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AEROSPACE TESTING INTERNATIONAL

MARCH 2011

Space secret

As the second vehicle is launched, the USAF opens up about the X-37B, its top-secret reusable spacecraft

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Embedded Success dSPACE

In the aftermath of the June 2009 mid-Atlantic air disaster in which Air France 447 went down during a storm, I wrote about the argument emerging between those who think that mechanical-based controls (part of 'grass-roots' pilot training) are safer than complex computer-based, next-generation fly-by-wire airliners. This is still a very contentious issue.

Major General (retired) Des Barker, a former senior South African Air Force test and demonstration pilot and an icon within his field, has taken this debate a step further by looking at pilot training versus engineer and regulator advancement. I am pleased to give him the opportunity to share his views here…

"There is no doubt that innovative engineering and technological advances have increased aviation efficiency and safety at a higher rate than any of the other sciences, but how we are actually directing the benefits of this technology gain should be a concern to all.

Within the pilot community worldwide, a concern prevails at the lack of basic situational awareness and handling capabilities appearing in the cockpits. The causes of several accidents could be traced back to pilots' inadequate 'hands-on' abilities or loss of situational awareness in the latest generation aircraft.

It is no secret that engineers seized upon the fickleness of pilot judgment to deliberately design pilot error out of the cockpit. The universally accepted 72% of accidents attributed to man spurred engineers to introduce automation technology to improve handling and judgment inadequacies.

The problem stems from the fact that smart avionics, smart aerodynamics, and smart flight control systems have made modern aircraft a lot easier to fly. Consequently, pilot workload has decreased to the extent that the 'pilot-out-of-the-loop' philosophy increasingly poses a risk of decaying piloting skills.

During the final flight of the Air France 447 Airbus, 24 ACARS messages were sent automatically, indicating speed measurement inconsistencies, the disconnection of the autopilot, and the airplane going into 'alternate law' flight control mode, which happens when multiple failures of redundant systems occur.

The loss of major systems left the pilots with information overload but no real option to control the aircraft manually under the adverse weather conditions prevailing at the time. [The actual failure of Flight 447 is still unknown, but is generally attributed to the pitot tubes and related electronic systems – editor's note.]

In February 2009, the simple failure of a radio altimeter led to the delayed attempts at stall recovery of Turkish Airlines Flight 1951 as it approached Schiphol Airport in the Netherlands. The investigators' preliminary report confirmed that the pilots allowed the automatic systems to decelerate the aircraft to a dangerously low speed before scrambling to accelerate out of the stall. But the Boeing 737 crashed to the ground, killing all three pilots.

The radio altimeter had 'informed' the automatic flight system that the aircraft was 8ft below ground level when it was actually nearly 2,000ft in the air, which caused the auto-throttle to pull back the power to idle, as if the plane were touching down. A recent FAA study found serious flaws in pilot training for handling automation and suggested that flight crew have never been properly trained for operating highly automated aircraft.

Between 2001 and 2009, inadequate crew knowledge of automated systems was a factor in more than 40% of accidents and 30% of serious incidents. Presenting progress in her research, FAA human factors specialist Dr Kathy Abbott cataloged the evidence of disharmony between crews and highly automated aircraft. She identified recurring handling problems demonstrated by pilots, including: lack of recognition of autopilot/auto-throttle disconnect; lack of monitoring of and failure to maintain energy/speed; incorrect upset recovery; and inappropriate control inputs. Abbot delivered the judgment: 'Failure assessment is difficult, failure recovery is difficult, and the failure modes were not anticipated by the designers.'

The threat is real. Engineers are getting ahead of – and out of synch with – pilots' abilities and regulator knowledge. Advanced technologies instituted to ameliorate human deficiencies could turn out to be a bigger threat to safety than the human factor unless methods of reconciliation can be found between pilots, engineers, and regulators."

Disturbing thoughts.

Christopher Hounsfield, editor
Special thanks to Major General Des Barker

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REGULARS

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COVER IMAGE: The second X-37B prior to launch February 2011

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High-speed hybrid

THE H3 CONCEPT (HIGH-SPEED, LONG-RANGE, HYBRID HELICOPTER) TOOK TO THE SKIES IN 2010 AND IS ALREADY AHEAD OF SCHEDULE. IT REPRESENTS A REVOLUTION IN HYBRID DESIGN

BY CHRISTIAN DA SILVA

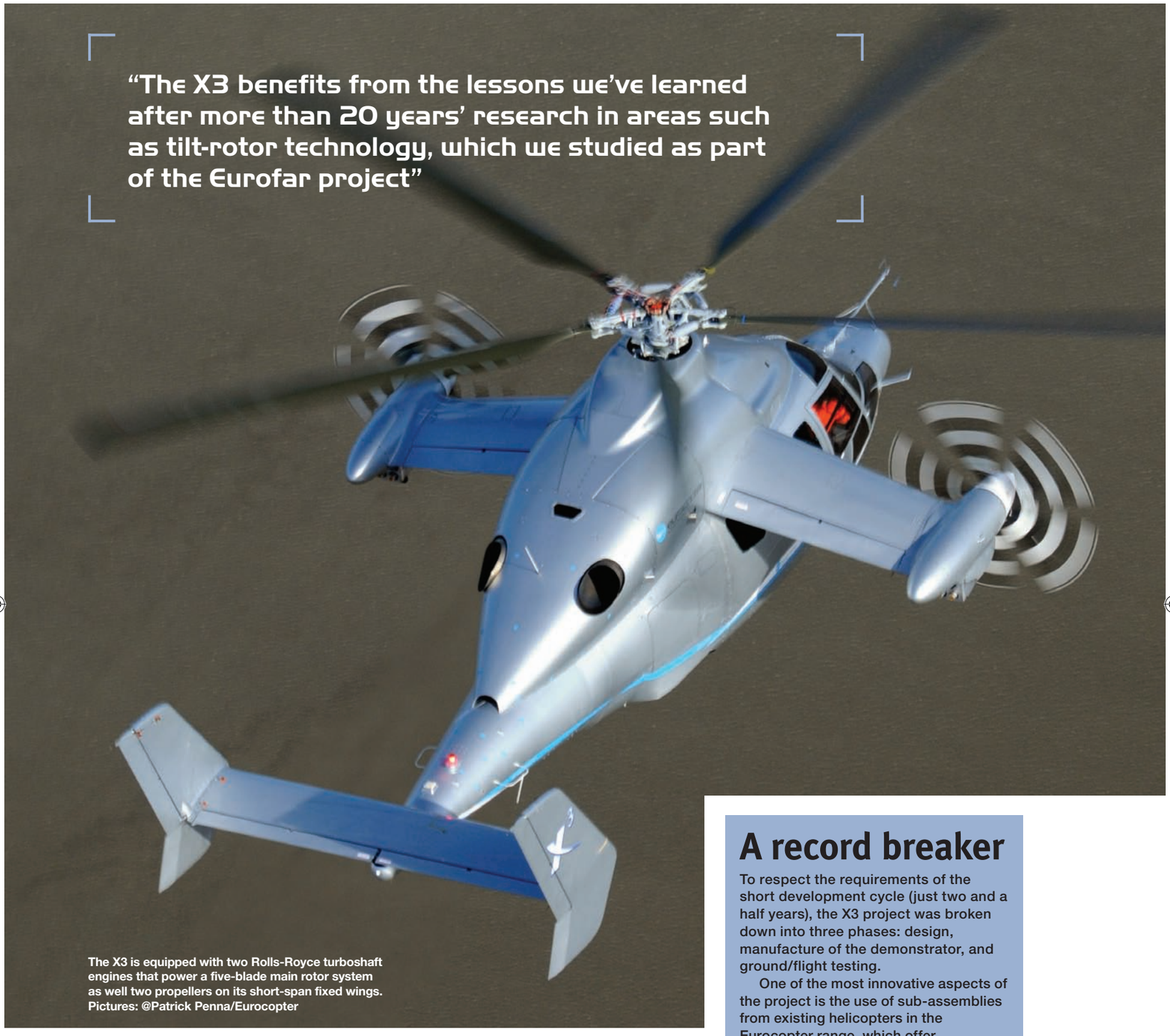
With the efficiency of a turboprop engine and the excellent hover flight capabilities of a helicopter, Eurocopter's H3 concept (high-speed, long-range, hybrid helicopter) can perform vertical take-offs and landings and obtain cruising speeds of approximately 220kts.

A major goal of the H3 concept is to offer more cost-effective transport missions. This is achieved by ensuring that the aircraft is not much more expensive than a standard helicopter (a maximum of 25% more) yet has a faster cruising speed (up from 145 to 220kts). This leads to an increased productivity of approximately 50%, which far exceeds cost increase per flight hour, and the purchase, maintenance, and ongoing costs of using the aircraft. In other words, the cost per transported passenger is reduced when the increase in productivity outweighs the increase in the machine's overall cost.

Operators can also benefit from indirect gains, as increased productivity means fewer aircraft will be needed to satisfy long-distance transport needs.

The concept becomes a reality

The H3 will mainly be targeted at civil passenger transport and offshore missions, inter-city shuttle services, and long-distance SAR missions over both land and sea. The 'long-distance' capacities of the aircraft are a key point, as the expected gains in productivity imply that the majority of the mission will be spent in cruise flight (five minutes for the take-off and landing phases, and the



"The X3 benefits from the lessons we've learned after more than 20 years' research in areas such as tilt-rotor technology, which we studied as part of the Eurofar project"

The X3 is equipped with two Rolls-Royce turboshaft engines that power a five-blade main rotor system as well two propellers on its short-span fixed wings. Pictures: @Patrick Penna/Eurocopter

remainder at high cruising speed). But the concept may also attract military customers interested in rapid intervention capabilities in remote theaters, as an aircraft offering vertical take-offs is the ideal tool for rescuing downed crews behind enemy lines.

The X3, the technology demonstrator for the new concept, performed its first flight on September 6, 2010 in Istres, France.

A simple concept

The configuration of the H3 is actually quite simple and offers excellent hover flight performance by reducing the disk load (the weight for which the rotor must provide lift, divided by the surface area swept by the blades).

The lower the disk load, the less power the machine needs in hover flight. The rotational speed of the high-speed rotor is also decreased (thereby reducing lift) to avoid reaching the drag divergence Mach number on the forward-moving blade profiles. The H3 also includes a fixed wing that adds additional lift and relieves the load on the main rotor,

A record breaker

To respect the requirements of the short development cycle (just two and a half years), the X3 project was broken down into three phases: design, manufacture of the demonstrator, and ground/flight testing.

One of the most innovative aspects of the project is the use of sub-assemblies from existing helicopters in the Eurocopter range, which offer guaranteed reliability. This decision also kept development costs and cycles to a minimum and did away with qualification phases that would have made it impossible to remain on such a tight schedule. But the success of this extraordinary challenge also depended on the know-how and determination of the few dozen engineers, technicians, and mechanics who make up the project team at Eurocopter.

New flight testing of the X3 is now due to get underway after a three-month upgrade.

Flight preparation

The engines were accepted in January 2010, and fatigue testing was performed on the transmission gearbox and shaft following their delivery in April. This was the final stage of the ground test phase, which ended in June. Flight authorization was issued for the X3 on July 13, 2010. Then the work teams really moved into high gear. On the night of July 31, the aircraft was transported to the airbase in Istres, where it would then perform its first flight, right on schedule on September 6 2010.

One of the most crucial developments for the project was the new propellers. A great deal of controlled simulation work was necessary to check the aircraft's behavior: failure analysis, finalization of piloting laws, and power management to find the perfect union between two different concepts – the airplane and the helicopter.

which prevents stalling on the backward-moving blades.

Another key phenomenon must be taken into account. As drag increases on the airframe, the lift-to-drag ratio of high-speed rotors drops. This means that additional thrust is essential, and the cyclic pitch of the rotor must be increased continuously to drive the helicopter forward. But in the H3 concept, propellers take over from the rotor to provide thrust. The propellers also provide anti-torque and yaw controls, making a tail rotor unnecessary. For level flight, the aircraft has been equipped with 'trimmable' (adjustable) components.

In fact, these are not control surfaces but small flaps located on the horizontal stabilizer and tailfin that provide balance during pitch and yaw movements. Their actuators are powered by electric motors controlled by the automatic pilot. It should also be noted that the unique conception of the H3 means it is capable of performing autorotation just like a standard helicopter. Although the concept may be mechanically more complex than a conventional helicopter, it is actually much simpler than other technologies that have been proposed (such as tilt-rotor aircraft, for example).

The X3 technology demonstrator

The X3 is the proof-of-concept demonstrator that will be used to validate the H3 concept. It has three functions. First, it will be used to validate the technical concepts: anti-torque function and yaw controls, optimization of controlled thrust via the propellers or a slight rotor inclination, and rotor and propeller controls (power management system). Second, the X3 will make it possible to evaluate performance, flight quality, stress, and vibration levels in an expanded flight envelope. Third, different aircraft configurations will be studied and adjustments made to determine optimal settings. For example, in hover flight there are numerous ways to neutralize torque by adjusting the pitch settings on the two propellers. To reduce the demonstrator's development costs and cycles to a minimum, sub-assemblies from other helicopters in the Eurocopter range were used whenever possible. The structure is based mainly on the Dauphin, the five-blade rotor and the automatic pilot were

American advances

In October 2010 Sikorsky Aircraft announced that it will design, build, and fly two prototype light tactical helicopters as the follow-on advance to the X2 Technology demonstrator aircraft that unofficially shattered the helicopter world speed record in September 2010 with a flight speed of 250kts. The decision to continue development of the next-generation rotary wing technology will enable Sikorsky and selected suppliers to offer the high-speed X2 prototype vehicles for flight test and evaluation by US armed forces.

"Having proved the X2 Technology design to ourselves, we have full confidence we can now mature the technology for the US Army's light armed reconnaissance helicopter size," says Sikorsky president Jeffrey Pino. "Self-funding the design of a brand new light tactical helicopter – the Sikorsky S-97 – and manufacturing two prototypes we have designated as the Raider X2 helicopter will help military aviation evaluate the viability of a fast and maneuverable next-generation rotorcraft for a variety of combat missions."

In March 2010, Sikorsky submitted an X2 aircraft design to the US Army's Armed Aerial Scout (AAS) program in response to a request for information. The AAS program is currently conducting an analysis of alternatives for the Army's next armed reconnaissance helicopter. Like the X2 Technology demonstrator that broke the helicopter speed record, the X2 Raider prototypes will feature twin coaxial counter-rotating main rotors (in place of one main rotor and a tail rotor) and a pusher propeller.

The test teams during preparation for the first flight

All in the design

The program was officially launched on January 25, 2008. In parallel, flight simulations began with the SPHERE simulator and were continued into 2010. This enabled the piloting concept to be validated well before the test flight campaign. The definition was already frozen by May 2010 (preliminary design review), and when the critical design review was established in August, the production documents could then be drawn up. Between June and August, the initial designs were also sketched out for the propeller gearboxes, and wind tunnel testing was conducted.

Testing of the dynamic assemblies on a multipurpose rotor bench was completed in November.

taken from the EC155, the central module for the gearbox comes from the EC175, the engines from the NH90, and the servocontrols and trim actuators from the EC145.

Development work was necessary only for components required specifically for the X3 or for those adapted from existing components, such as the MGB/propeller coupling shaft.

