller generates drive signals for each actuator to produce the desired vibration.

There are several different strategies available to control MDOF vibration. All involve measurement of the multiple-input multiple-output (MIMO) frequency response function matrix between the actuator drive signals and the control accelerometer response signals.

DIRECT CONTROL

The most common control strategy is to assign a reference profile to each of the control accelerometers. This strategy must have at least as many control accelerometers as actuators. The control accelerometers must also be located to ensure that all unconstrained rigid body degrees of freedom are measured. It is also desirable using this control strategy to have more control accelerometers than actuators. This is commonly referred to as 'overdetermined' control. The overdetermined control scheme uses singular value decomposition for control matrix inversion and can better handle singularities in the control matrix. The table is controlled using a matrix of reference profiles that include not only the vibration levels for each control location, but also the relative amplitude and phase between control locations.

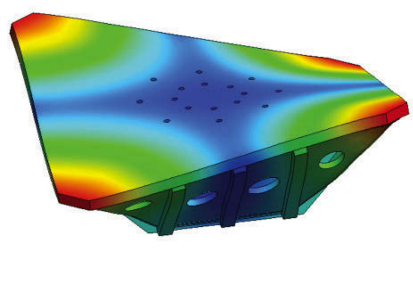
KINEMATIC TRANSFORMATION

Another strategy for MDOF control is kinematic transformation, which uses geometry information and rigid body kinematics to transform the linear acceleration measurements to equivalent six rigid body degrees of freedom.

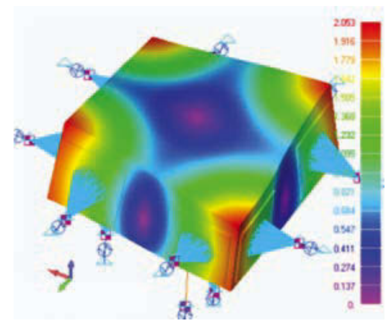
Kinematic transformation has several benefits. For example, when performing three-axis testing on a 6DOF table, it is convenient to define the test using kinematic transformation. The desired vibration profiles are entered for the three translations and the rotations are minimized or nulled. This can be much more straightforward than assigning reference profiles to individual accelerometers.

Kinematic transformation also provides the ability to calculate the vibration response at another location using rigid body assumptions. This is beneficial when a control transducer in the laboratory must be at a location that was not measured in the field data.

Another key benefit of kinematic transformation in MDOF testing is the ability to reduce the rank of the control matrix when there are more shakers or control accelerometers than control degrees of freedom. This simplifies the control computations.



Head expander bending mode



Team Tensor 18kN first bending mode

FLEXIBLE MODE CONTROL

The challenges of controlling an MDOF table above its first resonance are not unlike the problems controlling a large head expander or slip table. Because of the non-uniformity due to resonances, the measured response will be dependent on the location of the control accelerometers on the table. Different locations can see significantly different acceleration response at certain frequencies. The figures below show the finite element analysis of the first bending modes of a large head expander that is used with a single shaker and the Team Tensor 18kN 6DOF table.

When the number of actuators is equal to the rigid body DOF, there is nothing that can be done to control the flexible modes of the table. The table resonances will be excited in the same way that the head expander resonances are excited with a single shaker. Overdetermined control is often used to provide more control response locations in this case. However, if there are more actuators than rigid body degrees of freedom, and the actuators are properly located, kinematic transformation may be extended to include measurement of flexible mode response.

Flexible mode control tests were run using the Matrix controller on a Team Tensor 18kN 6DOF table at the Naval Air Weapons Station, China Lake. This table has four vertical actuators that are positioned such that they may be driven to counteract the first bending mode shown in the figures above.

The first test simply controlled the table using kinematic transformation. The second test added measurement and control of the first bending mode of the table to the control strategy. The figures below show that flexible mode control not only eliminated the control errors at the first bending mode, but also significantly reduced the effect of higher frequency modes in the vertical axis.

The Data Physics SignalStar Matrix multishaker vibration controller offers MDOF control for a wide range of vibration environments. Control applications include random, sine, shock (including shock response spectra synthesis), time waveform replication and mixed mode (sine on random; and random on random).

Thomas Reilly is director, product management for SignalCalc and SignalStar and Kevin McIntosh is director, product management for SignalForce and SignalSound

MATT HARGREAVES

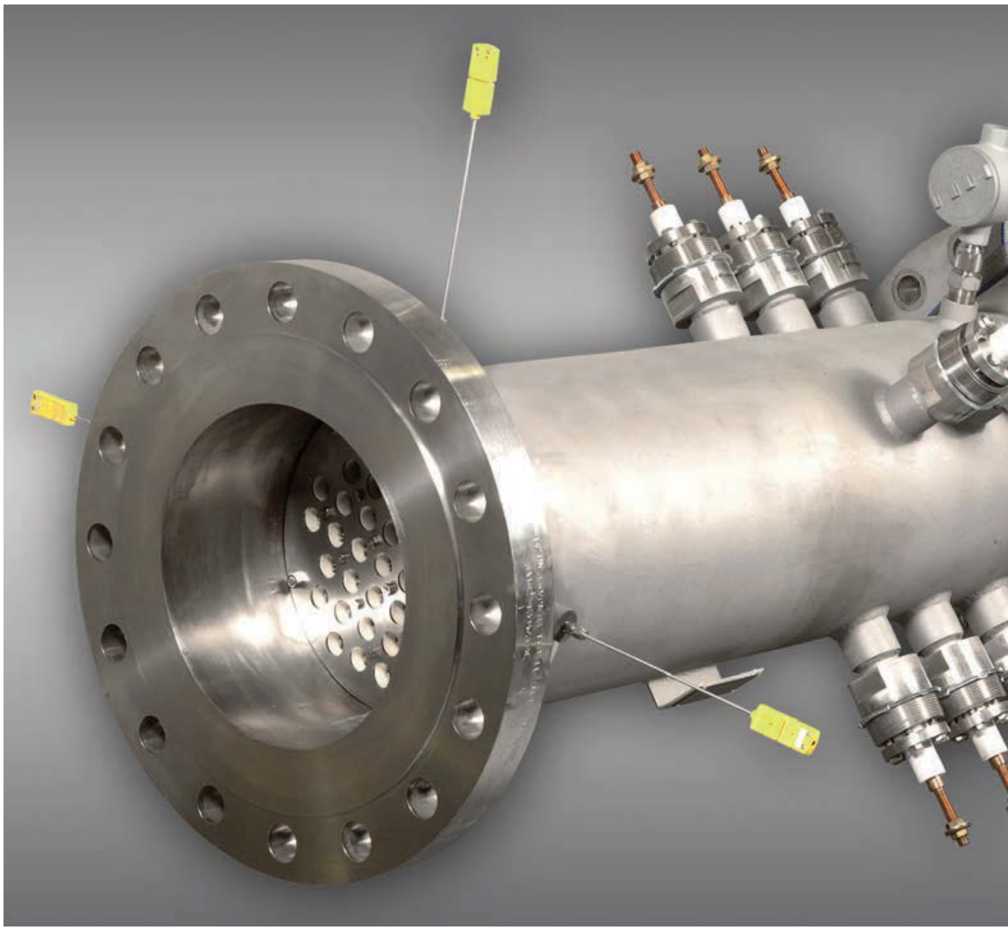
TURNING UP THE HEAT

The advantages of open-coil technology for high-temperature and high-pressure testing in the aerospace and aviation industry

BY MATT HARGREAVES

High-capacity electric in-line air heaters, as an integral part of a compressed air system, are used throughout the aviation and aerospace industry for R&D simulation of the high-temperature and high-pressure conditions produced by an aircraft turbofan compressor. Open-coil electric heaters provide the most optimum heating solution for rig testing as compared with traditional sheathed ('tubular') heating elements.

A turbofan engine's compressor stage generates the high-temperature and high-pressure air that directly feeds the engine internal combustion process, and indirectly feeds the environmental control systems via high and low 'bleed' ports in the compressor stages. These environmental control systems use a system of air cycle machines (ACMs), flow control valves, and heat exchangers, to provide a clean pressurized cabin air environment to passengers.



TRADITIONAL HEATER TECHNOLOGY

Original equipment manufacturers (OEMs) of turbofan engines, ACMs, flow control valves, and other auxiliary equipment need a compact, efficient, and controllable system to provide pressurized hot air to enable their ongoing development efforts for new products. Similarly, FAA-certified repair stations also need this capability to provide pass/fail testing as part of the routine service and repair work on the ACMs, valves and other components necessary to extend the operating life of the aircraft. Historically, the aviation industry used sheathed element type electric heaters for heating the compressed air for testing. The iron alloy (FeCrAl) resistive heater element is a wound helical coil encased in an insulation material, typically magnesium oxide (MgO), which, in turn, is encased in a steel alloy tube (incoloy, etc). This basic tube or ribbon type construction is very similar to what you would find on an electric stove element.

This protective construction surrounding the heater element is ideal for heating liquids or corrosive gases, but the high thermal mass and poor heat transfer between the element and the casing make it very inefficient for heating air, steam, or other inert gases. Similarly, the internal heater element must operate at extremely high temperatures just to overcome the thermal mass of the insulation and the alloy sheath. The end result is not only poor efficiency, but also shorter element life resulting from the elevated element wire temperatures.

OPEN COIL TECHNOLOGY

In contrast, the preferred solution for air or gas heating is to use an open coil heater, which allows the air stream to make direct contact with the heater element, greatly improving the heat transfer.

There are several key advantages to using an open coil heater for air/gas heating, including:

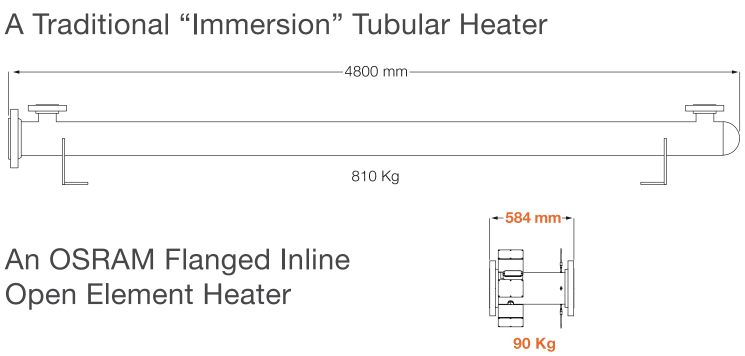
- The heating element actually operates at a lower temperature to produce a given air temperature. The result is an improved element life due to less thermal stress on the heater wire;
- The safe maximum process air temperature can be much higher while still maintaining long life of the element. This allows for more operating flexibility with the more demanding test conditions typical of aerospace and aviation;
- The time to reach operating temperature and/or cool down the heater during a typical operating cycle is much shorter, allowing for much

ABOVE: OSRAM specialty flanged in-line heater

FEATURES TO INDICATE WHEN SPECIFYING A HEATER UNIT

- Required temperature range. Typical OSRAM-type open coil electric heaters can produce up to 1,400°F (760°C) in standard designs and 1,652°F (900°C) in custom designs.
- Pressure ratings: Typical electric heaters can withstand up to 600psi (40 bar) standard, up to 1,100psi (75 bar) in custom designs.
- Code requirements – for US customers: either ASME Section VIII Div. 1 or B31.3 (process Piping).
- Code requirements – for EU customers: Pressure Equipment Directive (PED) certification.
- Special control requirements.
- On-site startup assistance or training.

200KW HEATER SIZE COMPARISON



more productive use of the heating equipment, under more flexible and dynamic operating conditions;

• The higher watt density in an open coil heater allows for a significantly smaller overall package, which reduces weight, floor space, and minimizes the need for heavy rigging equipment to install and service the unit.

CONTROL METHOD

Open-coil heaters require faster responding control systems to safely operate; however this can be achieved easily with modern power and temperature control systems. Key components to a good control system include the use of a phase angle-fired or burst-fired (zero crossing) SCR power controller, PID loop temperature controller, and high-limit safety devices. These control systems can be easily configured for remote or local operator access. The block diagram in the figure above shows an example of a typical control setup for an OSRAM in-line heater with open-coil elements.

In this configuration, one K-type thermocouple probe is used for process temperature control, while another separate probe is used for a high limit. At the heater inlet is a flow-sensing device to ensure the system does not operate unless a minimum flow rate is achieved through the heater. The combination of these devices ensures a safe, reliable system.