2011: a decisive year

Following the first flight on September 6, 2010 in Istres, the test phase is going to be conducted in two steps. The Step 1 speed objective was attained ahead of schedule in November 2010. The speed objective was to attain a true airspeed of 180kts (333km/h) in level flight at a reduced level of engine power.

In the flight testing performed so far, the flight envelope has been opened with and without autopilot to validate the basic hybrid demonstrator aircraft's stability and handling characteristics. The X3 has reached an altitude of 12,500ft (3,810m) and performed maneuvers with left and right turns at bank angles of up to 60°.

In Step 2, the aircraft is undergoing a three-month phase of work, with a view to beginning flying again in March 2011 in the Step 2 configuration to reach a speed of 220kts. "The X3 benefits from the lessons we've learned after more than 20 years' research in areas such as tilt-rotor technology, which we studied as part of the Eurofar project," says Jean-Michel Billig, executive vice president of research and development at Eurocopter. "Tilt-rotors switch from a vertical position during hover flight to a horizontal position for forward flight. The problem with this technology is the extreme technical complexity, not to mention major concerns about its cost-effectiveness.

"It can perform hover flight, autorotation, and a wide range of missions," continues Billig. "We also examined other concepts for the aircraft's architecture but finally abandoned them as they proved to be too complex as well. The key thing we focused on when designing the X3 was maintaining the multifunction capabilities of the aircraft.

"The X3 is no more difficult to pilot than a traditional helicopter," reports test pilot Hervé Jammayrac. "It was very smooth and stable during acceleration and deceleration. We also noted that it accelerates very quickly. The demonstrator showed good behavior during the forward flight at only 30kts." ▮

Christian da Silva is a member of the editorial team of Rotor Journal, for Eurocopter

Hervé Jammayrac, test pilot and Daniel Semioli, flight engineer

Craft production

The pace of work began to pick up in January 2009. After the structure was assembled, the fixed wings were built and the hydraulic distributors for the propellers underwent qualification. Between September and November, the teams at Eurocopter assembled the aircraft: tailfin, tail boom, cowlings, instrument panels, etc. Everything was then ready for the test phase to begin in 2010.

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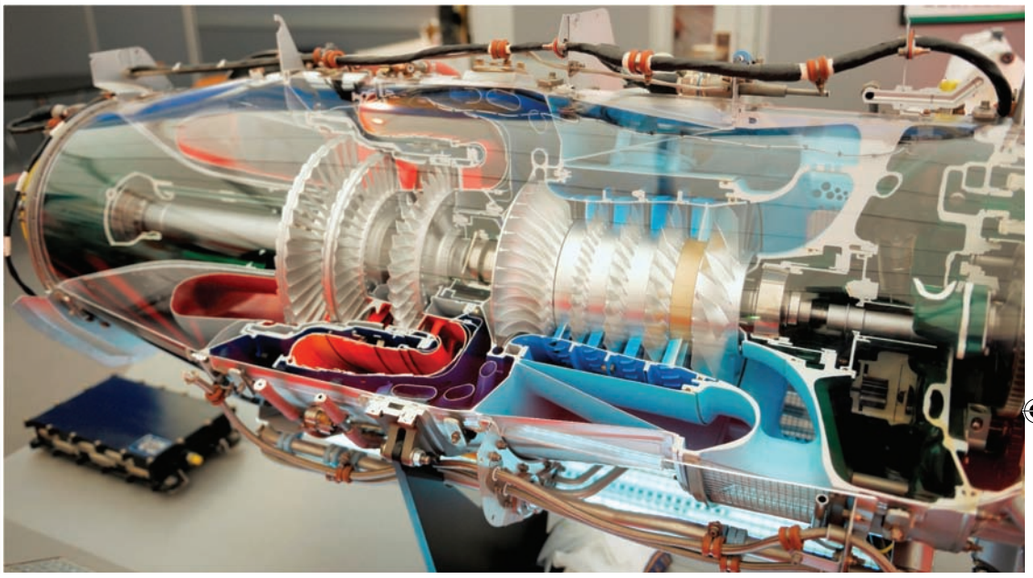

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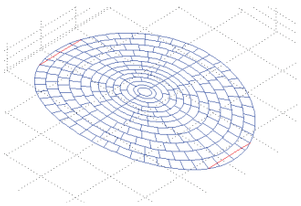

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Gorgon Stare blinded?

A prestige Pentagon project that has cost more than US$500 million to date to increase the capability of the General Atomics MQ-9 Reaper unmanned aerial vehicle to simultaneously monitor multiple targets during a single missions has gotten a big thumbs down during operational test and evaluation by the USAF's 53rd Wing at its Eglin Air Force Base test center in Florida.

Its report on the Gorgon Stare system leaked to the media and its conclusions made unpleasant reading for the system's USAF sponsor, the 645th Aeronautical Systems Group, also known as 'Big Safari' office, and its developer Sierra Nevada Corporation.

Gorgon Stare consists of two pods containing five electro-optical (EO) cameras and four infrared (IR) cameras in one pod and a processor pod that are fitted to a standard Reaper. The imagery is down-linked to a ground station that allows analysis to create mosaics of video imagery covering a wide area, such as a village or town under surveillance and then 'stream' it to multiple users to monitor it in real-time.

> **"The 53rd Wing found 13 'Category 1' or serious deficiencies and recommended that Gorgon Stare not be 'fielded' to Afghanistan"**

The project was launched with the aim of giving the Reaper the ability to offer up to 50 video feeds. This was seen as way of helping to meet the high demand for UAV imagery from frontline commanders in Afghanistan.

After conducting seven initial sorties, totaling 64 flight hours, the test team called the system deficient and its imagery unusable, and a pause in testing was ordered on November 11, 2010 to enable software modifications and changes to the pod. The testing resumed and after a total of 20 sorties, up to 234 hours of test flights, the overall assessment was that Gorgon Stare suffered from deficient infrared performance, 'numerous' interoperability problems, a lack of stability and reliability problems.

The reports conclusion was that Gorgon Stare was 'not operationally effective' and 'not operationally suitable' due to unreliability. It apparently cannot readily find and identify targets, especially human targets, a major problem for a system intended to help Reapers find individual Taliban fighters in Afghanistan or Al Qaeda chiefs in Pakistan.

The 53rd Wing found 13 'Category 1' or serious deficiencies and recommended that Gorgon Stare not be 'fielded' to Afghanistan. The multicamera aspect of the design seems to have created problems, with some of the imagery "subject to gaps between stitching areas (where the camera images meet), which manifests itself as a large black triangle moving throughout the image."

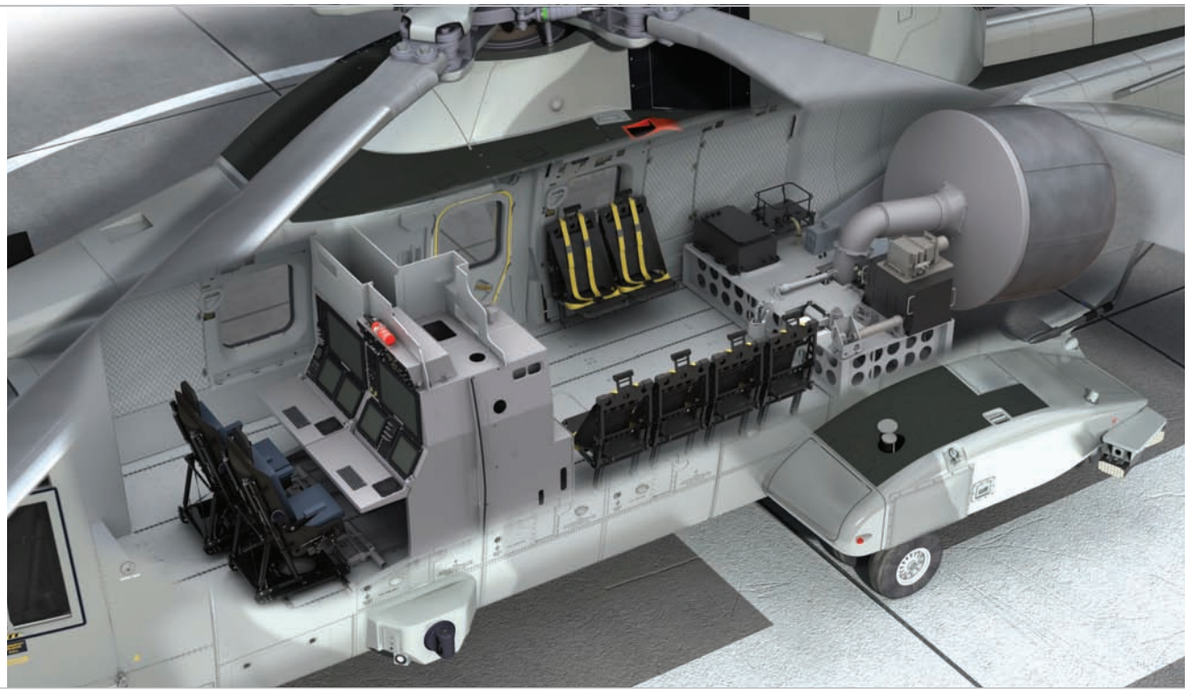
The Big Safari responded by claiming that the tests were unfair as they probed performance areas that were beyond the specifications for the system. Retired Lieutenant General David Deptula, who was the USAF's deputy chief of staff for intelligence, surveillance and reconnaissance until last year, said the problems listed in the leaked report were caused by the testing process and human errors, and not by the system itself. "The test program was not sufficiently constructed to objectively evaluate the capabilities of the system," he said.

UK technology Green Paper

In December 2010, the UK government launched a Green Paper to start the formal start of consultation on defense and security equipment, support, and technology.

The consultation, led by the Ministry of Defence and the Home Office, will cover a range of issues including national security, working with other countries, exports, small and medium-sized enterprises, and cyber security. This is the first time these issues have been considered together from both defense and security perspectives.

The Green Paper, officially titled, 'Equipment, Support, and Technology for UK Defence and Security: A Consultation Paper' provides details of the exercise that will run until the end of March 2011. The Green Paper will lead to a White Paper setting out the government's approach to industry and technology policy in the defense and security domains



RAF Tristar woes

The grounding of the RAF Lockheed Tristar fleet for safety checks on December 17th last year was a reminder of the challenge in keeping so-called 'legacy' or 'aging' aircraft operating at a high tempo toward the end of their service life.

Apparently, the checks were ordered after concerns emerged that sudden cold weather might have damaged the aircraft but the impact on the UK's strategic airbridge to Afghanistan was dramatic. Hundreds of troops were left waiting in Afghanistan for flights home for the Christmas holidays and the RAF had to divert its Vickers VC-10 aircraft to clear the backlog until checks on the Tristars were complete and they were cleared to fly again.

This might be a taster of things to come because plans to upgrade the cockpits of the Tristar's have stalled due to the annual review of spending on procurement programs by the UK's Ministry of Defence. It had been intended to have the upgrade to all of the RAF's nine aircraft under contract last year but technical delays, and now the 2011 spending/planning review (PR11), is forcing another review of the project. A decision is now not expected until the end of March at the earliest.

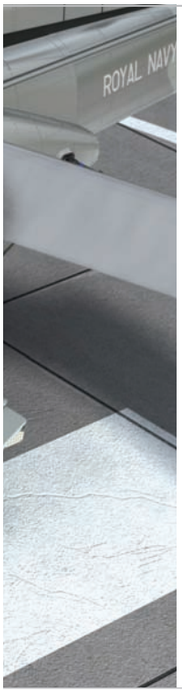
Last October's UK Defence and Security Review (SDSR) decision to bring forward the retirement of the all RAF's Tristars from 2016 to the end of 2013 has led to a re-examination of the business case for the £20 million project, according to RAF officers knowledgeable about the work.

"With less than three years left in service we are getting a lot of pressure from the Ministry of Defence financial people and the Treasury (UK finance ministry) saying its not worth spending this money," said a RAF officer.

The installation of flat screen displays, air traffic management systems and a new engine power limiting system was launched because many of the components in the 1960s vintage aircraft are no longer manufactured and are increasingly unavailable on the second-hand market.

Only 15 Tristars are now flying globally and RAF officers say spares availability is a major issue for the service's fleet of the aircraft. They fear that unless the cockpit upgrade goes ahead it may result in them cannibalizing aircraft for spares, which could seriously impact on the ability of the RAF's 216 Squadron to sustain the UK's strategic airbridge to Afghanistan or reinforce the Falkland Islands in an emergency.

Marshall Aerospace completed the first trial cockpit installation in a RAF Tristar last December after a delay for several months due to technical problems at its



over the next five years, which will be published later in 2011.

Launching the document, the Minister for Defence, Equipment, Support and Technology, Peter Luff, said, "To ensure our armed forces have the equipment and support they need, industry requires as much clarity as possible to plan its investment in research and production."

Ian Godden, Chairman of AIDIS aerospace, defense and security industry lobby organization, said the consultation paper went 'a step further' than last October's Strategic Defence and Security Review and this will help industry – from large multinationals to small and medium sized businesses – engage fully with the Ministry of Defence, the Home Office and government more widely in order to identify what the government requires of industry to support our armed forces and as a major contributor to wealth creation in this country. "We also welcome that the consultation addresses both defense and security" said Godden. "There are clear benefits in considering defense and security together, particularly where sustained research and technology investment could support both sectors. But we should not underestimate the major differences between the two markets, in both customers and suppliers. Security will need increasing coordination between the many departments, agencies, and the private sector owner-operators of key infrastructure. In such a diverse market, characterized by public and private purchases, issues such as standards and regulation will be of key importance.

The launching of the Green Paper comes three months after the UK government canceled several major defense procurement projects and scaled back others. This process included the abrupt termination of a number of contracts with industry without significant consultation, making many industry executives suggest that the government needed to make efforts to rebuild confidence with the defense industry.

"It remains to be seen if the government will treat this exercise as true consultation and take on board the views of industry in a meaningful manner" said a senior executive. "The coalition track record has not been good on this to date."

Cambridge facility and the single aircraft is expected to enter frontline service during the first half of this year.

A Ministry of Defence spokesperson said that "it was currently in discussions with Marshall Aerospace following expiry of the Minimum Military Requirement upgrade contract. Due to commercial sensitivities, it would be inappropriate to comment further."

RAF officers say this issue has become more critical because the SDSR reduced the overlap period between the introduction of the service's Airbus A330 multirole tanker transports (MRTTs) and the retirement of the Tristars from four years to only two years. This halves the time required to mature the capability of the new aircraft or cope with any unforeseen delay in the deliveries of the replacement Airbus A330 aircraft that might require an extension of service of the Tristars.

X3 hybrid steps on up

Eurocopter's X3 high-speed hybrid helicopter demonstrator reached its Step One speed objective on November 29, last year, attaining a true airspeed of 180kts (333km/h) in level flight at a reduced level of engine power.

The flight testing, at the French Ministry of Defence's Flight Test center at Istres, opened the hybrid helicopters flight envelope – with and without autopilot – to validate the demonstrator aircraft's stability and handling characteristics. During the tests, the aircraft reached an altitude of 12,500ft (3,810m) and performed maneuvers with left and right turns at bank angles of up to 60°.

The X3 flights, which began in September 2010, were performed by Eurocopter test pilot Hervé Jammayrac and flight test engineer Daniel Semioli. "The X3 has performed extremely well, demonstrating handling and flight qualities that are exactly in line with our ground-based simulator evaluations," Jammayrac said. "This helicopter is really built for speed, and our test team looks forward to taking the X3 to the next step of its flight regime."

> **"The X3 will enter a second set of flight tests during which it is expected to reach sustained cruise speeds in excess of 220kts"**

Having already surpassed the speed of a traditional helicopter, the next milestone for the demonstrator is the Step Two phase at Eurocopter's headquarters in Marignane, France, where the X3 will enter a second set of flight tests during which it is expected to reach sustained cruise speeds in excess of 220kts.

The X3 utilizes a Eurocopter Dauphin helicopter airframe. It is equipped with two turboshaft engines that power a five-blade main rotor system, along with two propellers installed on short-span fixed wings. This hybrid configuration creates an advanced transportation system that offers the speed of a turboprop-powered aircraft and the full hover flight capabilities of a helicopter. It is tailored to applications where operational costs, flight duration and mission success depend directly on the maximum cruising speed.

As Eurocopter moves ahead with development of its X3 technology demonstrator with a view to introducing the radical high-speed technology commercially in six years, the key challenge is not technical development, but finding an agency to certificate the machine.

Eurocopter chief executive Lutz Bertling, speaking at his annual state-of-company briefing in Paris in January 2011, said dealings with the Federal Aviation Administration or European Aviation Safety Agency will 'take time', because the X3, with its main helicopter-style lifting rotor and side-mounted forward-drive propellers, may be seen as something in-between a traditional helicopter and a fixed-wing aircraft.

Bertling says the X3 may not be the fastest helicopter on the market – Sikorsky's X2, with contra-rotating main rotors and a pusher prop, may be quicker – but he is confident it will win a 'race for productivity' by offering 'cost-effective speed'.

For a full report on the X3 from Eurocopter see the 'Lead' article.

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Sikorsky Innovations and the US Army Aeroflightdynamics Directorate demonstrated autonomous formation flying on a fly-by-wire helicopter last year. Frank Colucci looks at the hands-off formation technology tested on RASCAL, the airborne laboratory

Follow that helicopter

Optionally piloted flight is one of the technology pillars of Sikorsky Innovations, the advanced projects group within Sikorsky Aircraft. Autonomous flight following (AFF) demonstrated last June (2010) is itself one step toward the company's vision of a helicopter with two, one, or no pilots flying alone or in formation with other aircraft.

"We look at our products and services and think about how aircraft remain relevant to the warfight," explains advanced projects manager, Jim Kagdis.

A Sikorsky Black Hawk with a crew of two in the cockpit typically flies only four hours a day, notes Kagdis, and an optionally piloted aircraft could maximize productivity.

"If every day you have to resupply a firebase and get vehicles off the road, perhaps the optionally piloted aircraft offers a way to do that."

About seven formation flight hours have been logged so far on the JUH-60A Black Hawk of the US Army Aeroflightdynamics Directorate (AFDD). This provided data on the passive video capture and flight following algorithms key to AFF. Follow-on tests this year will add an active sensor to hold consistent formation distances.

The AFF evaluation pilot flew the test helicopter manually behind an unmodified EH-60L Black Hawk, acquired the leader on a rudimentary cockpit display, and turned the AFF system on for coupled formation flight.

"Once he engages it, that's pretty much it," says Innovations autonomy lead, Jesse Lesperance. "It's very much like a flight director mode."

Hands-off formation flights back and forth in the airspace between Moffett Field, California and San Francisco International airport to the north included straight runs at 70kts and gentle turns. Following distances approximated manual formation flying.

"One of the biggest work-intensive operations that a pilot does today is doing a formation flight," observes Lesperance, explaining that AFF is meant initially to reduce pilot workload in manned aircraft.

"It's a very, very high workload flying at low altitude in close formation with changing flight paths. Our objective was to demonstrate the capability to reduce workload and then apply that to our products."

The Sikorsky UH-60M Upgrade with production fly-by-wire (FBW) flight controls remains in development for the US Army. However, the JUH-60A RASCAL (Rotorcraft Aircrew Systems Concepts Airborne Laboratory) used to develop control algorithms for the Upgrade offered a flexible research flight control system (RFCS) for AFF testing.

Experimental flight control laws are routinely integrated into the RFCS using advanced pictures-to-code tools. Test avionics are integrated into the helicopter through a MIL-STD-1553 databus.

"These features make RASCAL an ideal platform for rapid prototype development of advanced flight control, avionics, and human-systems integration technologies for rotorcraft," says Army RASCAL program manager, Jay Fletcher.

The JUH-60A RASCAL has a full-authority fly-by-wire research flight control system, and hydromechanical safety controls

Sikorsky supplied the formation flying computer and algorithms tested on the RASCAL. Most of the video processing hardware and software came from AFF partners Georgia Tech and the United Technologies Research Center.

"We modified the flight control system algorithms and software around the existing software," says Lesperance.

Introducing innovations

Sikorsky Innovations now focuses its small, agile engineering teams mostly on helicopter speed, autonomous flight, and adaptive/aware technologies for future aircraft. The X2 high-speed technologies testbed exceeded 250kts last September and launched development of the S-97 Raider armed reconnaissance helicopter.

The Sandblaster anti-brownout system flew on the RASCAL testbed in January 2009 and mixed see-through radar with synthetic vision to sustain situational awareness in 'degraded visual environments'.

The AFF initiative self-funded by Sikorsky and its partners sought passive sensing technology to track distance, speed, altitude, direction, and offset angle of a lead aircraft.

"Our intention is we don't want any active, direct communication between the two vehicles," says Jesse Lesperance.

“Human pilots also typically fly offset rather than in direct trail”

Innovations engineers considered following sensors in near-infrared and visual bands: "We weighed both and chose visual." The AFF demonstration sensor was a commercial-off–the-shelf Sony video camera located in the modified Sandblaster nose mount: "The biggest focus was to develop the sensor processing algorithms and flight following algorithms."

Weight concerns limited AFF plans to a single, fixed sensor. However, most machine vision systems use multiple cameras to calculate range to an object. "People typically use both eyes to determine how far away the object is," explains Lesperance. "With a single camera, it's like having one eye, which makes telling range very, very difficult."

United Technologies Research Center, part of Sikorsky parent corporation UTC, has long worked on 'one-eyed' machine vision solutions. One previous approach drove the trailing vehicle in a sinusoidal path to determine following distance with less processing. Another used a more direct course but required more intensive processing to calculate distance. Innovations engineers chose algorithms best tailored to helicopter formation flight.

"Once the pilot feels comfortable where he is, where he engages formation following, the aircraft tries to stay in that position given a band plus-or-minus to the aircraft in front of him," says Lesperance, adding that human pilots also typically fly offset, rather than in direct trail. "If something happens to the aircraft in front of them, they don't want to be directly behind it."

RASCAL research

The Army Aeroflightdynamics Directorate (AFDD) at NASA Ames Research Center in California reports to the Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC) at Redstone Arsenal, Alabama. AFDD performs basic and applied research, and some technology development, for paying government and industry customers. For the AFF demonstration, Sikorsky signed a testing agreement with AMRDEC and was responsible for system engineering. AFDD integrated the flight following system into the RASCAL and made sure it fulfilled flight safety requirements.

Sikorsky Aircraft tested a visual camera system that enabled a helicopter to autonomously follow a lead aircraft in formation flight. The photo shows two off-the-shelf visual cameras mounted to the nose of the US Army's RASCAL (Rotorcraft Aircrew Systems Concepts Airborne Laboratory) with fly-by-wire flight control system

The RASCAL cockpit has an evaluation crewstation with FBW sidesticks on the right side and a safety pilot position with back-driven hydromechanical controls on the left. Either pilot can manually disengage the RFCS at any time, and a flight test engineer's station in the cabin oversees and records the experiment.

AFDD gave Sikorsky engineers an interface control document for the RASCAL databus to link the AFF vision sensor to the RASCAL flight control computer. The combination was tested in the RASCAL development facility at NASA Ames before flight. AFDD technicians also integrated the AFF control module with the RASCAL flight control computer and the UH-60M upgrade control laws. AFDD also provided engineering support for AFF system integration, ground testing and flight work.

A 19in electronics rack in the helicopter cabin held the digital video amplifiers, multiplexers, and a digital video recorder. AFDD has its own independent airworthiness office to approve aircraft modifications related to flight control.

Sikorsky evaluation pilots Russ Stiles and Glenn Knaust flew the AFF trials through the Research Flight Control System. Army Lt Col Steven Braddom, chief of the AFDD Flight Projects Office, was the RASCAL safety pilot. About 12 hours have been logged so far, including data collection time in preparation for formation flying.

Sikorsky and AFDD developed the AFF test plan jointly. Sikorsky defined AFF performance requirements and suggested test maneuvers. AFDD refined the plan based on past experience and

safety-of-flight requirements, and provided guidance on how many maneuvers could be accomplished per paid flight hour.

RASCAL rules say the RFCS cannot be engaged below 25ft altitude, and autonomous formation flying got no lower than 50ft. Army testers also imposed a conservative minimum distance of 200ft between the leader (craft) and follower to give the safety pilot time to disengage the RFCS technology and recover the RASCAL in case of an AFF system failure.

Formation following distance for the tests was set from 300-400ft and monitored using differential GPS (DGPS), cheaper and more accurate than ground radar or laser trackers. Each helicopter had a rover GPS navigator, and an AFDD telemetry station provided the DGPS correction signal. DGPS fixes from each aircraft were monitored in the ground station, and engineers watched relative positions in real time.

"One of our principal concerns was what kind of angle of bank could the

> **"We have to improve our range capability and the human factors interface"**

The JUH-60A Rotorcraft Aircrew Systems Concepts Airborne Laboratory has a full-authority fly-by-wire research flight control system, and hydromechanical safety controls

Autonomous formation flying tests at Moffett Field, California saw the JUH-60A RASCAL helicopter follow an unmodified EH-60L without pilot intervention. Straight-line formation flying was maintained at speeds up to 70kts, and mild turns were followed

system operate in and stay within the field of view of the camera," says Lesperance. "We found pilots typically don't do very intensive maneuvers in formation flying."

The AFF system itself incorporated safety settings that limited command rates and range, elevation, and azimuth errors. The system would disengage automatically if the lead helicopter left the sensor field of view, and it enabled the evaluation pilot to take manual control instantly by moving his cyclic out of a detent position.

The RASCAL cockpit has 12in horizontal and vertical situation display screens used to show the evaluation pilot AFF imagery and data.

"It was not a fully integrated system like you'd' expect in a production system," acknowledges Lesperance. "We have to improve our range capability and the human factors interface."

The nose mount carried a second camera for additional data collection and following distances and video imagery were recorded aboard the test aircraft for post-flight analysis.

"Having a fused or hybrid sensor going forward will be a valuable capability in making a production system"

The test helicopter held stable autonomous formation flight in straight and level conditions with an acceptable ride quality.

The tendency of the RASCAL Black Hawk to accelerate and decelerate incorrectly when flying formation, However, showed visual tracking alone could not provide consistent, accurate range information for the flight control computer in background clutter. Sikorsky plans to test a hybrid visual/radar sensor on the RASCAL in the first half of 2011.

"Visual was very good for helping us determine elevation, azimuth, and altitude changes," says Lesperance. "But it's not very good at range. That active sensor is required. Having a fused or hybrid sensor going forward will be a valuable capability in making a production system.

"We're looking at a couple of sensors that are already out there today," Lesperance adds, "Usually, the longer the distance, the higher power you need, and the more weight it's going to cost you."

Separate from the autonomous formation flight work on the JUH-60A, Sikorsky also plans a manned/unmanned resupply aerial lifter (Mural) demonstration this year with a fly-by-wire UH-60M. ▮

What goes up, must come down

THE FIRST X-37B OPERATIONAL TEST VEHICLE LANDED SUCCESSFULLY FROM ORBIT IN DECEMBER 2010, AND THE SECOND CRAFT HAS JUST BEEN SUCCESSFULLY LAUNCHED. IT IS THE VERY LATEST IN REUSABLE SPACE TECHNOLOGY, BUT UNTIL NOW THE USAF HAS BEEN SOMEWHAT RELUCTANT TO DISCUSS IT

BY CHRISTOPHER HOUNSFIELD

The X-37B is one of the world's newest and most advanced re-entry spacecraft. Designed to operate in low-Earth orbit, the unmanned vehicle is the first since the Space Shuttle with the ability to return experiments to Earth for further inspection and analysis.

The USAF has announced its plans to launch the second test flight for the X-37B space plane on March 4, 2010. The second craft, known as Orbital Test Vehicle-2 (OTV-2), is planned to remain in orbit for more than 270 days, collecting test data similar to that from the first flight last year and expanding the flight envelope. The test team will also be paying particular attention to the performance of the electromechanical and autonomous landing algorithms, the service says. There will also be fewer cross-range and wind restrictions for the second flight.

The first orbital flight of the first X-37B, named USA-212, was launched on an Atlas V rocket at Cape Canaveral Air Force Station, Florida on April 22, 2010. The spacecraft was placed into low-Earth orbit for testing.

The US Air Force announced on November 30, 2010 that the X-37 would return for a landing during the early December timeframe. As scheduled, the X-37B de-orbited, re-entered Earth's atmosphere, and successfully landed at Vandenberg AFB on December 3, 2010, although it did sustain a tire blowout causing minor damage to its underside.

The X-37B, with its possibility to stay in orbit for 270 days, could give the Air Force an ability it lacks: sending a satellite into orbit for months, seeing how it operates and returning it to Earth for more thorough analysis. However, the details of the mission and its future, experiments placed on board the spacecraft, and the program's budget remain highly classified as the Air Force is reluctant to divulge any information.

Speaking exclusively to *Aerospace Testing International*, a program official 'spokesman' who did not wish to be identified did go into some detail.

"Since the successful landing of OTV-1 on December 3, 2010, the team has been busy getting ready for the second test flight. This included a quick-look assessment of the re-entry and landing performance of OTV-1, shipping OTV-2 to the launch base, and integrating OTV-2 to the Atlas V," he says.

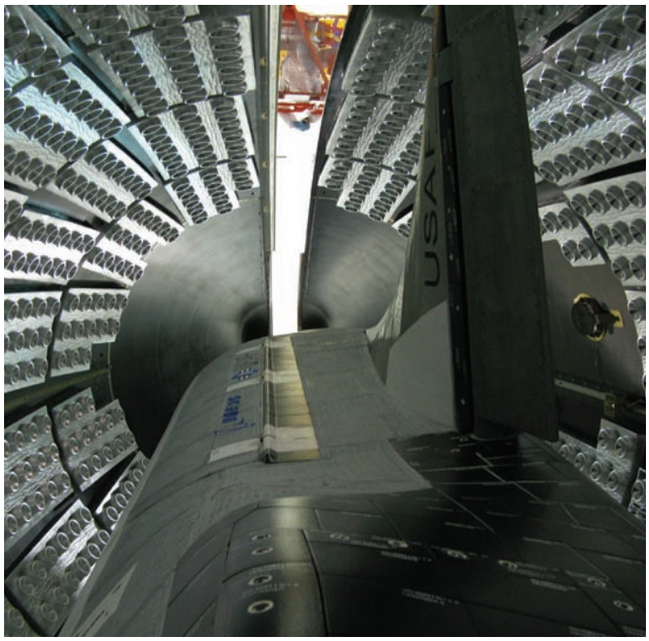
"The OTV program is a test program examining the affordability and reusability of space vehicles. The primary objectives of the program are twofold. Firstly, to demonstrate reusable technologies for America's future in space and operating experiments, which can then be returned to and examined on Earth; secondly, to develop the concepts of operations required to affordably operate reusable spacecraft."