APPLICATION TO AEROSPACE INDUSTRY

Larger open-coil in-line heaters are commercially available to handle the extremely high pressure and flow requirements needed by the aerospace industry. For example, air mass flow rates as high as 200 lb/min (3.4 lb/sec) can be heated to 1,000°F using the 800kW OSRAM heater above left, at pressures up to 300 psi and beyond. The compact 14in-diameter pipe size and 60in length makes it easy to install into existing compressed air lines and it can be positioned much closer to the test articles. By placing the heater indoors and close to the test article, the system is much more convenient and accessible, and the heat losses and startup time is much reduced.

SIZING AND SELECTING

A number of considerations must be given to sizing and selecting an open-coil heater. Of primary importance is to specify the temperature rise across the heater needed, and the air mass flow through the heater. A simple formula for sizing the heater power (kilowatts) is given by: kW = SCFM x (Delta T)/3000, where SCFM is the mass flow rate in standard cubic feet per minute, and the Delta T is given in degrees Fahrenheit across the heater. When determining the temperature rise across the heater, the customer should take into consideration the heat losses that occur between the heater and the test point. This may require a higher heater temperature in order to reach a desired process point temperature.

The next step to selecting a heater is to know the maximum static pressure the heater will be subjected to in order to correctly size the pipe and flange material. Depending on temperature and pressure conditions, the materials can vary from common 304 stainless steel to high-performance superalloys, which is a major driver in the overall unit cost.

With safety in mind, the demands of aviation and aerospace customers are arguably more critical than those of other industrial customers. So when selecting a new heater system, it is essential to select a partner which has the right products and experience for the job.

Matt Hargreaves is head of global sales and marketing at Osram Sylvania Inc based in the USA


PETER SIMS

SOUNDS CRUCIAL

After safety, fuel economy and production costs, noise minimization is one of the most important considerations throughout aircraft development

BY PETER SIMS

For companies at all levels of the supply chain, minimizing noise is big business that requires concerted effort. Regulators set ever-tighter legal certification agendas for aircraft noise. Airports and their environmental overseers add more local stipulations. Airframe manufacturers set noise targets, and efficiency programs compel more suppliers to meet demanding quality standards.

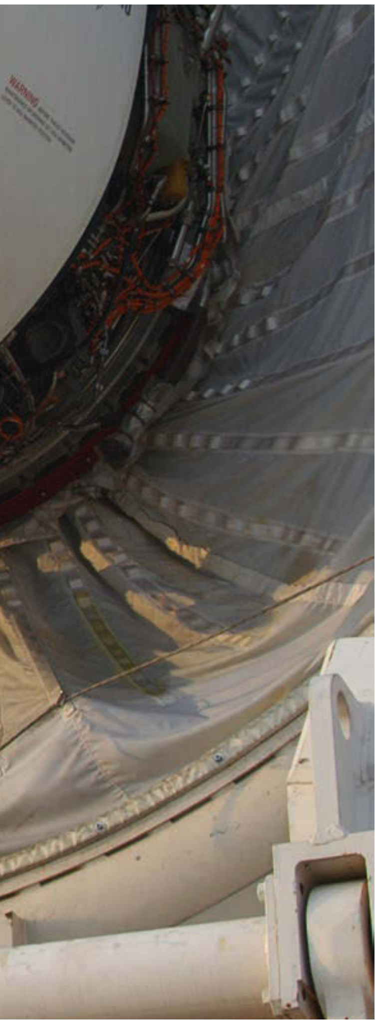
But acoustic issues often play second fiddle to economics; weight, fuel use and production costs remain the primary criteria. Acoustics must therefore be optimized within the confines of these harder parameters, their natural opponents. Noise mitigation must neither interfere with aerodynamic performance nor add weighty damping material, so acoustic solutions need to be smart and 'pay their way' onto the aircraft.

NOISE REDUCTION

Engine noise is the key acoustic contributor at the flight certification measurement points. Consequently, it must be predicted before the final aircraft flies from static engine tests. Noise source reduction also happens here, where testers trial many differently shaped components, such as nacelles and acoustic liners.

As jet engines have developed, higher bypass ratios have reduced noise immensely, as the mean jet velocity has dropped. But with less jet noise, the fan tonal and broadband sound elements are more prominent, and fan noise has become more significant at all power settings. At high power, supersonic fan blades produce noticeable 'buzz-saw' noise, with low-frequency components that travel far at high sound pressure levels and easily into the cabin.

Optimizing low-noise engine design, such as contouring fan blade shapes, relies heavily on accurate flow modeling – which must be informed and validated by testing. For minimizing propagation, it is necessary to characterize and model how noise develops through the non-uniform flow fields in the acoustically lined engine duct and then onward to the



ABOVE AND LEFT: Arrays of microphones enable engineers to precisely identify near-field and far-field sound directivity

"THE DESIGNS OF ACOUSTIC PANELS ARE SO CONSTRAINED THAT THEY NEED CAREFUL OPTIMIZATION. SO DESIGNERS MUST OPTIMALLY BALANCE ATTENUATION FOR THE DIFFERENT ENGINE SETTINGS AND MEASUREMENT POSITIONS AT TAKE-OFF, APPROACH AND SIDELINE"

DATA ACQUISITION HARDWARE

The same LAN-XI system is used throughout aerospace acoustic and vibration testing, requiring a flexible structure. For this reason, the system is modular and distributable. Many different modules suit different demands, including battery modules that quickly create portable systems. Swappable front panels on all modules suit connection to different transducers. The automatic input ranging feature uses parallel DSPs that seamlessly switch when the dynamic range of one is close to the limit, giving an effective dynamic range over 160 dB, and reducing overload risks – while minimizing setup time. Over 10,000 modules are in use in the world today.

far field. This requires investigation of individual sources and paths, such as those along the inlet, bypass and nozzle ducts.

Around static test stands, arrays of microphones enable engineers to precisely identify near-field and far-field sound directivity. Portable microphone arrays enable beamforming of the noise propagation, where the data is processed into precise noise maps with easy-to-understand, colored noise contours. These allow individual source locations and relative amplitudes to be determined. Here, data acquisition hardware needs to be robust, and must minimize setup time. Brüel & Kjær's LAN-XI hardware system helps by removing the requirement for input ranging – it's done automatically. Completing the system, Brüel & Kjær's engine testing acquisition software reflects the workflow's stages of setup, calibration, measurement, real-time monitoring, analysis, data management and reporting.

Beyond better design, mitigation requires interfering with how the sound escapes. But the designs of acoustic panels, such as nacelle liners, are so constrained that they need careful optimization. So designers must optimally balance attenuation for the different engine settings and measurement positions at take-off, approach and sideline.

This requires effective prediction of which frequencies need attenuation at which engine power settings. Engine sound propagates in clear pressure patterns (modes) that can be extracted through the use of in-duct microphone arrays to improve model inputs. One major success from improved understanding is the rejection of hard splices where materials join. New liners on aircraft, including the A380 and B787, bring improvements of 5-10dB without adding weight – just limiting the designers' toolkit.

Around engine intakes, rings of flush-mounted microphones can characterize the circumferential modes in which acoustic energy emerges. With maximum sound levels in the region of 160dB, this requires microphones capable of reliable accuracy at high sound pressure levels, such as the Type 4944. In order to extract the mode acoustic pressure amplitudes, post-processing of recorded time data requires powerful software, such as Brüel & Kjær's PULSE Reflex platform.

When converting a theoretical acoustic liner design to a manufactured design, small excursions can cause large deviations from the acoustic impedance needed for maximum attenuation. For quick compliance tests after the completion of all manufacturing processes, the lightweight portable impedance meter tests fully bonded, curved constructions at high sound pressure, enabling their response in the non-linear acoustic resistance regime to be measured. It is designed to be simple to use for workers without acoustic knowledge.

AIRFRAME NOISE

With the continuous success of engine noise reduction, airframes have become relatively more important. This is most critical for landing approach certification, when minimal engine noise coincides with deployment of high lift devices and undercarriages. Potential solutions to aeroacoustic noise from turbulent airflow include serrated flaps on trailing edges, fairings around landing gear, and acoustic liners on leading-edge slats.

Air pressure fluctuations on wing surfaces can be measured by flush-mounting a unique microphone

LAN-XI system is used throughout aerospace acoustic and vibration testing

designed to endure the demands of flight testing. Type 4948 was developed in collaboration with Airbus, whose engineers specified titanium construction and minimal susceptibility to environmental factors, such as electronic interference.

To map noise sources on flying aircraft, Brüel & Kjær's flyover beamforming software traces sound to individual engine or airframe sources. Large arrays of microphones are laid out according to geometries designed by Brüel & Kjær's specialists and connected to a network of data acquisition modules that are distributed, to keep analog cables short. Digital data is assembled through a central network switch and can be further conducted over a single fiber-optic cable. The hardware helps the operator to remotely check the health of the complete measurement chain for hundreds of dispersed microphones by sending a charge injection signal to the transducers and back with a single keyboard tap. A dedicated flyover data handling application assists with the test workflow, allowing remote monitoring for real-time validation with absolute test safety.

AEROACOUSTICS IN WIND TUNNELS

Aeroacoustic noise is first addressed on scale models in wind tunnels, where acoustic measurements often piggyback on other tests. The cold air in some scale model tests requires special microphones, since the condensed particles force frequencies higher. This conspires with demanding static pressures of up to six atmospheres to require carefully designed transducers that retain the necessary response at high frequencies and low temperatures down to -40°C – such as Brüel & Kjær's Type 4938 ¼in microphone. Data acquisition hardware and microphone arrays must be mobile, require minimal setup time, and handle very high sampling frequencies. The 264kHz sampling rates possible with high frequency LAN-XI data acquisition hardware modules are unsurpassed in COTS systems.

Larger parts are tested in wind tunnels too, where engine technologies like quiet nozzle designs are characterized. Arrays of microphones that are quick to deploy allow mapping of aeroacoustic noise sources in high fidelity. And for handling complex measurement, recording and analysis tasks, Brüel & Kjær's wind tunnel data acquisition software gives a simplified interface that guides the operator through each stage of the workflow of complicated measurements.

FLYOVER FLIGHT CERTIFICATION

Final noise certification demands that the complete aircraft satisfies limits at the approach, cutback and sideline points during different flight operations. Brüel & Kjær's data acquisition hardware is deployed in a distributed layout to provide flight certification noise levels. Although decentralized and located near the measurement points, built-in Precision Time Protocol (PTP) allows all measurements to be perfectly synchronized. The hardware fulfills the requirements of international standards like ICAO.

To be repeatable, certification measurements must conform with standardized daytime conditions of background noise and weather, and the aircraft's ideal flight path. This requires corrections due to inevitable flight path deviations, humidity, Doppler effects and background noise events. LAN-XI hardware assigns data an IRIG-B timestamp, allowing synchronization with external inputs like weather data and flight track information.

INTERIOR NOISE

Passenger comfort, aircrew occupational health and animal cargo require close attention to interior noise. Since modern engines generate more low frequency sound components, and carbon fuselages tend to transmit more low frequency aeroacoustic noise, it is a challenge – particularly during climb.

With few options for adding weight through insulation, modern fuselage designs have damping incorporated in lay-ups of composite materials. Material testing experiments are necessary to tune the desired transmission loss, using lab-based material testing solutions, such as the Type 4206 impedance tube or the portable impedance meter.

Airlines have different options when choosing the level of trim, while for business jet customers it is highly personalized. Acoustic performance data of trim materials like ceiling panels helps customers make informed choices, and allows airframe makers to offer 'acoustic packages' whose targets they can hand to sub-suppliers.

Inflight cabin noise testing requires microphones that can reliably cope with the uniquely challenging, unpredictable sound field. Brüel & Kjær's ¼in multi-field microphone is unique in working in all sound fields at any angle, with a low noise floor and high sensitivity. To map the sound field, a spherical array can take 360° snapshots.

For locating noise hot spots, a range of sound level meters, sound intensity probes and hand-held arrays are used, some with inflight positioning systems to help accurate mapping of large areas. Backing all these systems, the familiar LAN-XI data acquisition hardware can be distributed around the aircraft – near to transducers – with each module both connected and powered by a single LAN cable. ∎

Peter Sims works as a writer for Brüel & Kjær, based in Denmark

COMPONENT CONTROL

Covering just about every element of testing aerospace components, a founding company manager has spread his wings wide in just a decade

BY CHRISTOPHER HOUNSFIELD

After studying aerospace engineering at the University of Braunschweig in Germany, Hans-Jörg Dau worked for various companies, but became an airworthiness engineer and developer at Autoflug in Rellingen. He followed that route and found his own company in August 2003: DAUtec.