Data from OTV-1s performance has now been reviewed by the Air Force Rapid Capabilities Office and its prime contractor, Boeing. We have brought in experts from both NASA and the Air Force Research Lab.

"We're pleased with what we've seen so far," says the spokesperson. "Technology assessments are ongoing in areas including re-entry guidance, navigation, and control, thermal protection systems, and flight actuation systems. Assessments will continue during the refurbishment of OTV-1, which will demonstrate the reusability of the X-37B."

Space debris

There was one anomaly on landing. The left tire blew during roll-out. But it did prove that the vehicle had appropriate



The Boeing X-37B Orbital Test Vehicle is encapsulated within the Atlas V at Astrotech in Titusville, Florida, on February 8, 2011

Look back

The Air Force Rapid Capabilities Office is leading the Department of Defense's Orbital Test Vehicle initiative, by direction of the Under Secretary of Defense for Acquisition, Technology and Logistics and the Secretary of the Air Force. The Air Force OTV effort uses extensive contractor and government investments in the X-37 program by the Air Force, NASA, and DARPA to continue full-scale development and on-orbit testing of a long-duration, reusable space vehicle.

NASA's original X-37 program began in 1999 and ran until September 2004 when NASA transferred the program to DARPA. NASA envisioned building two vehicles: an approach and landing test vehicle (ALTV) and an orbital vehicle. The ALTV validated flight dynamics and extended the flight envelope beyond the low-speed/low-altitude tests conducted by NASA from 1998 until 2001 on the X-40A, a subscale version of the X-37 developed by Air Force Research Labs. DARPA completed the ALTV portion of the X-37 program in September 2006 by successfully executing a series of captive carry and free flight tests. NASA's X-37 orbital vehicle was never built, but its design was the starting point for the Air Force's X-37B Orbital Test Vehicle program.

capability to maintain the vehicle authority on roll-out and landing. The tires are about the size of a dinner plate and held at a pressure of 300psi. So far, it is believed that it hit something on the runway.

At the same time it was also noticed on the vehicle's return there were several areas of damage to the tiles and vehicle due to space debris. This is currently being evaluated by the USAF.

"Review of the OTV-1 re-entry and landing date and exterior inspection revealed no significant changes were required for OTV-2, but the Air Force continues its detailed inspection analysis as part of the refurbishment of OTV-1," explains the spokesman.

"It is inconclusive whether on-orbit damage was caused by 'orbital debris' or micro-meteoroids, but minor thermal protection tile repair will be required. The burst tire on roll-out was traced back to a minor imperfection in the runway and accounted for in OTV-2 by both runway modifications and a 15% decrease in the main landing gear tire pressures to accommodate these types of minor runway imperfections."

> **"This doesn't replace the other capabilities, the TacSats, the space test program and so forth – it gives us another dimension"**

Technical Readiness Levels

The question remains though; why does the Air Force need this capability and huge investment? What can the X-37B do that small TacSats cannot?

"This doesn't replace the other capabilities, the TacSats, the space test program and so forth – it gives us another dimension," says the deputy under secretary for the USAF space program, Richard McKinney.

"The ability to reuse technologies and the ability to operate experiments in space and return them to earth for examination is a capability that's been severely limited in the past for us. And we certainly have not had any long duration-type ability to return experiments to earth.

"Now we can test those capabilities well in advance of putting them in operation. So rather than having it go up for the first time and do an operational mission, we could actually test those capabilities.

"We have something in the test community called technical readiness levels (TRLs)," says McKinney. "One of the TRLs that we have basically says, 'Has it operated in the environment in which it's going to do its mission?' We really couldn't do that because we

The second X-37B Orbital Test Vehicle, built for the US Air Force, is shown during encapsulation within the United Launch Alliance Atlas V 5m fairing

The latest in space

The X-37B Orbital Test Vehicle is the newest and most advanced re-entry spacecraft. Based on NASA's X-37 design, the unmanned OTV is designed for vertical launch to low-Earth orbit altitudes where it can perform long-duration space technology experimentation and testing. Upon command from the ground, the OTV autonomously re-enters the atmosphere, descends, and lands horizontally on a runway. The X-37B is the first vehicle since NASA's Shuttle Orbiter with the ability to return experiments to Earth for further inspection and analysis.

Technologies to be tested include advanced guidance, navigation and control, thermal protection systems, avionics, high-temperature structures and seals, conformal reusable insulation, and lightweight electromechanical flight systems. In addition, the X-37B OTV will demonstrate autonomous orbital flight, re-entry, and landing.

Unlike the Shuttle, the X-37B deploys solar array to generate power to be able to stay in space long term.

can't test a satellite on the ground, as if it's going to operate in space.

"Now we're going to be able to do some of those TRLs that require the space-based type technologies in space, return it to earth, take a look at it and see what the potential impacts were of that duration on space. So that's what this potentially could bring us."

OTV-2

The second vehicle, is a Boeing-constructed 8.8m-long and 4.2m-wide, unmanned, reusable spacecraft. Air Force technicians launched the second X-37B on March 5, officials said. The intention is to validate the earlier program successfully demonstrated by the first flight, and expand the operational envelope. It has also been announced that the protection tiles have been improved from the Shuttle's to withstand heavier atmospheric conditions.

The spokesman says, "OTV-2 will build on the success of our first flight. This second mission will validate and replicate initial testing and fine-tune the technical parameters of the vehicle tests. In addition to the modifications made to the main landing gear tires, we have made additional changes to the test plan based on lessons learned from the first flight. For example, based on the demonstrated ability of the electromechanical flight control and autonomous algorithms in OTV-1, the OTV-2

OTV-2 EA Transport by STS Discovery

landing placards will be opened up to enable greater landing opportunities during high winds or orbital cross range. Also, the on-orbit duration for the X-37B is 270 days.

"We look forward to testing enhancements to the landing profile," said Lt Col. Troy Giese, X-37B program manager for the Air Force Rapid Capabilities Office.

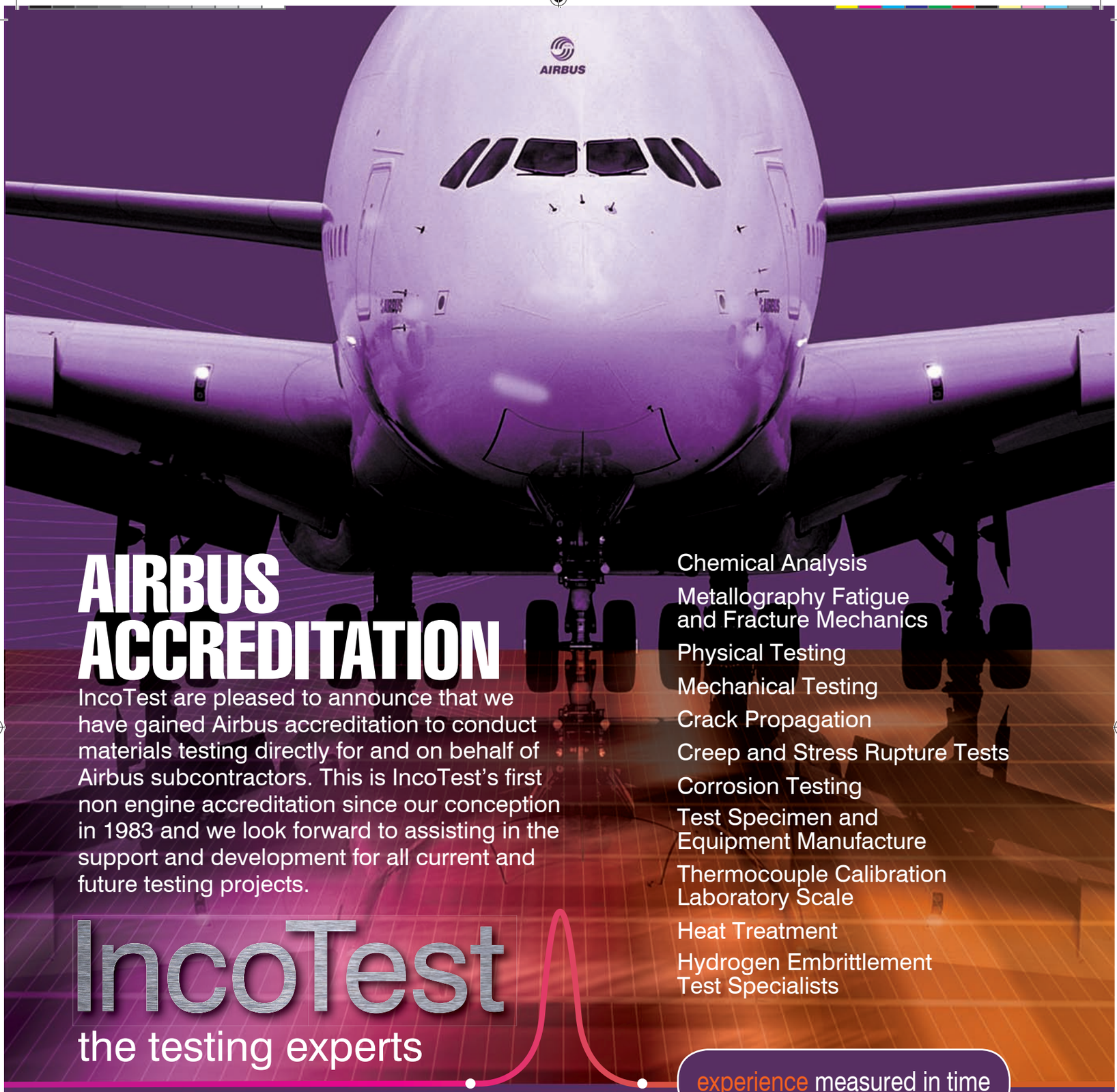
"OTV-1 was brought back earlier than this to accommodate an accelerated launch of OTV-2," the spokesman continues, "but the performance data suggests that the vehicle could have gone beyond the 270-day window. Subsequently, we may extend the flight duration of this mission to test the outside performance capabilities of the vehicle.

"The spacecraft arrived at Cape Canaveral Air Force Station in early January 2011 and has been undergoing final functional tests prior to its integration with the Atlas V, which happened in late February 2011.

"The X-37B program has advanced the state-of-the-art thermal protection systems and tiles, thermal control, solar power systems, environmental modeling, control algorithms, and autonomous control and landing," the spokesman reveals.

The X-37B was built at several Boeing locations in southern California, including Huntington Beach, Seal Beach, and El Segundo, but it is to be operated by the USAF. How has it become so involved in the concept and deployment? The spokesman explains, "By direction of the Undersecretary of Defense for Acquisition, Technology and Logistics and the Secretary of the Air Force, the Air Force Rapid Capabilities office is leading the effort to develop and flight test the X-37B based on NASA's X-37 design that underwent a series of flight tests in 2006 by DARPA. The Air Force X-37B program addresses risk reduction, experimentation, and operational concept development for reusable space vehicle technologies in support of long-term developmental space objectives. This is an important and valuable capability for the Air Force."

There are so many questions regarding the X-37B that remain unanswered. The team confirm that there is no real plan for the future and they simply do not know where the project is going exactly. McKinney stresses, "Obviously we wouldn't be doing this if we didn't expect there to be more flights, but frankly, right now we just don't know where we're going. The X-37B remains an experimental aircraft, and it's still too early to draw too many conclusions about the program. "Test aircraft have hundreds, if not thousands of test flights," he said. "We've had one flight. We are really at the very beginning of this," he concludes. ■



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Charge of the light jet

HAVING APPROACHED THE STANDARD DESIGN OF BUSINESS JETS WITH A TOTALLY INNOVATIVE APPROACH, HONDA IS NOW JUST A SHORT STEP FROM FULL FLIGHT CERTIFICATION OF ITS ADVANCED LIGHT JET

BY STEPHEN KEENEY

It should come as no surprise that a company that incorporated a wing design into its original corporate logo would be determined to take flight. At the same time, one could be forgiven for not considering such a company to be an aerospace challenger when that company has focused its most visible efforts to become one of the world's mobility leaders on land.

That is the course Honda has taken by establishing itself as one of the world's most successful automobile companies and the world's largest manufacturer of motorcycles and internal combustion engines. Nevertheless, the company considers itself to be more than just a manufacturer of automobiles, motorcycles, and power equipment.

The company is dedicated to developing and implementing advanced technologies to enhance the quality of life in terms of general mobility and in areas far beyond. It has used its fundamental strength as an engineering-driven company to become a leader in areas as diverse as rice genome research, thin-film transistor solar cells, robotic walking assist devices, and hydrogen fuel cells. Honda's technological leadership is evident in myriad accomplishments from areas as diverse as the first EPA-certified, zero-emissions hydrogen fuel cell vehicle, and the first mass production of such vehicles on a standard assembly line, to the creation of the world's first independent bipedal human-sized robot.

The company has achieved its numerous leadership positions by focusing its efforts on harnessing the power of research and advanced technologies – all of which it develops in-house – to create products that redefine categories.

The most dynamic symbol of Honda's efforts is evidenced by its most technologically advanced product to date. Following more than 20 years of research and endeavor, the company is now expanding its commitment to further enhance and expand human mobility by taking to the third dimension – the sky – with the HondaJet advanced light jet (see *Guiding Light Jet*, September 2006 issue, *p40-44*).

Honda moved one step closer to realizing its dream of flight on December 20, 2010, with the first flight of the first FAA-conforming HondaJet. The successful 51-minute flight signaled the transition of the HondaJet program to flight test status under conforming article and marked the most significant milestone yet in the company's efforts to deliver to its customers this innovative advanced light jet in mid-2012.

Since the introduction of light business jets in the 1960s, there have been few significant advances in the fundamental design characteristics of this category of aircraft. For example, the fuselage-mounted engine configuration has not changed in over four decades, even though this layout requires sacrificing usable interior space and is not ideal in terms of high-speed drag rise characteristics. Furthermore, aluminum is still mainly used for this class of aircraft, despite the introduction of light-weight composite materials.

The advanced light jet

It is, therefore, no mere coincidence that Honda has chosen to define the HondaJet as an 'advanced light jet'. The aircraft incorporates a number of ground-breaking design applications and advanced technologies that set it well apart from other aircraft of its size in terms of

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The spirit of challenge

Honda's corporate culture is steeped in the philosophy of 'challenging spirit'. Throughout the company's history, Honda associates have been encouraged to reach beyond preconceived notions of the merely possible to realize products that move people – literally and figuratively – in ways never before imagined.

This was the environment that created the HondaJet – an aircraft of unequaled performance, efficiency, and comfort destined to be built by a company best known for some of the world's most dynamic and reliable automobiles and motorcycles. Realizing this challenge would be a great undertaking for Honda, as it would be the company's first commercial aircraft. Immediately, one very important issue was raised: how to validate the integration of the aircraft's systems in the most efficient manner possible to maintain program momentum while delivering an exceptionally reliable, high-performance aircraft.

The answer came in the form of Honda's Advanced Systems Integration Test Facility (ASITF), which was developed by Honda engineers specifically to confirm, before first flight, the integration of the HondaJet's electrical, avionics, mechanical, and flight control systems. By creating a full-scale test-bed environment that accurately replicated the onboard integration environment for critical aircraft systems, Honda has been able to precisely assess and validate the performance of many of the aircraft's primary systems before first flight.

The HondaJet ASITF incorporates a fully representative primary flight control system with a high-fidelity control-loading system, including autopilot, stall warning protection systems (SWPS) and rudder bias systems (RBS), among others. The HondaJet ASITF also features actual aircraft systems hardware and software, installed in a spatially representative manner and interconnected with actual aircraft electrical harnesses. Additional simulation capabilities have been integrated to provide real-time simulation of navigation RF data, including GPS. At the same time, the production Garmin G3000 avionics system has been employed as the ASITF pilot interface to ensure overall control compatibility.

By effectively identifying any developmental issues at the earliest possible stages of the process, Honda's ASITF system has supported an accelerated program momentum now reflected in the very positive performance of the first conforming aircraft. With the successful certification and delivery of the HondaJet to its customers, Honda will no longer be regarded simply as a mobility leader on land.

Honda's ASITF confirms before first flight the integration of the aircraft's electrical, avionics, mechanical and flight control systems, including stall warning protection systems (SWPS) and rudder bias systems (RBS)

performance, comfort, and quality. The HondaJet is the brainchild of Honda Aircraft Company's president and CEO, Michimasa Fujino, who conceived a dramatically different design for an all-new light business jet after many years of research and experimentation. His vision was solidified in 1997 when he conceptualized his new aircraft design.

"I wanted to shift the way the design of an aircraft was approached," says Fujino. "To me, there seemed to be a pervasive comfort level with traditional aerodynamic design that stifled innovative thinking. There would be no reason for me to simply design another airplane that brought no new value to customers. My goal was to approach aircraft design from a fresh perspective to achieve new benefits in efficiency and performance."

The most striking indication of the HondaJet's departure from traditional aircraft design is easily seen in its over-the-wing engine-mount (OTWEM) configuration. Through extensive wind tunnel analyses at many of the world's premiere testing facilities, including NASA's National Transonic Facility (NTF) in Virginia, Honda engineers confirmed the OTWEM configuration's reduced shockwave characteristics and, as a result, reduced high-speed drag relative to a fuselage-mounted engine design.

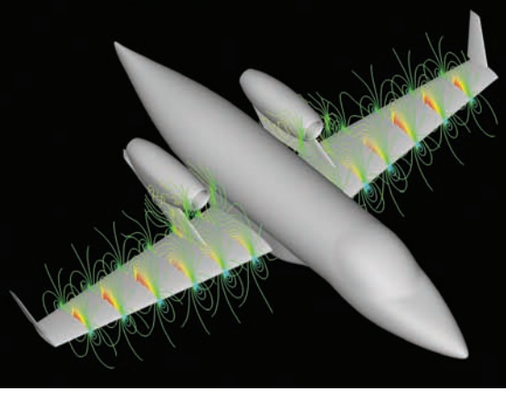
By combining the OTWEM configuration with HondaJet's proprietary Natural Laminar Flow (NLF) wing and fuselage nose designs, overall drag has been reduced, thereby increasing overall performance and fuel efficiency of the aircraft. Honda engineers estimate approximately 15-20% improved fuel efficiency for the HondaJet. The handling and performance benefits of the HondaJet's OTWEM configuration and NLF designs have been validated through extensive flight testing with the company's proof of concept (POC) HondaJet. This aircraft has accumulated over 500 flight test hours since its maiden flight in late 2003. Knowledge gained from extensive performance and data analyses of the POC HondaJet has been reflected in the company's production configuration aircraft now in certification.

Power and composites

To power the aircraft, Honda has partnered with GE to bring to market the compact and fuel-efficient production version of Honda's original HF-118 turbofan jet engine that powers the POC HondaJet. Producing 2,050 lb of thrust, the HF120 production engine achieves high performance and returns improved fuel efficiency.

Additional performance enhancement has been achieved through the application of an all-composite fuselage, resulting in a reduction in weight and an increased payload capacity. The exceptionally smooth exterior surface of the composite fuselage is further enhanced by a significant reduction in the number of necessary rivets relative to aluminum construction. As a result, both airflow characteristics and build quality are

In December 2010, the HondaJet stayed in the sky for 51 minutes, during which time the aircraft's flight characteristics and performance were analyzed and systems checks were conducted. Right: HondaJet's in-hangar mechanical and structural tests



Follow the flow

HondaJet's innovative natural-laminar flow (NLF) design not only increases aerodynamic efficiency, but also simplifies manufacturing procedures.

Developed through extensive analyses and wind tunnel testing, the NLF airfoil design helps to achieve reduced wing drag. The larger the laminar flow in the boundary layer of the wing surface, the lower the drag becomes. To achieve a large laminar flow, the HondaJet wing employs integral, machined panels that minimize the number of parts required.

improved. Increased interior space also results from the reduced frame height of the fuselage provided by composite application.

Offering a top speed of 420kts with superior fuel efficiency, the US$4.5 million HondaJet delivers to light business jet owners the performance characteristics of a much larger aircraft with the fuel efficiency benefits of much smaller VLJ-category aircraft. Interior space and cargo capacity also have been maximized as a result of the OTWEM configuration, which eliminates the need for intrusive fuselage engine-mount structures. To maximize interior efficiency, extensive human factors analyses have been conducted on all aspects of human interface within the aircraft. Information gained through POC flight test studies has resulted in an optimized flight deck design featuring a low-workload user interface and enhanced safety awareness ideally suited for a high-performance jet.

Next trial stage

As the HondaJet program enters the FAA certification flight test phase, assembly of conforming aircraft progresses rapidly. In addition to the first FAA-conforming flight test aircraft, four additional test aircraft are in production. Two aircraft will be used for structural testing, and two will be used for further flight testing.

The second completed FAA-conforming aircraft has already undergone numerous structural tests required for the start of certification flight testing, including 100% limit-load and stiffness tests, landing gear load tests, pylon stiffness tests, and fuselage pressure tests. Structural testing has been undertaken at Honda Aircraft Company's R&D facility on its world headquarters campus in Greensboro, North Carolina.

All structural tests are conducted using Honda's structural test system. The system incorporates 61 hydraulic actuators and a 2,600-channel data-acquisition system within a structural test fixture designed exclusively for HondaJet testing.

Although compact in design, HondaJet provides a large cabin with enough interior space to comfortably seat six to seven

The entire aircraft can be tested simultaneously to prove static and fatigue strength under various flight- and ground-load conditions.

Testing will continue on static test aircraft as the HondaJet program moves through the certification process. The fourth FAA-conforming aircraft will be used for fatigue testing scheduled for 2012. The third FAA-conforming aircraft, to be used for mechanical systems flight testing, is currently in the systems installation phase of completion and is scheduled to enter flight testing in spring 2011. A fifth FAA-conforming aircraft for flight testing is also in production with major assemblies scheduled to be mated soon. This aircraft will take flight later in 2011.

As the FAA certification flight test regime commences, construction of the HondaJet production facility nears completion on the company's 83-acre Greensboro campus. With completion scheduled for spring 2011, Honda will soon begin the process of moving equipment and personnel into the facility and undertaking pre-production preparations and training necessary to support HondaJet production ramp-up, beginning in 2012.

The HondaJet production facility, which spans more than 250,000ft^2 under a single roof, will incorporate all aspects of aircraft assembly, completion – including painting and interiors – and flight testing. This innovative tightly integrated approach to production provides for a highly efficient environment that will support the highest possible levels of aircraft quality.

"Through the dedication and hard work of Honda associates and the establishment of industry-leading engineering and manufacturing infrastructure, we are confident we have the resources to realize a new standard within the industry," says Fujino. ▮

Stephen Keeney is the senior manager of corporate communications at Honda Aircraft Company Inc, North Carolina

Power-up

The lightweight, fuel-efficient, low-emission GE HF120 turbofan engine provides a high thrust-to-weight ratio that enables a long range and large payload.

Its specialized fluid dynamics software optimizes airflow within the compact engine, maximizing performance. With this, the engine's simple, high-performance combustion chamber keeps emissions levels well within requirements for compact jets.

Honda has created the first ultra-compact full authority digital electronic control (FADEC) system for this class of engine.

The big freeze

THE DYNAMIC GULFSTREAM/IAI-DESIGNED G250 BUSINESS JET HAS COMPLETED THE LATEST PHASE OF ICE TRIALS. THE PROJECT'S CHIEF ENGINEER SAYS THIS TAKES IT CLOSE TO FINAL CERTIFICATION

BY CHRISTOPHER HOUNSFIELD

It was a suitably cold day near Nashville when the Gulfstream G250 flight test aircraft finally completed natural ice-test certification points in anticipation of the aircraft's certification later in 2011.

Serial Number (S/N) 2001, the first aircraft to join the flight test program back in December 2009, has now flown with simulated ice shapes applied to the non-heated areas of the aircraft, including the nose, tail, winglets, and engine pylon. These tests were used to evaluate the aircraft's handling, stability, and control characteristics in icing conditions.

S/N 2002, which joined the flight-test program in March 2010, has also now completed anti-ice system dry-air testing, clearing the way for certification flight testing into known icing conditions. The joint cooperation aircraft with Israel Aerospace Industries (IAI) aircraft has now crossed the Atlantic to the USA in search of natural icing. The anti-ice system used on the G250 is similar to Gulfstream's large cabin aircraft. Heated bleed air from the engines is routed to the leading edges to prevent ice formation.

Busy program

Gulfstream is not concentrating on the G250 alone; the company is also hitting a number of business jet milestones. The fifth and final Gulfstream G650 flight test aircraft took to the skies on January 24, 2011. All five aircraft that are part of the test campaign have now entered the program.

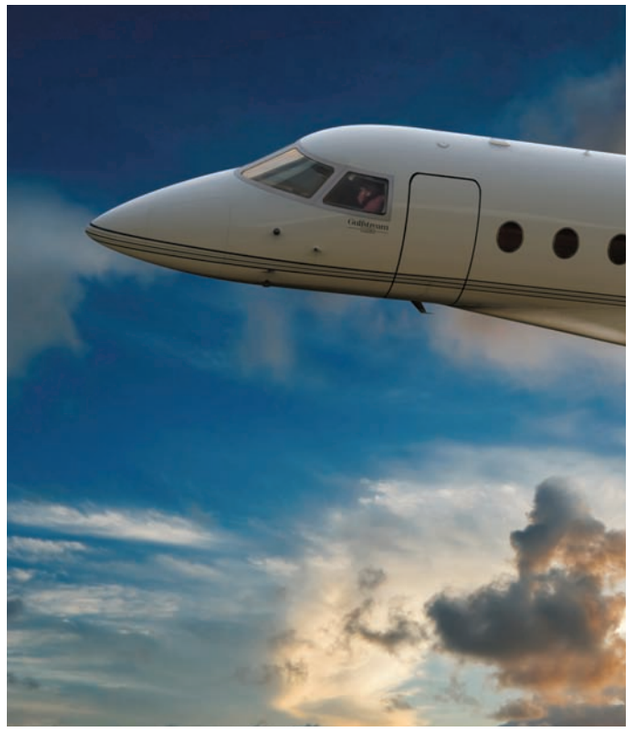
S/N 6005 launched from the Savannah/Hilton Head International Airport in Georgia with experimental test pilots Bill Dobbs and Al Moros at the controls and flight test engineers Heather Burke and Nathaniel Rutland in the cabin. The aircraft reached a maximum speed of Mach 0.94 and a top altitude of 51,000ft (15,545m).

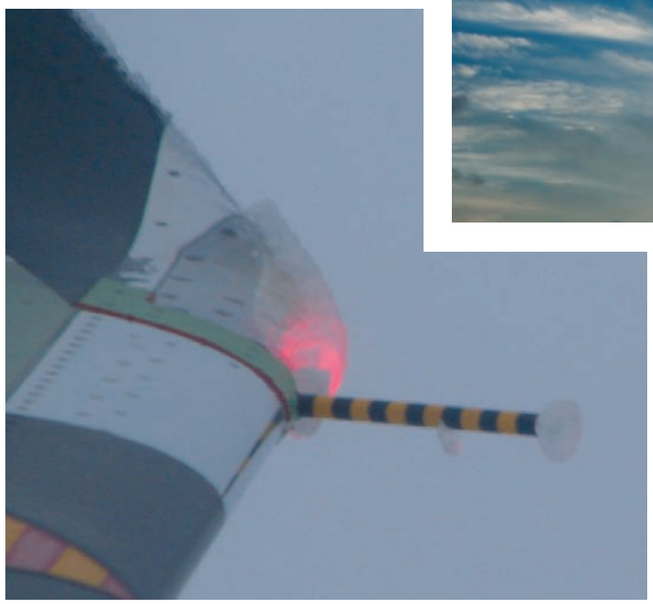
The high Mach number was achieved to validate the aircraft's maximum speed for stability characteristics, a requirement for receiving a Certificate of Airworthiness from the FAA. Such high speeds are outside the aircraft's normal flight envelope. The G650's maximum allowable Mach number is Mach 0.925.

Throughout the flight, the crew evaluated the aircraft's avionics, flight control systems, and handling qualities. "This flight represents a significant milestone in the overall certification program," says Pres Henne, senior vice president of programs, engineering and test at Gulfstream. "We've had four aircraft flying for some time now, so we've already accomplished a broad range of tests. In addition, the fatigue test article has moved to the structural test hangar, where it will be used to evaluate the lifelong structural integrity of the aircraft. The flight-test program is moving along at a brisk pace."

Before its first flight, S/N 6005 underwent certification ground tests for lightning and high-intensity radiated fields (HIRF). Performed at the company's headquarters in Savannah throughout November and December 2010, the lightning test indicated that the airframe and systems can withstand a severe lightning strike, and HIRF testing demonstrated the ability of the aircraft's flight-essential systems to withstand external radio frequencies without interference.

The four other aircraft flying in the test program have also completed several tests required as part of the G650's certification by the FAA and European Aviation Safety Agency (EASA) later in 2011.





Top left: Ice accumulates on the radome of the G250 flight-test aircraft during natural icing tests in the Great Lakes region

Left: There is ice accretion on the unprotected winglet and a test probe, but the leading edge of the wing is ice-free

Larry Dowler is the chief engineer of mid-cabin programs at Gulfstream. Speaking to *Aerospace Testing International* he says, "S/N 2002 was fitted with cameras and also with special instrumentation on the top of the fuselage to measure cloud conditions. It was then dispatched to Smyrna, Tennessee (near Nashville), to be closer to the Great Lakes region in order to find icing conditions aloft.

"Israel Aerospace Industries (IAI), our partner on the G250 program, enlisted the support of a meteorology specialist and an icing researcher to direct the aircraft where to operate in the appropriate conditions," explains Dowler. "The aircraft completed several flights during which it accumulated several hours of exposure to icing conditions. Some tests were designed to build up ice on the unprotected surfaces and then subject the aircraft to maneuvers to verify the stability and control characteristics with ice on the airframe. Other tests were designed to test the ice protection systems and tolerance of the aircraft to 45-minute periods of exposure to icing conditions."

All in the location

The three aircraft in the flight-test campaign have completed more than 220 test flights, spending more than 700 hours in the air. The longest flight was more than seven hours. The maximum speed achieved was Mach 0.85 and the maximum altitude was 45,000ft (13,800m). On December 9, 2010, all three flight-test aircraft flew simultaneously for the first time.