The company supervises and implements airworthiness tests and everything to do with them. This begins with the documentation (qualification test plan), selection of the right laboratories, and supervision of the test unit in the laboratories. This is where many companies have staffing constraints or are going through the qualification process for the first time and therefore have no experience. We talk to the company founder…

DO YOU SPECIALIZE IN ANY PARTICULAR AIRCRAFT TYPES?

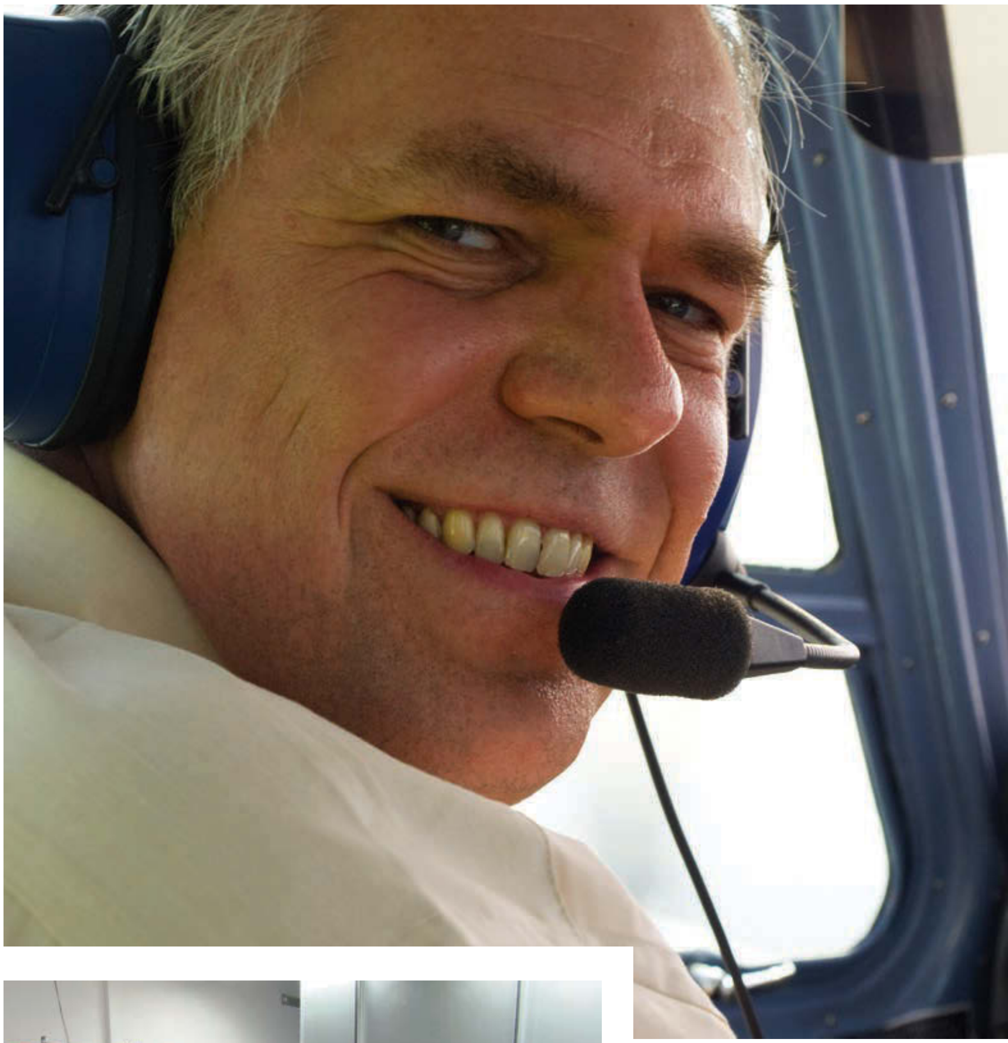
No we don't. We test device components ranging from mechanical parts (e.g. safety belts) through to complex avionics and IFE [in-flight entertainment] for aircraft manufacturers of both civilian and military aircraft.

WHAT RECENT TECHNOLOGIES HAVE YOU INCORPORATED?

We have been working very closely with Lufthansa Technik in Hamburg for the last three years and we operate an environmental laboratory that is located at the LHT premises. With this business expansion, we are now one of the most advanced EMC laboratories in Germany, specifically able to conduct EMI tests in accordance with the RTCA DO-160. We use the latest equipment here, which LHT has only just bought.

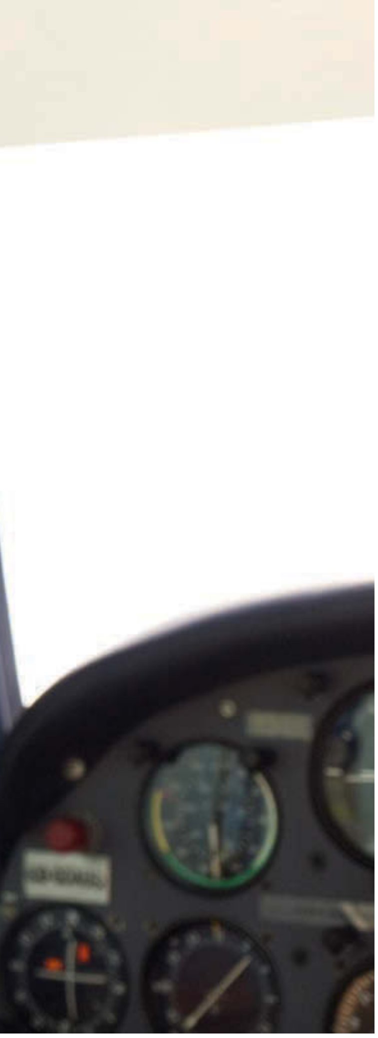
YOU INSTALLED A TEST CENTER WITH LUFTHANSA TECKNIK. CAN YOU GIVE MORE DETAIL?

Yes, that's right. We have been in a strategic partnership with LHT for three years now for the purpose of operating this laboratory. The lab is not only available for internal LHT projects; unused capacity is marketed to external customers. This is also one of our tasks. The lab has an EMC



ABOVE: Hans-Jörg Dau is managing director of DAUtec and has been a pilot for 30 years

LEFT: LHT test laboratory shaker



anechoic chamber with the latest measuring technology, antennas and amplifiers. In addition, with the RMS shaker, we can also offer vibration and shock tests. We have the facilities to conduct temperature and humidity tests too. Most recently, the HASS and HALT test methods have also been used in aviation. These originally come from the automotive industry. LHT has a modern HASS/HALT chamber, which we operate.

YOU ARE INVOLVED IN FLIGHT ACCIDENT INVESTIGATION… TO WHAT LEVEL?

Yes, I personally am a representative of the German Aircraft Accident Investigation Bureau in Braunschweig. I have been doing this for over 15 years. Representatives are consulted on all accidents if needed, regardless of whether it involves small or large aircraft. Luckily, there are only a few accidents, and even fewer involving large aircraft, so usually we are called in for accidents involving smaller aircraft. The last incident I attended was only two months ago; it was a mysterious accident involving a homemade aircraft in which, unfortunately, an acquaintance of mine lost his life.

DO YOU WORK CLOSELY WITH THE BUREAU?

We maintain regular contact with the Bureau so we are always up-to-date. Once a year, there is a conference over several days and a lot of information is exchanged then. However, we also very often work as consultants for insurance companies and prosecutors.

YOU PROVIDE A GREAT DEAL OF DOCUMENTATION. DOES THIS ALL GO TOWARD AIRCRAFT CERTIFICATION?

Without documentation, no aircraft will fly. Alongside this, there would be no physical correct execution of the tests; I think documentation is the most important part of qualification. Unfortunately, we find again and again that this is not taken very seriously by some. But if you don't write down anything at all, you're actually liable to prosecution for gross negligence. We always tell our customers, "If you want to stick around, you have to write it down." And it's also a big help for aircraft accident investigation if major importance is placed on documentation, especially on it actually being available.

WHAT ENVIRONMENTAL TEST FACILITIES DO YOU HAVE?

As mentioned earlier, together with the LHT, we operate our own laboratory where we offer EMC, vibration and shock tests, as well as temperature, humidity and HASS/HALT tests. We also have a network of laboratories where we can carry out all sorts of other tests, such as salt fog, sand and dust, waterproofness, etc.

WHAT ARE YOUR LATEST PROJECTS?

In addition to Lufthansa IFE systems, which we qualify regularly, we are also currently running a project to do with the latest technology for cabin lighting. Unfortunately, however, we cannot give you names or other details.

WHAT EMC WORK DO YOU DO?

Everything from the RTCA DO-160 to direct lightning tests. Also, power input, voltage spikes, emission, RF susceptibility, ESD electrostatic discharge and more.

DO YOUR SYSTEMS DIFFER BETWEEN MILITARY AND CIVIL STANDARDS?

Basically, the tests for civilian and military are the same – just the limits are different. In civil aviation, in addition to manufacturer-specific requirements, the DO-160 is usually applied too. For military projects, the MIL-STD 810 and the MIL-STD 461/462 are applied.

YOU INCLUDE INTERNATIONAL PARTNERS IN YOUR AEROSPACE NETWORK. HOW DOES THAT WORK? WILL IT INCREASE?

We have national and international clients. We also work with international laboratories, for example in the USA. Since we sometimes have to carry out very specific verifications and tests, and because the market is a niche market, international cooperation is inevitable.

WHAT PROBLEMS DO YOU HAVE AS A QUALIFICATION SUPPLIER?

The biggest problem is that qualification and testing is not given enough importance in the planning of large projects, both in terms of cost and time. Sometimes it is not even incorporated into the plans at all. Many of our customers are, of course, under great financial and time pressure.

As a service provider, we strive to achieve that fine balance between safety and economic implementation of qualification for our customers. So far, we've always managed this quite well, but it's getting harder because the test requirements are also becoming harder and harder. Flight safety is our top priority and sometimes we have to reject a project because we do not agree with the customer's specifications or because their specifications are against the rules.

WHERE DO YOU SEE YOURSELF IN FIVE YEARS?

In recent years, we have grown steadily by one employee a year. Although growth is limited in niche segments, we hope to be able to achieve an even broader spread. At the moment, we have 10 employees. I think in the context of extending our laboratory capacity, our staff could be doubled. We are currently looking for suitable premises so that as well as the LHT laboratory, we could also offer additional testing capabilities to our customers independently, for example in the field of fluid susceptibility tests.

WHAT DO YOU SEE AS THE FUTURE OF AEROSPACE TESTING?