The tests were not undertaken from Gulfstream's headquarters in Georgia, but near Nashville. "No test facility is used; this test requires natural icing," continues Dowler. "A fixed-base operation (FBO) in Smyrna was a favored base of operations due primarily to location and services. It is far enough north to be within easy reach of the northern states and particularly the Great Lakes region, where icing conditions aloft tend to be most prevalent at that time of year. But it is not so far north that it is susceptible to ground icing conditions and snow, which could interfere with the ability to operate and take off to conduct tests.

"The aircraft successfully completed the required handling and stability tests, and

The G250 boasts the longest range at fastest cruise speed in the super mid-size business jet category with a new high-speed wing and Honeywell HTF7250G engines

> **"Despite the extremely demanding conditions and ice accumulation on all untreated surfaces, the aircraft performed flawlessly"**

airplane systems also performed beautifully," Dowler explains.

The plane players

Since its first flight in December 2009, S/N 2001 has confirmed a wide range of data, including minimum control air speeds, initial cruise performance, and flight-control system/flight-control law performance.

Additionally, S/N 2002 (just over from IAI in Tel Aviv) has undergone certification for smoke evacuation, auxiliary power unit (APU) electrical loads, fuel system functionality, the cabin pressure control system (CPCS), overall aircraft loads, and stall characteristics with different centers of gravity.

S/N 2003, the last aircraft to join the flight-test program, has undergone avionics certification testing and numerous systems checks. Additionally, S/N 2003 made its first transatlantic crossing in support of the 2010 National Business Aviation Association (NBAA) Conference and Exhibition in Atlanta. It also performed far-field noise and high-field elevation testing.

Dowler is keen to establish how few problems were encountered during the ice trial phase: "Some tests were repeated following assessment of the data," he reveals. "In most cases, the repeats were done to obtain additional data for repeatability or to address slight deviations from the requirements of the test. It is important to be 100% sure that everything is completed properly because there is no chance to repeat the tests once the special icing instrumentation is removed and the aircraft is relocated – plus, the weather conditions may not return for a year."

Dowler is even keener to emphasize the numerous achievements of the test program: "Icing tests are difficult and expensive because the environment is unpredictable and unforgiving and there is a limited window in which tests can be completed. Moreover, this was a foreign deployment and off-site operation for IAI, which adds to the strategic and logistical challenges. The biggest achievement is simply that the icing tests were completed successfully, which is testament to the G250 GAC/IAI team and the robustness of the aircraft.

"The G250 icing system performed exceptionally well. The preliminary results agreed very well with the pre-test predictions. During one particular flight, heavy icing concentrations in excess of the regulatory design envelope were encountered. The aircraft remained in this condition for an equivalent icing exposure time of over 50 minutes to enable adequate accumulation of ice. Despite the extremely demanding conditions and ice accumulation on all untreated surfaces, the aircraft performed flawlessly," declares Dowler.

Split the bird

G250 manufacturer Israel Aerospace Industries (IAI) has developed an innovative structural concept for protecting aircraft from damage due to bird impact.

The Bird Splitter structure is located on the aircraft's tail and is designed to 'split' an incoming bird and thereby protect aircraft structure and crucial systems. The concept was implemented on the new G250 business jet, a member of the super mid-size category jet.

Few details are known, but the image shows what appears to be a sharp structural element on the leading edge of the vertical fin.

Above and beyond

While the test aircraft continue to push through the flight-test campaign, several other activities are underway on the ground. Testing is ongoing in the Integration Test Facility (ITF) at Gulfstream's base in Savannah, Georgia, where engineers are evaluating the PlaneView TM 250 avionics system by examining software and hardware integration, systems development, and human factors.

They are also developing and validating the procedures that will be used in the airplane flight manual (AFM). Optional avionics features, such as the head-up display (HUD) and Gulfstream Enhanced Vision System (EVS) II, are also being tested in the ITF.

Additionally, all structural limit and ultimate load tests have been successfully completed. The fatigue test article has been moved to the structural test hangar, where it will be used to test the structural integrity of the airframe over more than 40,000 cycles.

But the G250 is not out of the cold quite yet as Dowler notes: "The G250 still has to complete its cold weather (or overnight cold-soak) tests. A company test was recently performed in Finland to help prepare the aircraft for the overnight cold-soak certification testing. Hot weather testing has been performed on S/N 2002 in Eilat, Israel, on the Red Sea coast.

"The flight-test aircraft will complete remaining certification testing as well as Function and Reliability testing," he concludes. "The aircraft continues to perform as expected and getting this milestone under our belt was a huge success."

Right now, manufacturing of the first non-test aircraft, S/N 2004, continues at IAI near Tel Aviv. The forward, center, and aft fuselage sections have been joined, and systems installation is underway. Production of the interior furnishings has also begun at Gulfstream's mid-cabin completions center in Dallas, Texas, where the G250 will be outfitted and painted. ▮

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Saxony and the city

"The focus this year is on increasing the level of information available to visitors during the show"

AFTER ALMOST A DECADE, AEROSPACE TESTING EXPO IS STILL GOING STRONG. THE SHOW AND ITS SEMINARS JUST GET BIGGER AND BETTER, AND THIS YEAR IT RETURNS TO ITS HAMBURG HOME IN GERMANY'S LOWER SAXONY, CO-LOCATED WITH AIRCRAFT INTERIORS EXPO

Now in its ninth year, Aerospace Testing Expo returns to the Hamburg Messe from April 5-7, 2011 to bring together the active core of the test industry.

For any visitor, attending the Expo is a time-efficient way to keep up to date with the latest innovations and solutions from across the market, connecting the visitor with a concentrated source of industry expertise for aerospace test engineering.

Seminar program

The focus this year is on increasing the level of information available to visitors during the show, especially as the organizers understand that delegates have limited time in their busy work schedules. As well as the usual array of exhibitors to meet, the 2011 event will once again host a free program of technical seminars covering a wide range of testing disciplines.

Organizer Reed Expo welcomes speakers from organizations including ACRA Control, BAE Systems, National Aerospace Laboratory, MOOG, MTS, the Society of Flight Test Engineers, and a host of other innovative companies, each of which will provide visitors with a rich source of new ideas and techniques that can be taken back to the workplace to improve and streamline operations.

Over the three days, sessions are grouped into key subject areas, including structural testing, engine testing, NDT, avionics, materials

Seminar highlights

Here is a taster of what there is to look forward to from the Aerospace Testing 2011 seminar program...

The conference on avionics features automated model-based testing of a complex avionics algorithm for the NH-90 helicopter, with Edwin van de Sluis, senior scientist of avionics software at the National Space Laboratory. There will also be a presentation about using real-time signal analysis technology to debug EMI/EMC problems in aerospace, radar, and avionics from Joern Hoepfner, RF product specialist EMEA at Tektronix GmbH.

The data acquisition seminar features a case study of a networked data-acquisition system in space, from Milos Melicher, principal engineer of space & ground stations at ACRA Control.

One of the most exciting focuses of the seminar is flight testing, and Nikki Cranley, principal engineer of networks & recorders at ACRA Control will be presenting a case study on the challenges and solutions for complex Gigabit FTI Networks.

The ground testing seminar is headlined by BAE Systems specialist engineer Phil Liston-Smith, who will give an overview of the company's 1.2m high-speed wind tunnel refurbishment program. CRP Technology will also be represented, with a seminar led by marketing and sales director Livia Cevolini that focuses on material and composites engineering and the construction of a CubeSat using additive manufacturing.

The NDT seminar highlights the FANTOM FP7 project, an innovative NDT technique development with a single sensor for simultaneous temporal and spatial full-field thermography and deformation measurements in structural tests. This is hosted by Dr Marc Georges, head of laser techniques activity at Centre Spatial de Liège at the Université de Liège. There will also a fascinating discussion talking about the latest shearography science, NDT on aerospace material, from Raphael Schoen, international sales manager at Steinbichler Optotechnik.

The final seminar focuses on structural testing, with a look at online full-scale testing from L. C. Ubels, principal project engineer at the National Aerospace Laboratory NLR, and also structures and materials courtesy of Dany Paraschivoiu, manager of operations at the National Research Center, Canada.

and composites engineering, data acquisition, sensor technology and ground testing. Each half-day program is backed by a dedicated 'technology trail' that highlights exhibitors who provide solutions that match each key subject, helping visitors to quickly locate the content and suppliers that can provide the right solution to meet their specific needs.

Networking lunches

For the third consecutive year, the organizers will once again be hosting two VIP networking lunches during the show. Sponsored by Moog and situated on the show floor, these invitation-only lunches are a great chance for senior and chief engineers to meet their peers, and also give visitors the opportunity to talk informally to some of the testing suppliers attending the exhibition.

PRODUCT LAUNCHES

Laser imaging

LaVision is a leading manufacturer of integrated (laser) imaging systems to the scientific and industrial markets. LaVision offers customer-designed (laser) imaging systems for reactive and non-reactive flow field analysis, fluid mechanics, combustion research, and non-destructive material testing.

The LaVision team has extensive professional experience in laser imaging spectroscopy and optical techniques such as: laser-induced fluorescence (LIF), absorption and emission spectroscopy; raman, rayleigh and mie scattering; particle image velocimetry (PIV); spray analysis; digital image correlation (DIC) techniques; and ultra-fast time-resolved imaging and high-speed image recording.

Component trials

Phoenix Testlab is a one-stop-shop for a wide range of services for component testing in the aviation industry, providing the expert guidance needed.

Test labs are set up according to international standards such as RTCA DO 160 and products are tested in line with the company standards and delivery conditions of well-known aircraft manufacturers.

Phoenix Testlab offers a variety of services for this sector, including testing of EMC, environmental simulations, testing of electrical safety, and testing of radio.

Noise and vibration

Brüel & Kjær is the world's largest noise and vibration group. At the Hamburg show visitors can see its latest range of vibration and acoustic sensors, LDS shakers, LAN-XI data acquisition, and PULSE reflex analysis. Also on show will be acoustic testing systems for interior and exterior noise analysis, noise certification, and acoustic material testing, environmental testing systems for vibration and shock testing, structural dynamics systems for modal analysis and verifying design models, and HUMS transducers and aircraft ground vibration check systems.

Pre-registrations already include representatives from leading aerospace manufacturers, including Airbus Military, Airbus Operations, Boeing, Cassidian/EADS, Embraer, Eurocopter, Lufthansa Technik, MTU Aero Engines, Pratt & Whitney, Rolls-Royce, Saab Aeronautics, and many more.

Aircraft Interiors Expo

Another important attraction to maximize the value of a visit to Hamburg is Aircraft Interiors Expo. Running alongside Aerospace Testing Expo, Aircraft Interiors is the launch pad for new cabin programs, with more than 500 leading suppliers showcasing tomorrow's designs, in-flight entertainment, connectivity, and avionics solutions.

What is more, over 50 companies represented at Aircraft Interiors Expo provide test, measurement, and certification solutions for the aerospace industry, giving visitors to Aerospace Testing even more to see during their visit. Exhibitors include Diehl, GOM, Panasonic Avionics, Rockwell Collins, TÜV SÜD, Zodiac Aerospace, and a host of other leading suppliers.

All visitors to Aerospace Testing Expo can gain free entry to Aircraft Interiors Expo throughout the three-day event. Visit www.aerospacetestingexpo.com/atpreview for free registration.

More than 100 suppliers of testing solutions will be on show in Hamburg and the organizers urge every visitor to make the most of the Expo by making new contacts, developing existing relationships, and capitalizing upon the free knowledge and insight on offer to ensure their business remains competitive over the next 12 months. ▮

Fatigue sensors

Honeywell offers expert thinking, extensive technology resources, and more than 50 years' experience to help address the highly demanding test and measurement challenges within aerospace.

A broad portfolio of precision fatigue-rated sensors (such as pressure, load, torque, vibration, LVDTs), engineered for enhanced precision, repeatability, and ruggedness in aerospace test applications such as: force/pressure for flight and ground-testing applications; airframe/structural, hydraulics, and fuel systems testing; ground-support testing; jet engine turbine stress, temperature, and vibration monitoring; pressure testing in actuators and engines; propulsion monitoring – torque, temperature, speed, and power monitoring of rotating propeller shaft.

Hardware & software

Silver Atena is a leading international organization specializing in engineering services for safety-critical electronic systems development and real-time HIL test systems.

The competencies include systems, hardware, software, safety engineering, and consulting services. In addition, Silver Atena offers test system design and modular-based development, combining self-developed components with COTS components. Operating independently in the aerospace, defense, and automotive markets, Silver Atena has a global workforce of approximately 500 highly qualified engineers based at various locations in Germany, the UK, Spain, and India.

Non–destructive testing

NDT Expert will be proposing a global solution around the aeronautic and space non-destructive testing activity.

The company owns more than 60 NDT certification level II techniques, as well as 22 level III. NDT Expert has settled up a workforce management policy to insure the best adaptation of its service according to the urgent need of the customers.

New activities such as the chemical analysis of A/C fluids, the monitoring of mechanical structures testing, the borescope inspection and the industrialization/sales of new systems dedicated to control have taken place within the company.

This map of Mediterranean sea surface temperatures is an example of data from satellites, such as the Sentinel. The UK's Critical Software Technologies has been heavily involved in the independent software validation and verification (ISVV) of the mission software. Picture courtesy of ESA

A British perspective

TESTING IS THE KEY TO SUCCESS FOR THE UK'S FALTERING AEROSPACE INDUSTRY

BY BRIAN LUFF

Does anyone in the UK care about threats to its aerospace industry? Well, someone should. The country has an enviable record in advanced engineering skills, high-tech products, and world-leading manufacturing capability, and the aerospace industry is one of the foundation stones upon which its current, albeit declining, prosperity is built.

Almost 3,000 aerospace companies, employing (directly or indirectly) approximately 390,000 people, make the UK's aerospace industry still the second largest in the world, behind the USA. At a time when the country is struggling with huge indebtedness, it is worth remembering that the aerospace industry is still one of the UK's largest export industries (£14 billion/US$23 billion in 2008).

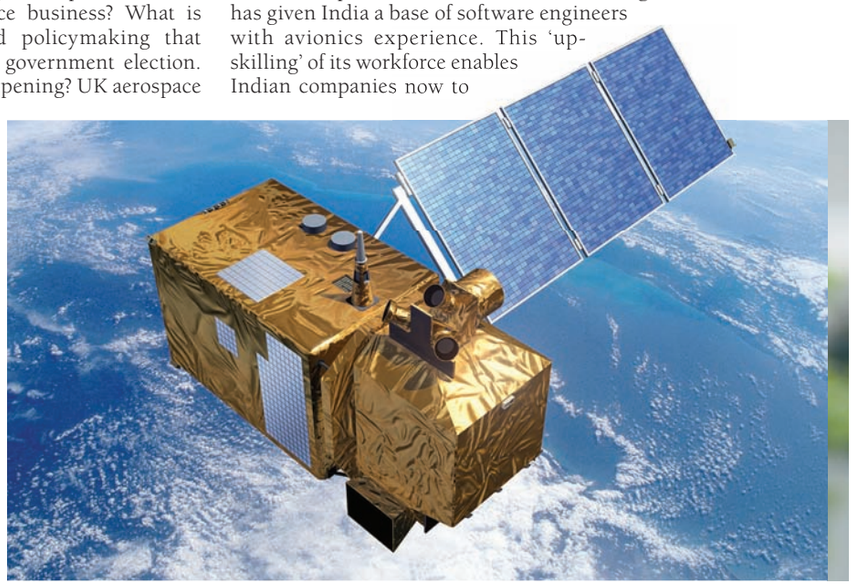
We all know things change. Supply expands to meet demand, prices fall, markets saturate. Geopolitical pressures such as emerging markets, and the communications that facilitate globalization, act seismically to produce long-term and largely irreversible shifts affecting whole industries. The effects of some of these factors are all too plain. Some of the greatest aircraft manufacturers were British but most have now, unfortunately, gone, or have been absorbed by foreign ownership.