Testing will gain even more importance in the future because aviation is still growing. In particular, qualification engineers have to meet high demands with respect to cabin modernization (IFE) and the introduction of new technologies (e.g. LED lighting); in both areas, the test requirements need to be correctly implemented and effects correctly interpreted. ∎

KATRIN STENEBERG

MEASURE THE INVISIBLE

Airbus supplier FACC and its subsidiary CoLT integrate non-contact sensors from GOM in fatigue and structure testing

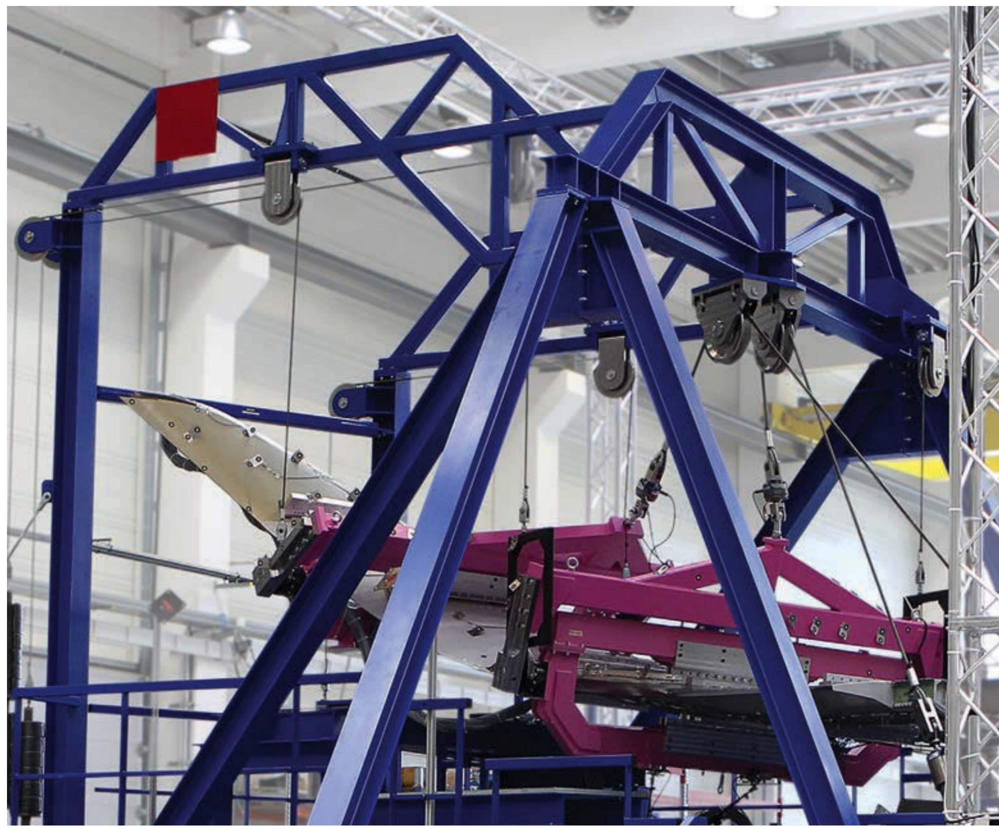
BY KATRIN STENEBERG

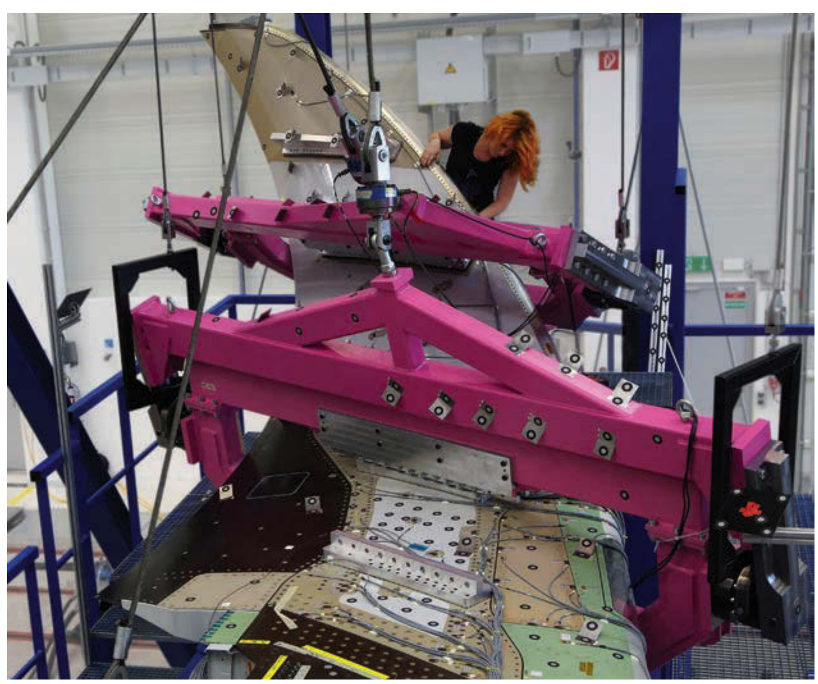
To reduce weight and fuel consumption, the aerospace industry increasingly relies on lightweight materials and new material combinations. That's why the entire fuselage of the new Airbus A350 XWB consists of carbon fiber composite (CFC) materials. In total, the long-haul aircraft reaches a CFC content of 53%. In addition, Airbus uses materials such as titanium and new aluminum alloys. As a result, the A350 consumes about one quarter less fuel than conventionally constructed aircrafts and environmentally harmful CO_2 emissions are reduced correspondingly.

However, these lightweight materials and new material combinations must meet the same high standards of performance, safety and durability as traditional materials. Accordingly, the materials and the components manufactured from them are tested intensively. To this end, the aerospace industry increasingly relies on optical measurement systems and evaluation software from GOM. Its non-contact systems provide data for part geometries as well as for 3D displacements and deformations. Static and dynamic deformations are determined based on individual points or full-field measurements. The measurement data optimize simulation and design processes and thus increase aircraft safety.

Currently, intensive tests are being performed for the certification of the A350. The new model has already completed test flights around the world and the delivery of the first aircraft to Qatar Airways is planned for the end of 2014. Airbus supplier FACC examines fiber composite materials and components of the A350 at the recently built Composites Lab & Test Center (CoLT), a subsidiary on the company's premises in St. Martin (Austria). The certification tests in the area of the translation sleeves have been completed successfully.

At the moment, CoLT is working on tests for the certification of the winglets and wingtips. The entire element, with a length of more than 6m, will be analyzed statically and dynamically in a special testing facility





LEFT: For the first time, non-contact sensors from GOM were integrated into the test setup. The two PONTOS systems are installed on top of the test stand to record 3D displacements and deformations

ABOVE: The winglet is 8m long, 2m high and 3m wide. Around 110 tons of steel was used on the test stand

LEFT: The PONTOS sensors measure the dynamic deformations of around 220 points, each of which can be analyzed three-dimensionally

for long-term and peak loading. The tests also include damage tolerance testing. These intensive tests are necessary because the component mainly consists of fiber composite materials with metal connections.

The load, fatigue and damage tolerance tests provide information about the structural behavior of the component. Along with standard measurement techniques, for the first time, the FACC subsidiary has fully integrated non-contact sensors from GOM in the test setup. Unlike conventional methods, such as using strain gauges, the two PONTOS systems record 3D displacements and deformations of the winglet.

In total, the test object is 8m long, 2m high and 3m wide – around 110 tons of steel were used on the test stand (14m long, 8m high, 10m wide). Loads are achieved with 15 servo hydraulic push and pull cylinders, with the force transmitted by five yokes. The two non-contact sensors measure dynamic deformations at around 220 points, with each point being analyzed three-dimensionally in the x, y and z directions. In addition, more than 2,000 synchronized channels measure static strain, deformation, force, pressure and temperature.

On the actual A350, the winglet and wingtip – the inside elements of the assembly – are fixed on the main wing box. In order to realistically reflect these connection points and the behavior of the main wing box during the test, a dummy wing box is used. It was specifically designed for the test and is identical to a real wing box in terms of material properties and connection of the winglet.

During structure testing, the component is loaded statically across several stages to simulate the loads occurring during flight. In this way, the test engineers examine three scenarios: maximum torsion and maximum load upward and downward. During fatigue testing, the engineers run through real flight profiles to analyze the behavior of the component within one lifecycle. During static and fatigue testing, load factors are applied to account for variations in the material properties and possible weight increases in the component.

For the damage tolerance tests, the winglet was damaged in advance at certain points. This way, the test engineers simulate manufacturing errors, as well as damage caused by hail impact and bird strikes, in order to precisely analyze their effect on material and component under load.

Unlike conventional measurement devices, such as using strain gauges and transducers, optical systems such as PONTOS determine 3D displacements and deformations while additionally measuring real speed and acceleration. The evaluation of the point-based data enables full 6DoF analyses. This way, test engineers can see exactly how the winglet moves in space and at which points it is particularly deformed. The PONTOS system can be easily integrated into the test setup, with inspection points identified by measurement markers. Using an optically tracked touch probe, nominal positions can be determined and adapters can be measured.

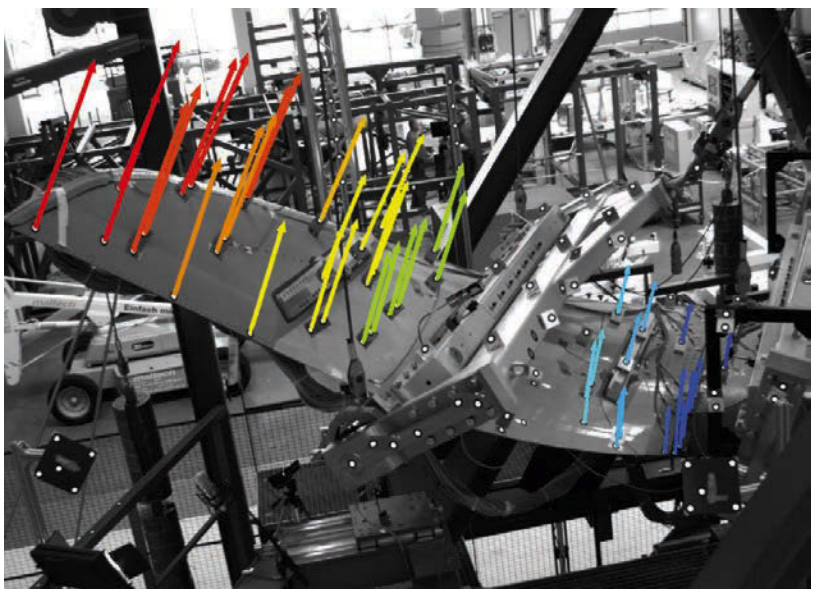
With the new PONTOS Live software module, the test run can also be measured online, enabling users to see directly in the software what happens during testing. Additionally, the measuring data can be communicated to other programs via a digital interface and can directly be processed by them. Analog signals from external measuring devices can also be recorded and processed.

Optical measuring systems also accelerate the test setup. For instance, 200 strain-gauge positions, which were defined in advance by Airbus and CoLT test engineers, were marked and applied to the component within one working day. To do so, the company Westcam, GOM's distributor and service provider in Austria, first measured the winglet and its components with the portable photogrammetry system TRITOP, which captures 3D coordinates of objects. After the measuring data were aligned to CAD software, the 3D scanner ATOS performed a back projection of the strain-gauge positions. During this process, the sensor projects the positions directly on the winglet based on the measurements. The positions are visualized as 3D elements in the CAD software. Staff from CoLT simply marked the correct points, which led to considerable time savings, because up to then it was very work-intensive to determine the positions with measuring tapes, starting from the edges or bore holes.

For demanding geometries, such as at the inner side of a leading edge, positioning using conventional methods was very complicated, due to the strong bending. Using GOM's systems it was possible in a fraction of the time. Optical metrology also allows the positions of the applied strain gauges to be checked. They can be measured again with TRITOP photogrammetry or the handheld

RIGHT: During test setup, the ATOS 3D scanner performed a back projection of the strain gauge positions

BELOW: Test engineers can see exactly how the winglet moves in space and at which points it is particularly deformed



touch probe and compared with the CAD data.

Lightweight materials are an essential part of the aerospace industry. Correspondingly, OEMs and suppliers test the new materials intensively to guarantee their performance, safety and durability. Optical measuring systems can be easily integrated in different test stands; at the same time, they determine static and dynamic deformations via point-based and full-field inspections. The recorded 3D measurement data is permanently available and can be evaluated long after testing and in different contexts. The results can be displayed in charts, videos and images.

One important area in which GOM systems are used is simulation verification. Modern flight vehicles are extremely complex, so everything is simulated during the development process. To compare the simulations with reality, comprehensive 3D measurement data is necessary instead of a few individual signals. The results enable users to review and improve simulation parameters, as well as to optimize current and future design processes. Therefore they can reduce the number of costly test runs and consequently speed up product development. At the same time, the 3D measurement results allow conclusions to be drawn on safety risks, part durability, as well as creep and aging processes. This increases not only the safety, but also the lifetime of products.

GOM OPTICAL MEASURING TECHNIQUES

GOM is a global industrial manufacturer that develops and produces optical measurement solutions and technologies for 3D coordinate measurement and deformation analysis. GOM's measuring systems are based on digital image processing and are used in product development, quality assurance, and material and component testing. Optical measuring technology and full-field surface measurement systems have become standard tools within virtually all industries. GOM's measurement systems and evaluation software provide invaluable data and results for quality assurance in modern product development and production process chains. Users of GOM systems include international companies from the automotive, aviation, aerospace and consumer goods industries, their suppliers, and research institutions and universities all over the globe. In the aerospace industry, GOM systems are mainly used for structure and fatigue tests, vibration analysis, wind tunnel studies and material testing. Applications range from smaller scale measurements, such as coupon and element testing, up to evaluating the entire deformation behavior of system components.