Instead of aircraft manufacturers, the UK now has a few divisions of the likes of Airbus and Bombardier making subsystems, such as wings and undercarriages. These are supplemented by the smaller companies in their supply chains, which are horribly vulnerable should Airbus, Boeing, Lockheed Martin, and even (the largely US-owned) BAE decide to do more business away from these shores.

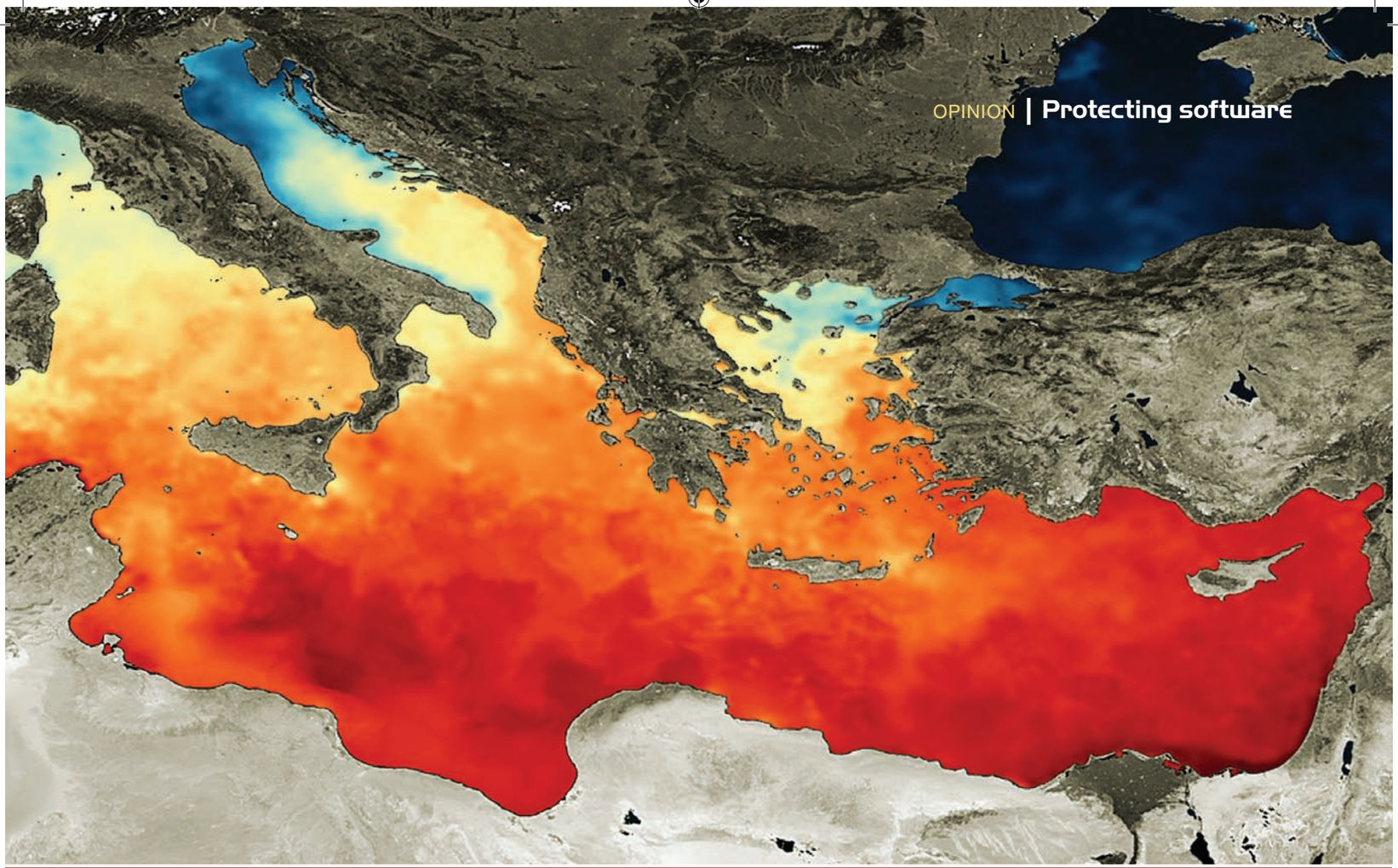
More support for businesses

Surely it's a no-brainer that the UK government should be acting to help sustain and even grow its aerospace business? What is required is far-sighted policymaking that looks beyond the next government election. But what is actually happening? UK aerospace organizations are being actively encouraged to shift jobs to Brazil, India or China. It's an attractive proposition for these countries – they get immediate capital injections and boosts to their employment, but the benefits are far longer term.

Quite wrongly, in my view, software testing is seen as being somehow at the lower end of avionics engineering. Either way, hundreds of millions of pounds' worth of software testing has given India a base of software engineers with avionics experience. This 'up-skilling' of its workforce enables Indian companies now to



A Sentinel satellite Picture courtesy of ESA. Far right: Brian Luff, chairman, Critical Software Technologies



challenge ever more strongly one of the UK's main industries. The threat is obvious, and yet it's being ignored by politicians and industry leaders who won't look beyond their own personal end games.

The graduate skills dilemma

For graduates joining the software industry, testing has often been a typical entry point. But now 17% of UK computer science graduates are currently still unemployed six months after graduating. That's one in six promising new engineers without a job! The aerospace giants can hardly be blamed for outsourcing their engineering projects to lower-cost suppliers abroad, where a wage of £10 (US$16) per hour for an advanced avionics engineer is hard to ignore.

"Some of the greatest aircraft manufacturers were British but most have now, unfortunately, gone, or have been absorbed by foreign ownership"

Surely, though, the answer cannot be to simply stave off short-term problems by creating worse ones in the medium term? The solution must be to support British industry, and to support it directly in those areas where it still has a lead over most of the rest of the world. Gradually pushing high-end skills out to India will simply give away the UK's position as a world leader. What high-end skills and innovation will there be in 10 years' time, unless we continue to grow and invest in our own avionics industry?

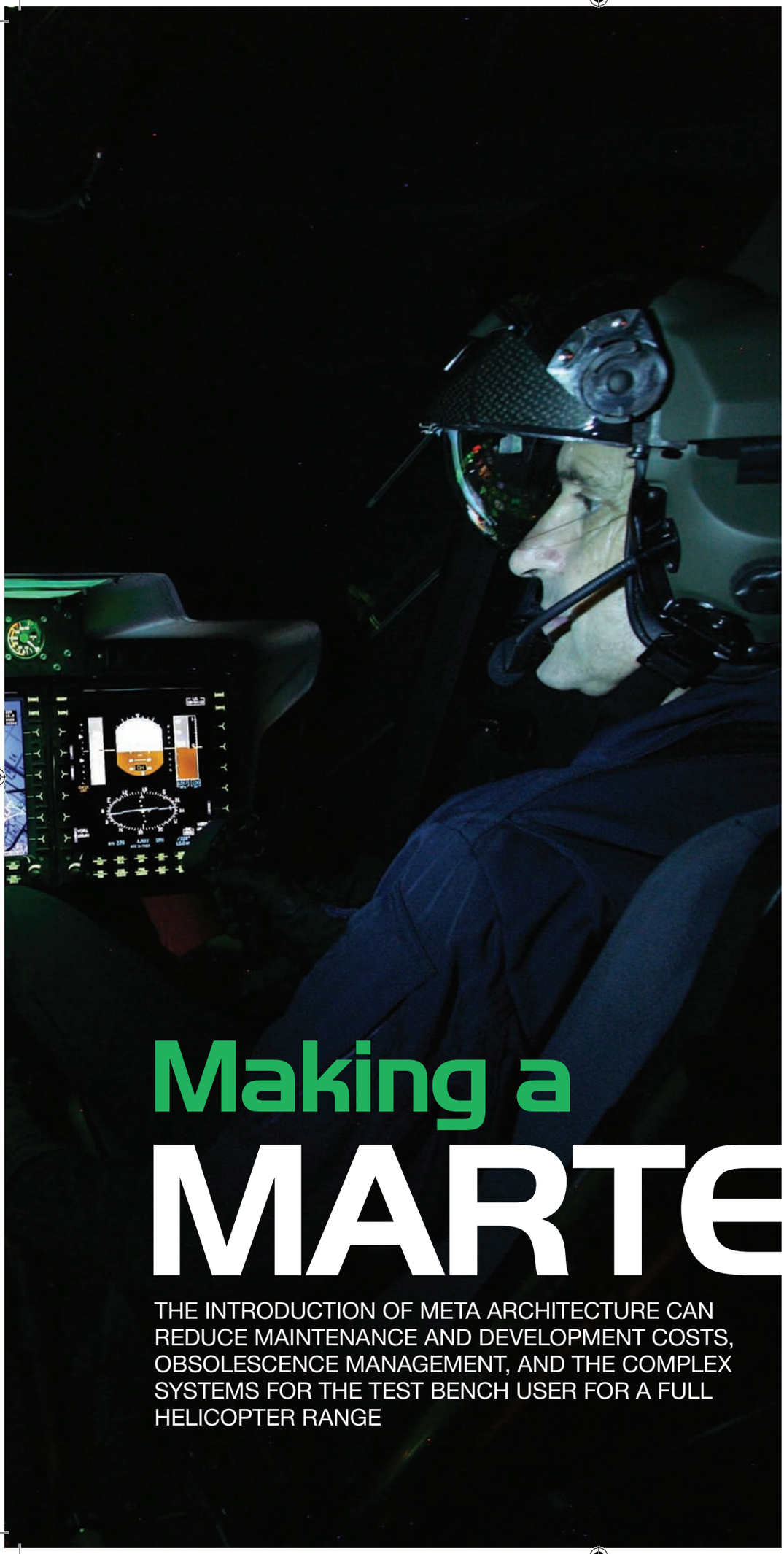
Protectionism as such is counterproductive, but there is a case for stricter export licensing of advanced technology (following the lead of the USA). US companies are sometimes difficult to deal with, but their model sustains economic well-being and protects the standard of living of generations to come.

It is imperative that the UK government, together with all those in positions of influence in the aerospace industry, encourages fresh thinking and innovation – that is how it has succeeded. For this we need a steady influx of bright and motivated engineering graduates. Let's not give away the jobs upon which many would cut their teeth.

Guarantees are needed for the long-term prosperity of the UK aerospace industry, as well as, but not instead of, supporting growth and expansion abroad. ▮

Brian Luff is chairman of Critical Software Technologies in the UK

An illustration of avionics complexity to be mastered by the test systems Picture: © Eric Raz/Eurocopter



Making a MARTE

THE INTRODUCTION OF META ARCHITECTURE CAN REDUCE MAINTENANCE AND DEVELOPMENT COSTS, OBSOLESCENCE MANAGEMENT, AND THE COMPLEX SYSTEMS FOR THE TEST BENCH USER FOR A FULL HELICOPTER RANGE

BY GEORGE AFONSO AND NICOLAS BELANGER

During an aircraft's development phase, the test process is considered a key challenge for safety-critical avionic systems. These systems often operate under complex dynamic conditions and ultimately provide safety, fault tolerance, and deterministic timing.

For a large range of helicopters, the processing of the different system units is verified using several software and hardware environments. By its nature, the test methodology heavily influences the time-to-market and the cost of the final product. Nicolas Belanger, strategy & innovation coordinator for Engineering Service Technologies at Eurocopter, highlights the situation in the avionics landscape: "For years, it has been widely accepted in the avionic test systems community that test benches should be dedicated to a specific helicopter configuration.

"It is certainly time to reassess this situation. We all know the global ratios, the cost of one flight test hour being equivalent to 20 hours on a test bench and 40 hours spent on simulation. This fact provides a strong motivation to increase virtualization on one side and test systems' reconfigurable architectures on the other. If we have in-house dedicated experts, capable of achieving the target of the virtual helicopter challenge, but on the opposite side we do not have the necessary internal expert competency in the derived scientific field of reconfigurable processor architectures, we are dependent on competent partners such as EADS Innovation Works and INRIA to improve and implement our orginal ideas."

Focusing on this issue, a generic test environment that can adapt easily to the helicopter fleet specifics and the unit-under-test (UUT) was proposed. Within this environment, a hybrid CPU/FPGA (field programmable gate array) 'meta architecture' was imagined to design innovative avionic test systems that meet performance and flexibility goals.

Furthermore, an efficient test methodology that favors the reuse of hardware and software models, the adaptability of the system according to the scenario, and the interoperability of heterogeneous units was defined. The whole project shows the strong impact of the test environment to reduce the complexity of the means employed for the test phase. Eurocopter intends to evaluate the operational benefits of this environment, in order for it to be taken into account when designing its next-generation test benches.

Reconfigurable computing

Stephan C. Stilkerich, expert for reconfigurable computing and computational intelligence at EADS Innovation Works, explains, "Reconfigurable computing has a long-standing history in the academic community, but up to now this field suffers from being exploited with respect to industrial applications. Although the reconfigurable computing technology offers interesting and promising architectural and system features, the lack of established and industrial relevant development environments, as well as runtime environments, halted this technology in industry.

"EADS Innovation Works researches and develops in this field to prepare the technology for use within EADS. The program on Pro-Active Test Systems with Eurocopter is an excellent case study, demonstrating the advantages of this technology in an industrial setting and for EADS Innovation Works and Eurocopter to complement their technical expertise."

It all started by pointing out the major limitations of the existing test systems. In present industrial practice, different test benches are used for the verification of various helicopter types, such as EC175 and EC135, and systems, such as the automatic pilot and navigation. Each test bench relies on a specific hardware architecture and software tools. This is due to the heterogeneity of the helicopter components – UUTs, in terms of computing requirements and handled data structures. In addition to this, dedicated avionic I/O boards (Arinc 429, 1553, etc) are required, depending on the UUTs. This test methodology calls for separate teams with different domain experts to achieve the test of each part. The overall avionic system verification is continued through to the first prototype of the helicopter. Today, this test process is very complex and expensive to perform.

Above: Nicolas Belanger, Eurocopter (left) and George Afonso, EADS Innovation Works (right) . Left: the X3. Picture: © Patrick Penna/Eurocopter

> **"Due to the present performance requirements, an increase in the computation rates is needed, which is difficult to achieve with affordable VME CPU board constellations"**

This project addresses the above test methodology limitations and calls for an innovative avionic test environment. The main objective is to build up a generic test environment by the means of offering more flexibility regarding the selection of the most suitable test system architecture. An efficient test methodology favors the reuse and the interoperability of hardware and software models while switching between different scenarios. Furthermore, automation in the development process is key to increasing the productivity and reducing the cost.

Eurocopter's contributions in the avionic test environment domain can be summarized as follows: First a hybrid CPU/FPGA architecture for the test system was proposed. In fact, today multicore CPUs come with high computation rates while the FPGA offers flexibility and adaptability to the system. Within this environment, great attention has been devoted to the real-time aspect to satisfy tight computing and communication deadlines. The proposal relies on industrial and certified technologies that can be embedded easily on the final avionic product. Second, an efficient methodology that makes profit from the hybrid architecture to adapt the test system according to the target realization was defined. The reuse and the interoperability advantages are ensured in this methodology with the help of the reconfigurable technology.