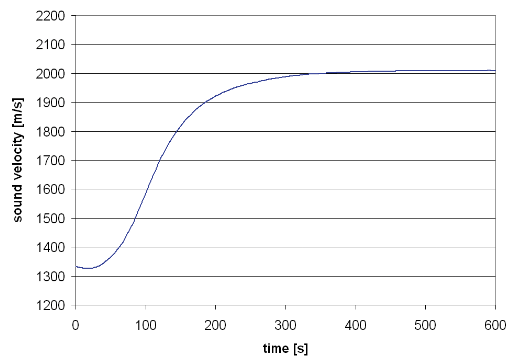
COLT COMPOSITES LAB AND TEST CENTER

FACC Operations is one of the world's leading companies in the design, development and production of advanced fiber reinforced composite components and systems for the aviation industry. Its range of products reaches or spreads from structural components for the fuselage and wings, to engine components, to complete passenger cabins for commercial aircraft, business jets and helicopters. FACC is a supplier to all large aircraft manufacturers, including Airbus, Boeing, Bombardier, Embraer, Sukhoi and COMAC, as well as to engine manufacturers and their suppliers. The newly built Composites Lab & Test Center on FACC's premises in St. Martin (Austria) has recently started operation. It gives FACC one of the most modern facilities for analyzing, testing and certifying fiber composite materials and components. ∎

M. A. Katrin Steneberg is a sales operations/applications expert at GOM, based in Germany

Monitoring of Cross linking Process
by Ultrasound US Plus

To have an information about the cross linking process becomes more and more important in state of the art production processes. RTM- and Autoclave processes demand such an online diagnostic.



Ultrasound diagnostic solves this problem.

- US Plus is applicable in lab and direct in production process
- it can be used as well for process control as for quality inspection
- US Plus works like "DMA or Rheometer incorporated into a mould" using hidden sensors at higher frequencies
- the US Plus transmitters don't influence the temperature in front of the sensor
- US Plus diagnostic delivers (averaged) information about the cross linking in the volume
- the sensors are small and can easily be installed
- US Plus can be applied for all kinds of reactive polymers (thermosets including composites, rubber)
- US Plus diagnostic delivers information about the flow front and the cross linking process

US Plus system with a mold

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VIBRATION RESEARCH

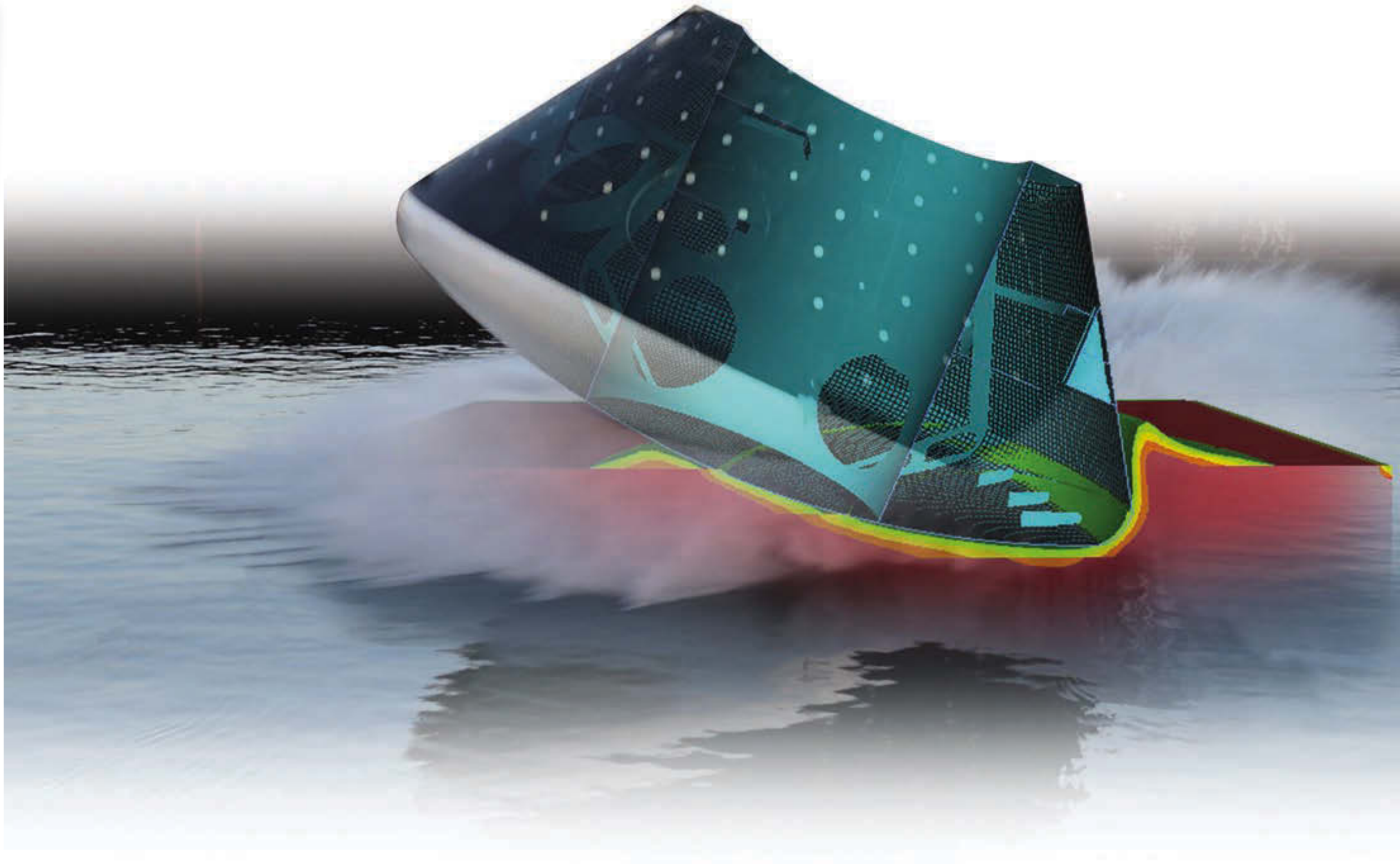
MAHESH PATEL

DREW BURKHALTER

DIVE AT THE DEEP END

Safe landings – simulation methods for the NASA Orion crew module

BY MAHESH PATEL AND DREW BURKHALTER



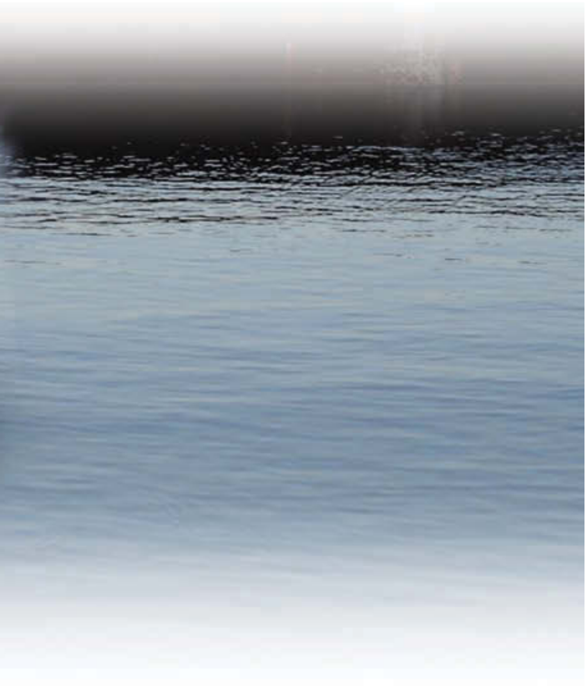
Landing is one of the most dangerous events in flying, whether in a conventional aircraft or a space vehicle. Water landings introduce additional complexity and risk. When an aircraft or re-entry space vehicle hits the water, many things are happening at once and are changing very dynamically depending on the conditions.

In August this year, a team of technicians, engineers, sailors and divers spent a week testing and preparing for NASA's new Orion spacecraft to splash into the ocean after its first space flight test in December. It will have traveled at speeds near 20,000mph and experienced temperatures as high as 4,000°F. When the Orion crew module lands in the Pacific off the coast of southern California, a US Navy ship will be standing by to retrieve it and the astronauts on board. Much planning went into the design and build of the Orion. Several years ago, analysis and virtual testing of the splash landing was conducted by Altair ProductDesign, the engineering services arm of Altair Engineering, headquartered in Troy, Michigan. Physical tests are time consuming and expensive, so virtual testing was imperative to enable engineers to perform all of the design analysis and iterations required to achieve the highest performance standard.

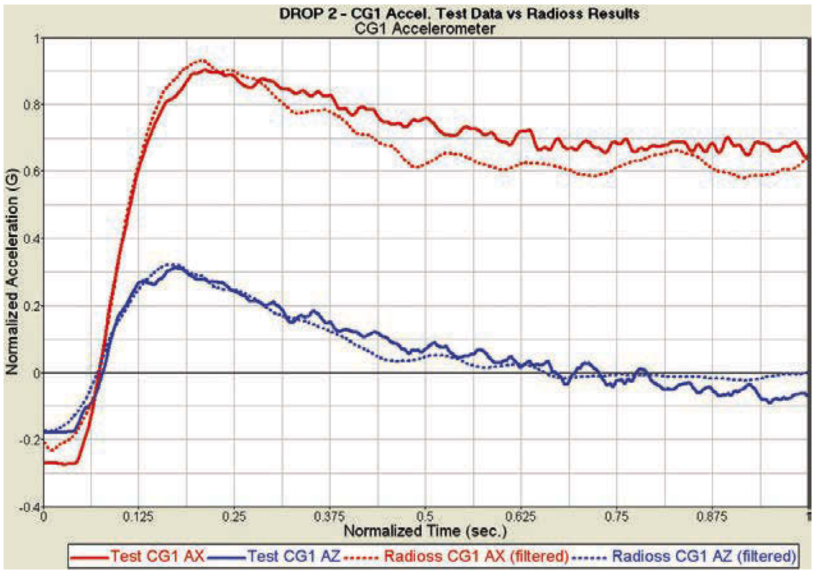
Simulation of this event is computationally intensive and input sensitive. The speed and angle of impact, as well as the impact's effect on structures and materials, are only a few of the physical variables. In addition, simulation input variables such as mesh density, boundary conditions, and contact interfaces must be defined properly to ensure an accurate simulation result. This requires expertise and the use of computer-aided engineering (CAE) methods.

In the case of the Orion crew module, a number of loading conditions were considered: lift-off loads, launch abort loads, re-entry loads and water impact landing loads. Of these, the Earth water landing load represented the largest loading conditions with respect to the integrity of the crew module's structure. Since astronaut safety is dependent upon maintaining the integrity of the structure upon impact, the focus of the simulation team turned to the water landing event.

Finite element analysis (FEA) was chosen to predict water impact loads at splashdown. This method would provide more detail than what is available from physical testing. Still,



> **"IN THE CASE OF THE ORION CREW MODULE, A NUMBER OF LOADING CONDITIONS WERE CONSIDERED: LIFT-OFF LOADS, LAUNCH ABORT LOADS, RE-ENTRY LOADS AND WATER IMPACT LANDING LOADS"**



LEFT: Test data vs FEA results – Drop test acceleration plot (X and Z directions)

physical test data was required to anchor the initial FEA models. Upon correlation of simulation data with the physical test data, accurate predictions could be expected.

TESTING AND ANALYSIS

A full-scale boilerplate prototype of the crew module was built for physical testing, which included a number of data collection devices: accelerometers, strain gauges, inertial measurement units, and pressure sensors. To confirm the crew module flight trajectories, photogrammetric targets were used on the exterior of the prototype and high-speed video cameras were placed at strategic locations.

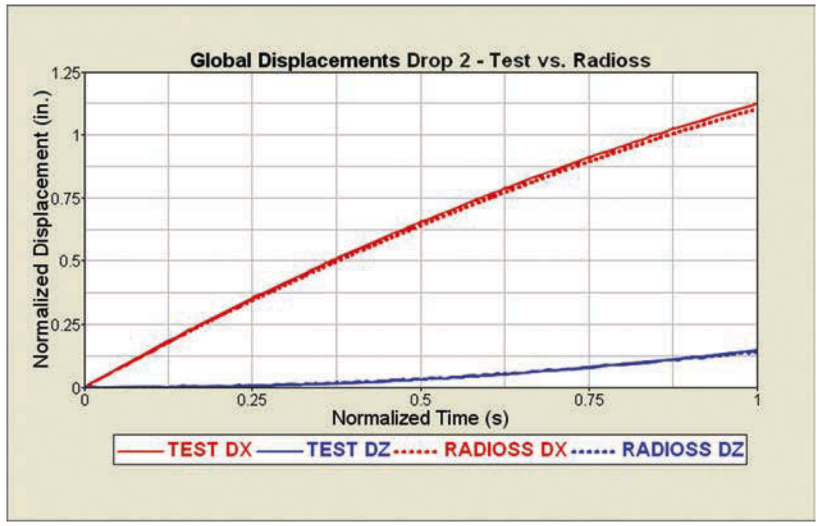
Altair ProductDesign team members were given the computer-aided design (CAD) files by NASA in preparation for the simulation analysis. HyperMesh, a pre-processing tool available in Altair HyperWorks, was used to set up the model with a uniform 4 x 4in average mesh size. Tied contacts were used to connect the outer surface mesh with the internal mesh structure to enable quick exchanges of the heat shield surface mesh to study mesh sensitivities. All of the internal structure of the crew module was modeled, even though it was considered a rigid body in the finite element analysis in order to give it the correct moments of inertia, bringing it within 1% of the measured mass of the fabricated prototype. Locations of the physical test accelerometers were replicated in the model and positioned using the crew module coordinate system, with an internal RADIOSS SAE 1000 filter for each accelerometer output.

To model the water and air at the point of impact, a Eulerian mesh was created of a 30 x 30ft section. A water depth of 25ft and 13ft of air height was used to align with the physical drop test conditions.

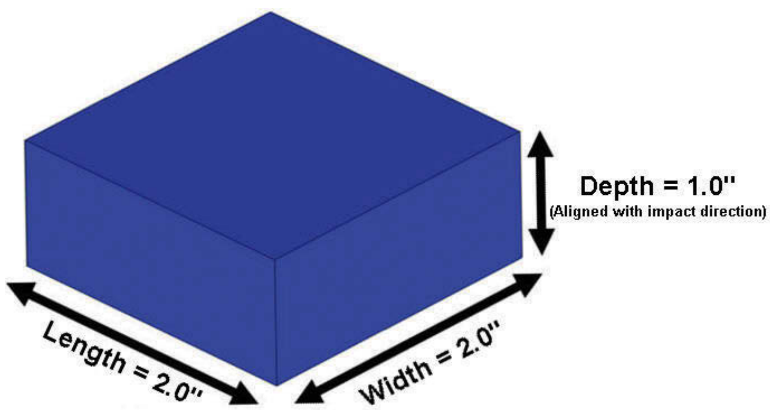
Because of air compression caused at the water-to-air boundary by the accelerating crew module, an initial 8in distance between the crew module and the water interface was used for the simulation. This was done to establish the Arbitrary Lagrangian Eulerian (ALE) coupling contact interface. For the definition of contact between the crew module and the water, a penalty stiffness-based coupled Eulerian-Lagrangian (CEL) method was employed. Parameters for contact stiffness and activation distance were calculated using RADIOSS.

The baseline analysis included the creation of the initial ALE models used to predict 'blind' results prior to the availability of test data. Once physical test data for trajectory and rotation were available, simulation results were compared and found to be quite similar. In contrast, acceleration data did not correlate well.

FEA modeling input parameters then needed to be modified and iterated to see if a closer alignment to physical test accelerations could be produced. Interface stiffness, mesh density, fluid pressure distribution, and boundary conditions were all variables optimized in the correlation exercise. The team ultimately determined that mesh density outweighed the other parameters in terms of importance. Mesh density was most sensitive in the direction normal to the impact surface (vertical), requiring the smallest mesh size, while the other two dimensions were less so. Faster runtimes were achieved by keeping the mesh size relatively large in the less sensitive dimensions, resulting in only a small loss of accuracy. Fluid elements of 2 x 2 x 1in were used at the impact interface of the air and water, while the crew module mesh size remained 4 x 4in. The final correlated models showed very accurate predictions for the crew module trajectories and accelerations for the two different drop angles and velocities studied.



ABOVE: Final correlated test and simulation trajectory results



LEFT: Best element size at water/air impact interface

THE IMPORTANCE OF MESH DENSITY

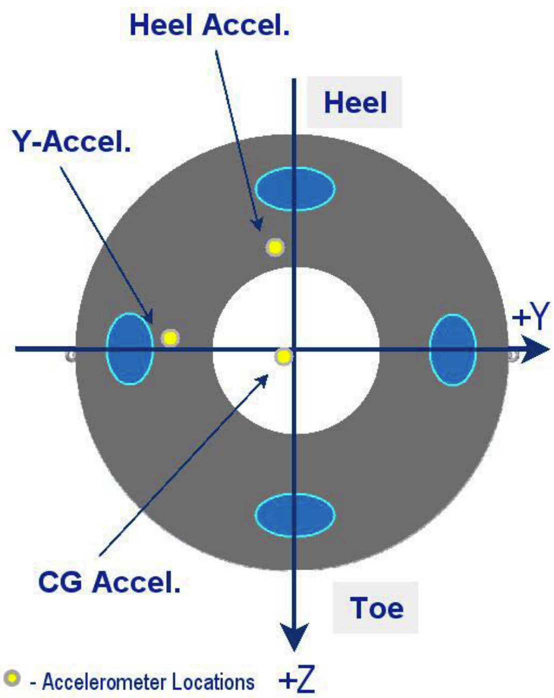
Combined effects of the Lagrangian (crew module) and ALE (air/water) mesh dimension sensitivities needed further exploration. Using the correlated simulation model, a mesh matrix sensitivity study was performed to investigate 20 different combinations of mesh densities. Both the crew module mesh and the fluid mesh were varied.

Because 2D shell elements were used to represent the crew module, its mesh was only varied in length and width, whereas the mesh of the fluid volume was varied in length, width and depth. The Fluid Mesh column (Figure opposite page) denotes the length, width and depth of the fluid elements at the air/water interface. The other columns depict average length and width of the crew module mesh coming into direct contact with the water. Notably, a rule of thumb observed with respect to ALE simulations is that the Lagrangian solid structure (crew module) should not be smaller than the Eulerian fluid structure (the air/water model).

Acceleration data from the 20 models were compared with physical test data accelerations, and patterns and trends of mesh changes emerged. Several of the mesh matrix models showed good acceleration and trajectory correlation, and those with a finer mesh in the direction normal to the impact consistently produced the best results. However, if a single simulation model were to be developed to deliver accurate crew module heat shield pressures as well, more analysis would be required. The table above shows the large variations in the maximum heat shield pressures between the mesh matrix models that correlated well to the acceleration and trajectory data. The maximum pressure reported during the testing was 1.0 normalized pressure unit.

CONCLUSION

Without physical test data, the initial blind fluid mesh size selected produced accelerations which over-estimated peaks, illustrating the importance of using physical test data to anchor predictions. Mesh size ratios of crew module (solid) to air and water (fluid) were very important for obtaining good correlation with physical test data and the fluid mesh dimension normal to the impact was the most critical. Simulation methods developed could be used to model water landing events for objects with



LEFT: Crew module accelerometers (top view)

Mesh Study Model Matrix				
Fluid Mesh	Rigid CM	Rigid CM	Rigid CM	Rigid CM
4"x4"x4"	7"	4"		
2"x2"x2"	7"	4"	2"	
1"x1"x1"	7"	4"	2"	1"
4"x4"x2"	7"	4"	2"	
4"x4"x1"	7"	4"	2"	1"
2"x2"x1"	7"	4"	2"	1"

ABOVE: Mesh study model matrix

comparable size, inertia, mass and shape. Crew module lateral velocities were not considered, but probably should be explored in future studies. The length dimension of the fluid mesh in the direction of travel will likely also be an important variable.

Astronaut safety is dependent upon reliable structures and systems. Employing simulations early on in the design process helps engineers make more informed decisions and can provide information that would not otherwise be obtainable. Additionally, simulation can reduce costly and time-consuming physical testing, although final testing must be done to confirm that all objectives are met to keep our astronauts safe. ∎

Mahesh Patel is an engineering manager and Drew Burkhalter is a senior engineer, both with Altair ProductDesign in Irvine, California. This article was sponsored by NASA under contract to Alliant Techsystems. Special thanks to the entire crew module water landing simulation methods development team under the direction of NASA based in USA

ANDREAS KIESLINGER

OPEN TO IDEAS

The need for highly sophisticated measurements during aircraft development calls for customized instruments, but building such systems has not been not easy – until now

BY ANDREAS KIESLINGER

Although simulation is a useful and important tool in any product development process, it can never fully replace the taking of real measurements. Measurement tasks are becoming more sophisticated, while the results need to be available in a shorter time or even instantly. Not only are raw sensor values required, but the results of analysis are also of interest, again in real time. This calls for advanced measurement solutions with powerful real-time and offline capabilities. While in the past an off-the-shelf strip chart recorder was a good choice, today tailor-made measurement systems are required.

The selection of an instrument solution is as important as the measurement itself, especially if the instrument is critical for the development process or if a decision has long-term implications or is for multiple instruments. There are risks involved – for example, selection of a certain instrument series can lead to dependency on a single manufacturer. Will the manufacturer support and maintain the product line and software in the future? Can it accommodate special requirements for measurements or analysis that have not previously been conducted?

The instrument manufacturer may be able to offer a customized instrument. In this case, through close cooperation between test engineers and the manufacturer, convenient and easy-to-use solutions can be achieved that can generate anything, from simple pass/fail results to fully automated multiple-page test reports, at the click of a button.

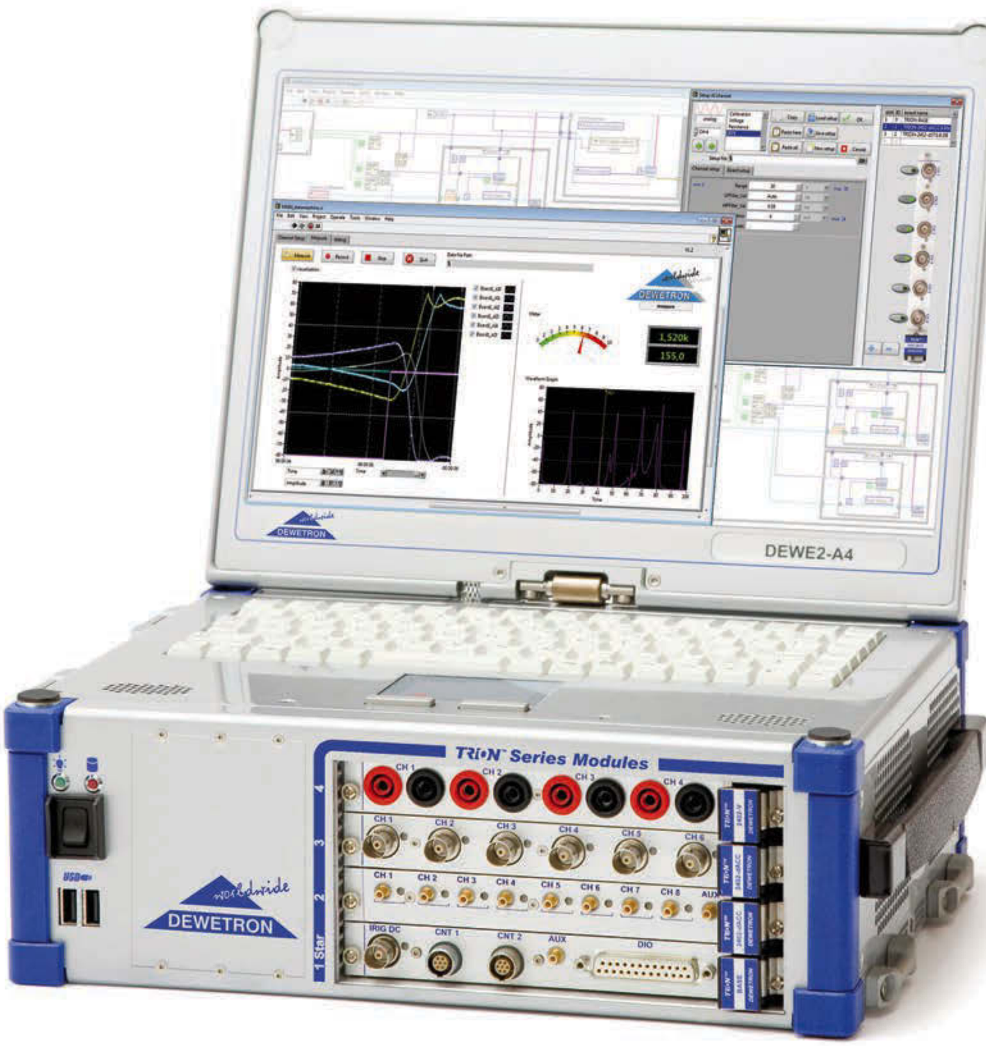
However, this can create new problems. Would a further customization or modification be possible in five years' time? What are the legal implications regarding the intellectual property? The testing method developed by the user will be a competitive advantage to their business and as such needs to be protected. It may be forbidden to share essential technology or measurement method details or sample recordings with anybody outside the user's enterprise. Not even a non-disclosure agreement is always sufficient.

What are the alternatives? Sometimes it is practicable to build a proprietary measurement solution. A wide range of measurement components are available, from low cost to high end. However, such an approach is time consuming and the outcome is not always predictable. Furthermore, building an instrument or test and measurement system is not a simple process. Engineers may not have the necessary expertise and their priority will be to design, validate or improve their own product.

To address this issue, Dewetron has recently developed a new approach. With 25 years of experience in the production of tailor-made test and measurement solutions, the company understands customers' needs for long-term reliability, flexibility and confidentiality. Beyond the powerful ready-to-use data acquisition instruments with standard measurement software, the Austrian firm now also offers Open Systems.

CHOICE OF SOFTWARE

Open Systems are based on Dewetron's proven hardware platforms and are



ABOVE: DEWE2-A4, with-running LabView

LEFT: The German Aerospace Center (DLR) example with screen

ready to use in terms of the instrument hardware, but they are not limited to the standard (yet powerful) instrumentation software. Instead of one piece of measurement software, several software products can be used. Depending on the popularity in the application field and the preference of the user, third-party measurement software can also be used.

For example, for embedded use in testbeds, the easy-to-use data acquisition software DASYLab will be a good choice. Without the need for programming skills, DASYLab enables the creation of worksheets for instant test results by placing function blocks and interconnecting them with lines ('wires'). For more sophisticated measurement tasks or to create most easy-to-use measurement surfaces, National Instruments' Labview graphical programming language is recommended.

For the highest-performance applications, the use of text-based programming languages such as C++, C# or Python could be a good choice, but of course, the software developer will need to decide which tool is appropriate for their purpose.

"FOR THE HIGHEST-PERFORMANCE APPLICATIONS, THE USE OF TEXT-BASED PROGRAMMING LANGUAGES SUCH AS C++, C# OR PYTHON COULD BE A GOOD CHOICE"

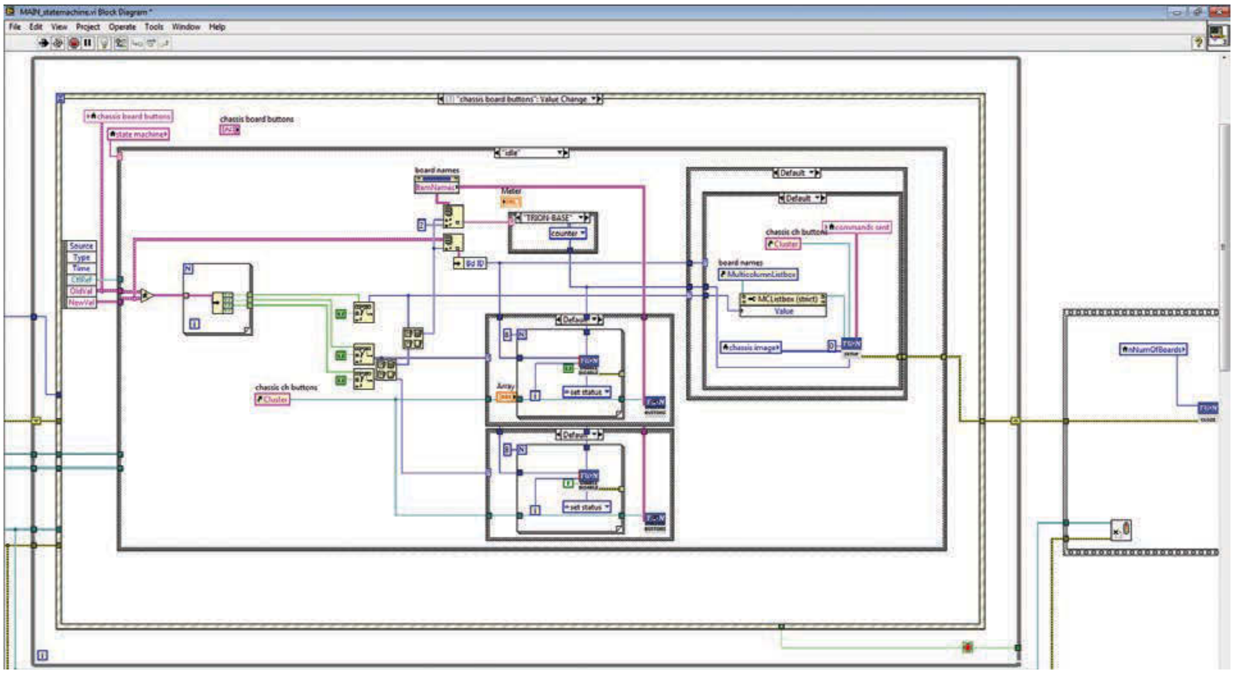
Dewetron Open Systems will be supplied with driver libraries, toolkits, sample programs and documentation enabling own software development by the end user – or any trusted third party such as a software service provider or contractor. Here the ownership of the final source code will be important.

BUILDING BLOCKS

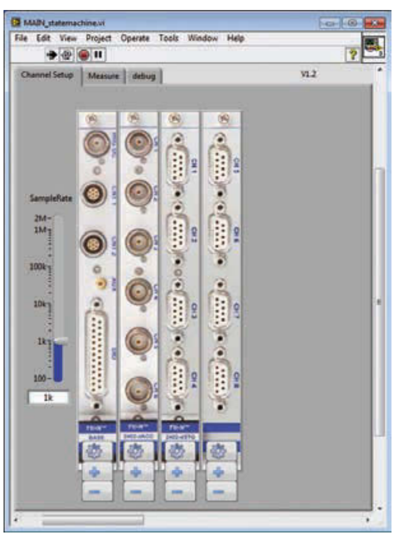
Depending on the user situation, own software development can start from scratch, for maximum flexibility and trustworthiness. This will enable the user to understand every single line (or block) of the code.

Alternatively, development can be built on small example codes, which can be selected from the available collection to form a basic framework. This will enable the test engineer to achieve initial results instantly while allowing their own ideas to be incorporated at a later stage.

The development can also be used on an existing project: if code for testing and measurement is already



ABOVE: System block diagram



ABOVE: Main screen

in use, it is important that this program, with all its features and accreditations, can be reused to minimize changes. Dewetron Open Systems can be integrated into such an environment. Existing code can simply be extended. The design of the driver library is based on common hardware drivers, which makes it easy for the software engineer to understand the way it works and to embed it seamlessly into existing software.

The development can also start from a basic, ready-to-use application supplied by Dewetron. This is most useful if a measurement is required immediately. Still the system should be able to accommodate future demands that cannot be foreseen today. In this situation an Open System is highly desirable, because the source code of the basic ready-to-use application will become legal property along with the hardware.

HARDWARE FLEXIBILITY

Dewetron Open Systems are also open in terms of hardware. The standardized PCI or PXI-based system architecture allows third-party hardware components such as video frame grabber cards or specific interface boards to be integrated. Data sources can be also integrated via USB or LAN. The only requirement for compatibility is a driver for a commonly supported operation system and programming language.

The Dewetron Open System product line also offers key measurement components such as multifunction I/O cards for the PCI bus (Orion cards), the latest PXI-based Trion boards with onboard signal conditioning for direct sensor connection or standalone analog signal conditioning modules. This enables system integrators and OEMs to take advantage of the superior signal quality of Dewetron amplifiers, without the need to invest in an entire 'closed' instrument.

Dewetron Open Systems are compatible with 32-bit and 64-bit versions of Microsoft Windows, including Windows 8. However, in the test and measurement industry there is growing demand for 'Windows-free' instruments, particularly in safety-relevant applications. The Open System is therefore also suitable for selected Linux distributions.

CONCLUSION

With an Open System, the problematic dependency on a single supplier can be avoided, while the instrument can be adapted easily for future requirements. The hardware is ready to use, while the programming effort remains minimal. ∎

Andreas Kieslinger is BU manager, Open Systems, at Dewetron, based in Austria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JONAS LINDE

GROUND BEATER

Founded in 1958, Vidsel Test Range is Europe's largest overland test range, located in the remote north of Sweden

BY JONAS LINDE

The vast and totally unpopulated air and ground space Vidsel, Sweden makes 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.

The very large restricted air and ground space also makes Vidsel 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).

The Vidsel Test Range is operated by the Swedish Defence Materiel Administration Test & Evaluation directorate (FMV T&E).

CAPABILITY T&E

Vidsel is well known for its potent capability regarding live firing and this case study will therefore focus on some other aspects of Vidsel's many possibilities.

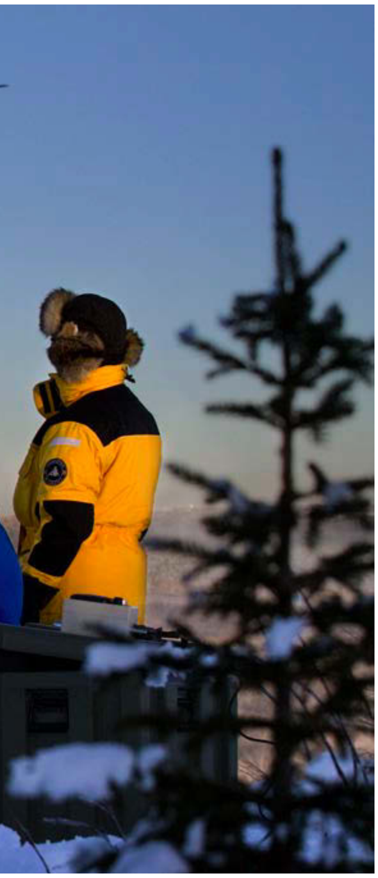
Development test and evaluation (DT&E) is about verifying specification compliance and to evaluate the military utility of the platform or system.

Operational test and evaluation (OT&E – or in this context, capability OT&E) is about validating that a subsystem, system or platform delivers the required operational effect in an operationally realistic environment. FMV T&E and Vidsel have a long track record of planning, leading/supervising, executing and hosting different kinds of both development T&E and OT&E projects.

THE BRIGHT NIGHT SKY

The very remote location of Vidsel offers a couple of unique and non-replicable or transferable advantages. One such unique advantage is the night darkness. At Vidsel, the night sky is almost unaffected by artificial night sky brightness (light pollution) which is very dominant over mainland Europe and the British Isles. This feature is crucial when it comes to evaluation of night vision imaging systems; modern systems incorporate night vision goggles (NVGs) that amplify incoming light more than 100,000 times. This means that any cultural lighting present will brighten the night sky and accordingly, make worst-case scenarios or operational light-levels conditions almost impossible to attain in most parts of the industrialized world.

Noteworthy is that the operational theaters of the last decades have been environments with light conditions very similar to those present at Vidsel, such as Afghanistan, Iraq and Libya.



ABOVE: Helicopters during EW training at Vidsel Test Range, Sweden

LEFT: Joint exercise between air and ground forces at Vidsel Test Range

CASE STUDY: JAS39 C/D

A project that has benefited from the lack of cultural lighting at Vidsel is the Swedish fighter program JAS39 Gripen. When the C and D versions were developed, the cockpit was fitted with AMLCD multifunctional color displays and there was also a requirement for using generation 3 type I class C Omnibus IV NVGs. An extensive DT&E and OT&E effort for verification and validation of the night vision imaging system capability was performed between 2004 and 2009. The test campaign incorporated around 10 ground trials and about 80 flight sorties. The NVG trials at Vidsel included NVG-aided live firing with gun, Sidewinder AIM-9L, GBU-12 Paveway II laser-guided bomb, and deployment of live IR-flares and NVG-aided use of laser designation pod (LDP). Several NVG-aided capabilities were also verified, including: NVG-aided visual identification of air, ground and surface targets; CAS with forward air controller (FAC); formation flying; and tactical maneuvers. The night vision imaging system capability was formally delivered by FMV to the Swedish Air Force (SwAF) early in 2009 and the first international use of NVGs by SwAF was in March the same year during the Cold Response exercise. The NVG-training of the operational squadrons was to a large part performed at Vidsel.

MULTISERVICE OT&E AND FORCE DEVELOPMENT EVALUATION

OT&E can, on the largest scale, be a full multiservice exercise that incorporates hundreds or even thousands of participants from all the three services and from different nations and/or organizations. OT&E on that scale is often referred to as force development evaluation (FDE). Normally, it constitutes requirements for access to vast restricted ground and airspaces, as well as use of advanced full combat loop scenarios and live firing of advanced weapon systems. This leads us to two other aspects of Vidsel's unique features: its vast size and lack of civilian air traffic. It is possible to host and operate with large forces from all the three services at the same time and also to expand the already large restricted airspace with little or no impact on civilian air traffic.

CASE STUDY: LOYAL ARROW 2009

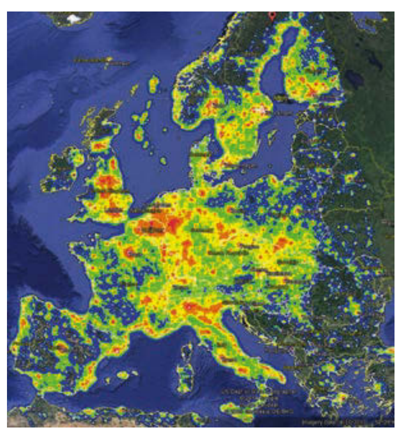
One typical project where these two unique aspects of Vidsel were turned to the best account is Loyal Arrow 2009 (LAW09), which was a major

The location of Vidsel Test Range, in the north of Sweden outlined in white

NATO exercise. The aim of LAW09 was to exercise and train units and NATO staff in the orchestration and conduct of air operations and specifically to provide component level force integration training for NATO rapid response assigned units. LAW09 comprised 10 participation nations, about 2,000 soldiers, 50 fast jets, helicopters, AWACS, tactical transport and tanker aircraft, and a hangar carrier.

Command and control was executed by the Joint Force Air Component headquarters from Ramstein Air Base. The area of operation was located to the north part of Sweden and air squadrons were based in Sweden (Luleå and Vidsel), Norway (Bodö and Örland) and Finland (Uleåborg). The hangar carrier was stationed in the Gulf of Bothnia.

Vidsel was one of the busiest airbases used, and hosted aircraft from several of the participating nations. During LAW09, Vidsel's already vast restricted air and ground space was enlarged in such way that a one-way flight distance of 700km was obtained. Extensive live firings on targets placed at Vidsel were executed during the exercise. Reconnaissance aircraft with electro-optical sensors were used to spot and identify real and simulated threats and for target identification.



Artificial night sky brightness shows the remoteness of the test site

Examples of threats that were present at Vidsel during the LAW09 are SA-6/7/8/15/16, ZSU23/4, Stinger, RF and GPS jamming.

TRAIN THE TRAINER

The shortage of deployable helicopter capability is a severe issue that has at least two underlying reasons. The first reason is the availability of operational airframes. The second issue is a lack of well-trained and combat-ready aircrews. The aircrew shortage can be addressed by increasing the pace at which new aircrews are trained. However, this has to be performed without affecting the quality of the graduated students.

CASE STUDY: THE HELICOPTER TACTICS INSTRUCTOR COURSE

The response of the European Defence Agency to address the aircrew issue is to 'train the trainer' in order to increase the efficiency of each sortie flown during the basic and initial tactical training flying phase. As a result, the use of the limited fleet of operational airframes is optimized, at the same time.

In 2013 and 2014, the Helicopter Tactics Instructor Course (HTIC) was performed at Vidsel due to its vast restricted airspace; the possibility to simultaneously host a vast array of different kind of sorties, such as live firing of weapons and deployment of EW systems; and furthermore, the capability to build advanced tactical scenarios with several parallel airborne and ground movements.

The HTICs performed so far have accommodated participants from Sweden, the UK, the Czech Republic, Austria and Germany – all in all, about 120 participants per exercise. The very positive results achieved will probably lead to the establishment of the HTIC as a regular course for front-line aircrew instructors.

SUMMARY

As demonstrated in these three case studies, the unique features of Vidsel can be used in many different ways. Vidsel is not only an advanced and well equipped live firing range; its versatility also makes it the ideal place for all kinds of T&E during the lifetime of a platform or system. It is also a training range suitable for basic and advanced tactical training, or it can be used for complex exercises on a large scale.

Military T&E and training has been staged at Vidsel for more than 50 years. The range is easily accessible, fully equipped, and manned with competent, dedicated and experienced personnel. ∎

Jonas Linde is director marketing and sales, senior flight test engineer at FMV T&E, Swedish Defence Materiel Administration

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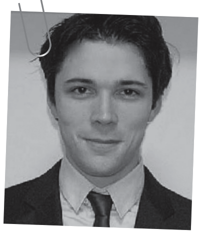


THIBAULT DE LA GRANDVILLE

TAKE ON BOARD

Recent rulings from the FAA and EASA regarding repair stations have put the avionics industry under pressure to evolve and adapt

BY THIBAULT DE LA GRANDVILLE

The new generation tester is more than 30% lighter than its predecessor

Over the past few years, economic downturn has meant less time for aircraft turnover and stability. This means tighter margins and being ahead of the game.

Since 1982, Laversab has built RVSM air data test sets, pitot-static testers that calibrate air data instruments such as altimeters, airspeed indicators, rate of climb indicators, and also ADCs, cabin pressure sensors and other pressure-related sensors found on board the aircraft.

While the company manufacturers many testers for aircraft, ranging from the smallest helicopter to the fastest fighter, it was important to design a unit that would be affordable and easy to use. To reach that goal, it decided to start everything from scratch, and that is how the 62 series came to life, with the model 6200 for non-RVSM aircraft, and the 6250 for light RVSM aircraft.

THE NEW REMOTE

One of the major improvements lies in a small and light remote that will be easier to operate in the cockpit. The remote will now feature an LCD sunlight readable touchscreen, and an option has been added to have the tester powered through an eight-hour internal battery, allowing flexibility when testing aircraft on the tarmac under the sun.

THE NEW UNIT

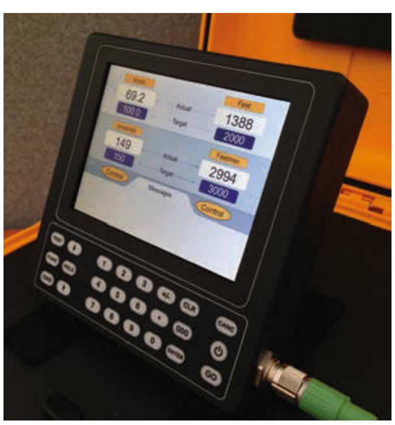
The new remote controller is just one of the number of innovations that the 6200 and 6250 are bringing. The unit has been made more flexible for all users. It is smaller and lighter, by using new alloys and fewer parts, thus also reducing the maintenance. The unit can now operate in even harsher environments, with new pressure sensors that can be compensated in temperature. The tester is also more energy efficient, due to the new electronic board and new, more efficient pumps that run only when needed.

This unit is also more secure for the user, due to the implementation of an extra security valve on the manifold that does turn off in the event of a loss of power, therefore gently venting the aircraft down to the ground with need for power. Manual valves are also available on the front panel of the unit. A full self-test will be performed at every startup of the unit to ensure that it is able to operate a task safely for the aircraft.

THE AEROSPACE CHANGE

The aerospace industry is dramatically changing. The demand for new aircraft has never been so high; this can be seen in the emergence of low-cost air carriers that are more and more conscious about their budgets. And just as any company looks at the emerging market, Laversab will maintain the same high levels of exigency that are expected in the aerospace industry. ▮

Thibault de La Grandville is the aviation products sales manager at Laversab, based in France



The new remote controller in action with its very bright display

The RVSM model 6250 in action

INDEX TO ADVERTISERS

THE COMMUNICATION GAME

A new approach for advanced communications systems for civil aircraft

BY ED CANNING AND DR ROB MAUNDER

The University of Southampton in the UK is part of a research program that has been awarded £6.4m (US$10.4m) to develop lighter, safer and more fuel-efficient aircraft. The HARNet (harmonized antennas, radios and networks) strategic research program has been awarded the funding from the Aerospace Growth Partnership (AGP).

The program is led by Thales, a global technology leader in aerospace, transportation, defense and security, working with key industry partner Cobham, a market leader in advanced antennas and high-data-bandwidth radios. The program will be match-funded by industry and aided and supported by the research of the universities of Southampton, Bradford and Queen Mary University of London.

The partnership aims to study the feasibility of replacing the current system of isolated, federated radio systems on board civil aircraft by developing the radio techniques and technologies required to produce an integrated modular communications (IMC) system.

The IMC concept involves the use of software-defined radios, reducing the number of avionics computers required on board an aircraft, as well as enabling a significant reduction in the amount of cabling required; complementing this will be the next generation of novel antenna solutions and compatibility with a range of current (and future) bearer technologies. Compliance with forthcoming advances in air traffic management, such as Single European Sky ATM Research (SESAR) and the North American NEXTGEN programs, are key requirements for the system.

The running costs of modern civil aircraft are highly sensitive to total weight, and internal space is at a premium. From the perspective of airlines, primary benefits of an IMC system will include reduced weight, reduced volume, reduced procurement cost and fewer spares, alongside higher flexibility and increased reliability, safety and security. Further benefits will include reducing fuel burn, noise and CO_2 emissions. Passengers will benefit from higher data rates, increased availability, and reduced cost of data services.

The new communications system could change civil aviation as we know it

Peter Hitchcock, vice president of avionics at Thales UK, says, "This investment will help bring to fruition the technologies and products that will tackle some of the big issues facing the aviation industry. It will also help retain valuable skills, expertise and technologies within the UK. We welcome this investment from the AGP and look forward to working with industry and academia to advance communications systems for civil aircraft."

Dr Vincent Mifsud from Cobham adds, "This prestigious and strategic program of research will help deliver next-generation aerospace communications to greatly improve safety and capability; and to reduce the environmental impact of civil aviation. We intend to exploit Cobham's expertise in cutting-edge antenna design and high-bandwidth MESH radio networks, in partnership with leading authorities from industry and academia, to develop this exciting project and support the broader objectives of the AGP."

The University of Southampton is contributing to the IMC concept via innovative approaches to data networking via meshed radio networks, which will allow aircraft to seamlessly exchange data with each other and the ground. This will enable the aircraft and their passengers to remain connected to the world, whether they are parked at an airport, taking off or landing, flying over populated areas, or flying over the ocean.

Dr Rob Maunder, of Electronics and Computer Science at the University of Southampton, says, "This research draws upon the university's expertise in wireless communication and networking, within electronics and computer science. This ambitious project offers us a fantastic opportunity for extending the reach, impact and profile of our research."

Professor Yang Hao from the Antenna Group at Queen Mary University of London, says, "Recently, Queen Mary has developed several innovative solutions in the design of electrically small antennas and novel lens antennas based on artificial and nanoscale materials. This partnership will ensure that we can transfer our research findings swiftly from blue skies research to industrial use, and places our research in the context of practical applications."

Professor Fun Hu, head of the Future Ubiquitous Networks Research Group, says, "HARNet will exploit our expertise in aeronautical communications, protocol definitions, and middleware design and development, as well as our knowledge and experience in the IMC system.

"We will design and develop an automated testing framework in HARNet, which is strategically important in the ongoing and future development of the IMC. I am delighted for my research team to be involved in this prestigious and strategic program. HARNet is set to change the future of communications technologies for civil aircraft. It will also ensure a safer, cleaner and greener civil airspace for the future."

Ed Canning is a HARNet systems engineer at Thales; Dr Rob Maunder is from the University of Southampton, UK