Hardware architectures

For the past 20 years, the avionic test systems were based on real-time specific hardware architectures such as the well-spread VME CPU boards. The VMEBus is particularly efficient and enables input/output (I/O) event management, multiprocessing synchronization, and transparent access to the different hardware resources. Like most aeronautic companies, Eurocopter has integrated the VMEBus as a standard backbone for the test benches of embedded flight systems. The proprietary test system ARTIST is based on VME technology and the real-time operating system (OS) VxWorks. These technologies have been used for all helicopter benches to validate the avionic equipment.

Due to the present performance requirements, an increase in the computation rates is needed, which is difficult to achieve with affordable VME CPU board constellations. Furthermore, this solution is considered a costly technology to maintain. To overcome these drawbacks, Eurocopter recently decided to move to an improved test system architecture based on a high performance PC workstation solution. Upcoming architectures are based on multicore computers plugged with I/O boards to communicate with the equipment under test.

Eurocopter selected the PEV1100 VME Bridge solution from the Swiss company IOxOS for its interesting capability to preserve test benches' legacy hardware with a view to a shift to more software-based test systems. The PEV1100 enables a local host to interface with a VME64x bus using a PCI Express (PCIe) external cable, which offers transparent access to I/O boards. To achieve higher communication performances, IOxOS Technology developed a dedicated interface between the PCIe and the VME64x bus. This interface is built with the latest FPGA technology to implement PCIe end-point hardware cores.

The usage of multicore hosts enables an immediate computation capacity increase. An important outcome of this transition is the removal of the legacy CPU boards. However, this solution still does not address the increasing hard real-time criteria anticipated for the execution of tomorrow's concurrent tasks, due to the constraints of the OS environments. Furthermore, the solution doesn't tackle the communication latencies between the CPUs and the I/O boards plugged into any backplane. The Eurocopter proposal profits from the available hardware computing resource (FPGA) in order to build adaptive avionic test systems.

George Afonso, embedded and critical systems engineer/PhD at EADS Innovation Works,

Above: Tiger. Picture: © Jérôme Deulin/Eurocopter

Left: NH90 simulator. Picture: © Eric Raz/ Eurocopter

Below: This test loop will be adapted by the system constraints configuring the test scenario, such as time and environmental parameters

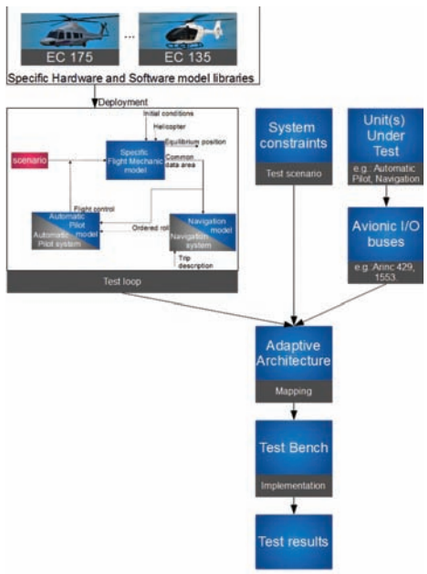
supports FPGA added value for test systems. "Indeed, FPGA technology could offer up to 10 times higher computation rates than CPUs," says Afonso. "It could implement heavy models in a hardware fashion and hide communication latencies with I/O devices."

Adaptive avionic test systems

To perform a complete simulation, it is necessary to model each part of the helicopter and the environmental parameters, i.e. weather conditions and geographical factors.

The 'test loop' part of the adaptive architecture figure presents a simplified test loop system that simulates the helicopter behavior involving three models: the flight mechanic model, the navigation model, and the automatic pilot model. In the initialization phase, the flight mechanic model takes several parameters such as the initial position relative to the ground and the aircraft configuration file. As a main result, this model gives back an equilibrium position. In addition, it sends the common data area structure containing the position and the speed of the aircraft to the navigation model. This later computes the helicopter destination and sends it to the automatic pilot model via the ordered roll structure. Finally, the flight control is managed by the automatic pilot. Each hardware model, such as the navigation or the automatic pilot, can be replaced by the real hardware-in-the-test-loop.

This test loop will be adapted by the system constraints configuring the test scenario, such as time parameters and environmental parameters, and also by the present UUT. Indeed, the UUT is specific to a helicopter using certain avionic buses. Finally, the UUT will be the main parameter of the architecture configuration, which in Eurocopter's case, is automatic. The main objective of the hybrid architecture is to exploit the new available



hardware computing resource (FPGA) to build up adaptive avionic test systems. The proposed hybrid architecture for the next avionic test systems is composed of multicore CPUs and FPGAs. Our expectation of the above described architecture is to prototype models that can be eligible and relocated in the FPGA.

The objective is to increase the performances of these models and to reduce the communication latencies by the means of embedding the different parts in the same chip. FPGA technology could implement heavy models in a hardware fashion with the management of the parallelism degree to address the real-time constraints of the application. Currently, most of the models are mainly based on software intellectual property (IP).

To obtain fast test system prototyping, heterogeneity of both hardware and software parts had to be dealt with. In current industrial practice, manual coding is still widely adopted in the development of hybrid architectures, which is clearly not suited to manage the complexity intrinsic in these systems.

Rabie Ben Atitallah, researcher at the University of Valenciennes and partner in the project, strongly supports the idea of high-level modeling in the global process. "For designers, manual coding is very tedious, error-prone, and expensive.

"To overcome this challenge, we propose the use of a model-driven engineering (MDE) approach in the specific context of CPU/FPGA hybrid system design," he explains. "The objective is to build a tool that automatically turns a high level specification of the test system into an executable implementation."

Hybrid system modeling

Eurocopter proposes the use of the MARTE standard UML profile to model the hybrid avionic test system. Later, a compilation chain will be defined to turn automatically the high level specification into an executable implementation. With the MARTE specification, an application is a set of tasks connected through ports. Tasks are considered as mathematical functions reading data from their input ports and writing data on their output ports. In addition, MARTE enables the description of the hardware architecture in a structural way.

Typical components such as processors, FPGAs, and memory can be specified with their non-functional properties. This innovative 'meta architecture' will reduce maintenance costs, development costs, obsolescence management, and the complexity to be mastered by the test bench user for a full helicopter range. The next step of the project will deal with event-driven and dynamic reconfiguration of the test environment. The Corresponding step 2 demonstrator is expected by the end of 2011, and the company is confident it will bring innovation to the generic test bench concept. ▮

George Afonso and Nicolas Belanger are from EADS and Eurocopter. Contributions also came from Rabie Ben Atitallah, University of Valenciennes and Stephan Stilkerich, EADS Innovation works. Email: george.afonso@eads.net; Nicolas.belanger@eurocopter.com

Lock 'n' load

UNDERSTANDING WHY LOAD CELLS ARE THE BEST CHOICE FOR AEROSPACE GROUND AND FLIGHT TEST APPLICATIONS

BY BRIAN DUFFY

The use of load cells is prevalent in many aerospace ground and flight test applications due to their inherent flexibility in design and form factor, which gives them the ability to handle various test scenarios and environments. With three common load cell structure designs – multiple-bending beam, multiple-column, and shear-web – the possibilities are nearly endless in creating load cell profiles and/or configurations. All of this is particularly inviting for the world of aerospace and flight where rigorous testing requirements are the norm.

Crossing over between commercial and military applications, load cells may be used throughout all phases of aircraft development and use, including initial design and build stages, pre-flight, structural and fatigue testing, inflight testing and monitoring, and flight-qualified force monitoring and control.

Initial design and build stage

Load cells may be instrumental in testing generic components for strength, force endurance levels, component longevity, etc. Components can be anything from seatbelts, to individual linkages, to aircraft flaps, to cockpit instruments. For the majority of component-testing applications, a standard load cell design can be used.

With pre-flight, structural, and fatigue testing, load cells can be used to test frame structure integrity, endurance, and lifecycles, with the goal generally being to validate aircraft design and ensure specified criteria are met. For instance, dual bridge load cells (two independent outputs on a single load cell) are used for airframe testing.

With inflight testing and monitoring, load cells can be used to test and monitor airframe structural forces during inflight testing. For example, bolts and pins used on critical points of the airframe can be redesigned, fabricated, and calibrated to perform as load cells and can be used to ensure that structural integrity is maintained.

Flight-qualified force monitoring

After new builds or designs pass the necessary performance testing and are ready for commercial or military applications, load cells can be used in the monitoring of the flight control system. In commercial use, load cells are designed for pilot force input. Another example is the measurement of the pilot's touch to the control stick. The force is measured and the data is stored in the Flight Data Recorder (the 'Black Box'). A redundant load path is used to ensure the mechanical integrity of the linkage.

In demanding military applications, a highly customized load cell can be used in the flight control system. These load cells can be used in many extreme applications such as inflight tanker refueling operations where the load cell is on the extreme end of a boom and exposed to harsh environmental conditions. The boom system is used to track the aircraft being refueled and the load cell, as part of that system, measures the force the aircraft exerts on the boom assembly.

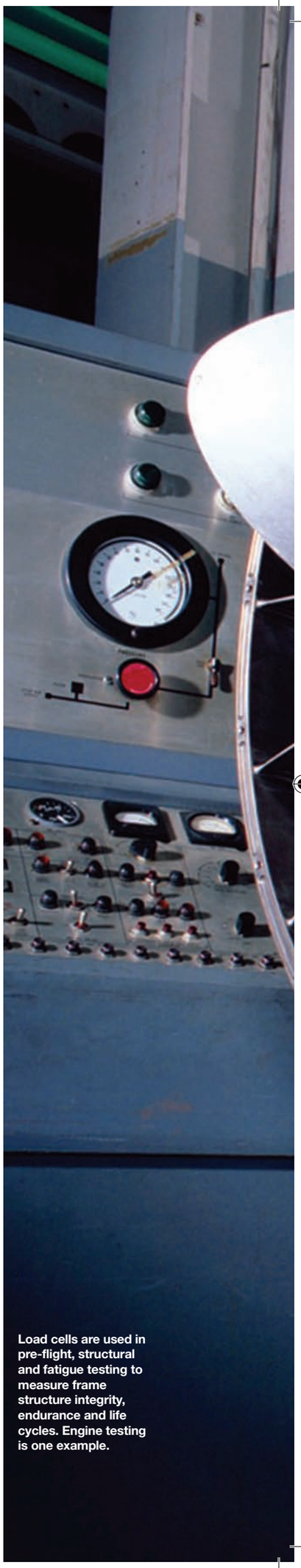
Benefits of load cell use

There are many benefits to using load cells in aerospace testing applications, flexibility topping the list.

Customized dual-bridge designs offer flexibility in testing, performing as two independent force measurements from the same load cell. For example, in airframe testing, the first force measurement can be used to control the loads applied to the aircraft. The second independent force measurement verifies what the load actually is, which is collected for data analysis, along with various other measurements on the airframe being tested. Basically, it provides independent verification of the load. This is a key feature and benefit in certain applications. Typically load cells in airframe testing have to compensate for off-center loading because they are mounted directly in-line with the hydraulic cylinder providing the force.

Effectiveness is another key benefit, and requirement, within aerospace testing applications. Load cells measure forces and transmit data needed to validate components, products, or complete aircraft to help ensure integrity and safe operation.

In addition, when required, load cells can be designed with a high fatigue life, or long lifecycle. They can be built for reliability and longevity of use. Often, they can maintain performance through more than 100 million force/load cycling



Load cells are used in pre-flight, structural and fatigue testing to measure frame structure integrity, endurance and life cycles. Engine testing is one example.

The majority of component testing applications within initial design and build stages utilize a standard load cell design

tests, making them a cost-effective choice for aerospace engineers who often conduct a multitude of tests on the same component.

A robust design ensures that the load cell lasts longer in tough applications. Load cells can be constructed to compensate for varying operational factors, particularly useful in flight applications. They can be built to withstand environmental factors such as *g*-forces and vibrations, as well as temperature and humidity fluctuations, chemicals, and even physical impacts. Load cells are typically encased by all-metal construction to protect the sensor from harsh environmental conditions or operating environments, without degrading the sensing capabilities. As a result, key operating parameters and performance are maintained.

Of course, redundancy goes hand in hand with both long load cell life and a robust design. Redundancy can actually be designed into the load cell and is a key benefit within aerospace applications. A back-up mechanism can be built-in to maintain the mechanical integrity of the flight control system.

In the aerospace world, imperfect conditions are the norm. Load cells can be designed to compensate for off-center loading, allowing sensor functionality and performance despite less-than-ideal situations. One example is in helicopter lift operations. Several hook load sensors can be used to confirm a safe lift. The load cell design compensates for uneven loading, so even if the load is not applied directly through the primary axis of the load cell, it will still perform to specification.

Load cell examples

Load cells, by design, have minimal deflection when fully loaded, but still retain high force sensitivity. A typical example is load cells used in throttle, wheel or pedal linkages detecting pilot input forces on the aileron, rudder, and elevator. Highly sensitive load cells allow the pilot to retain direct, active feedback to control the plane, while providing data to the black box and throttle control. The sensing element provides a direct linkage between the pilot's touch and immediate feedback to the plane's control systems.

Another example is in autopilot situations on aircraft. If required, a pilot need only take hold of the throttle to disengage the autopilot and take direct control of the aircraft.

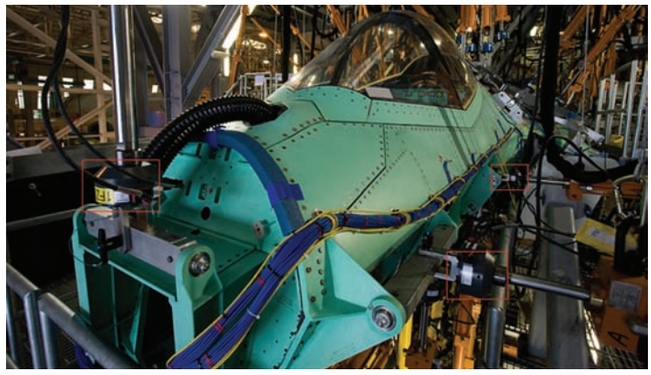
Although there are many standard product designs, custom load cell designs are often needed for specific applications. Depending on the function, load cells can be created in different sizes and profiles, with varying ranges, and for specific accuracy and sensitivity needs. This versatility brings us full circle, supporting what is perhaps the greatest benefit of load cell technology in aerospace applications – flexibility. ▮

Brian Duffy is the global applications engineering manager for Honeywell, sensing & control - Test & Measurement Products

"Load cells can be constructed to compensate for varying operational factors, particularly useful in flight applications"

Below left: Extensive inflight testing and monitoring on aircraft cockpit components is conducted utilizing load cells

Below right: Example of load cells used in airframe test system (courtesy BAE Systems)



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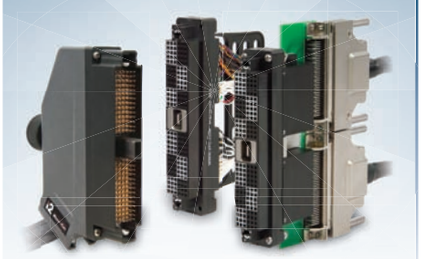

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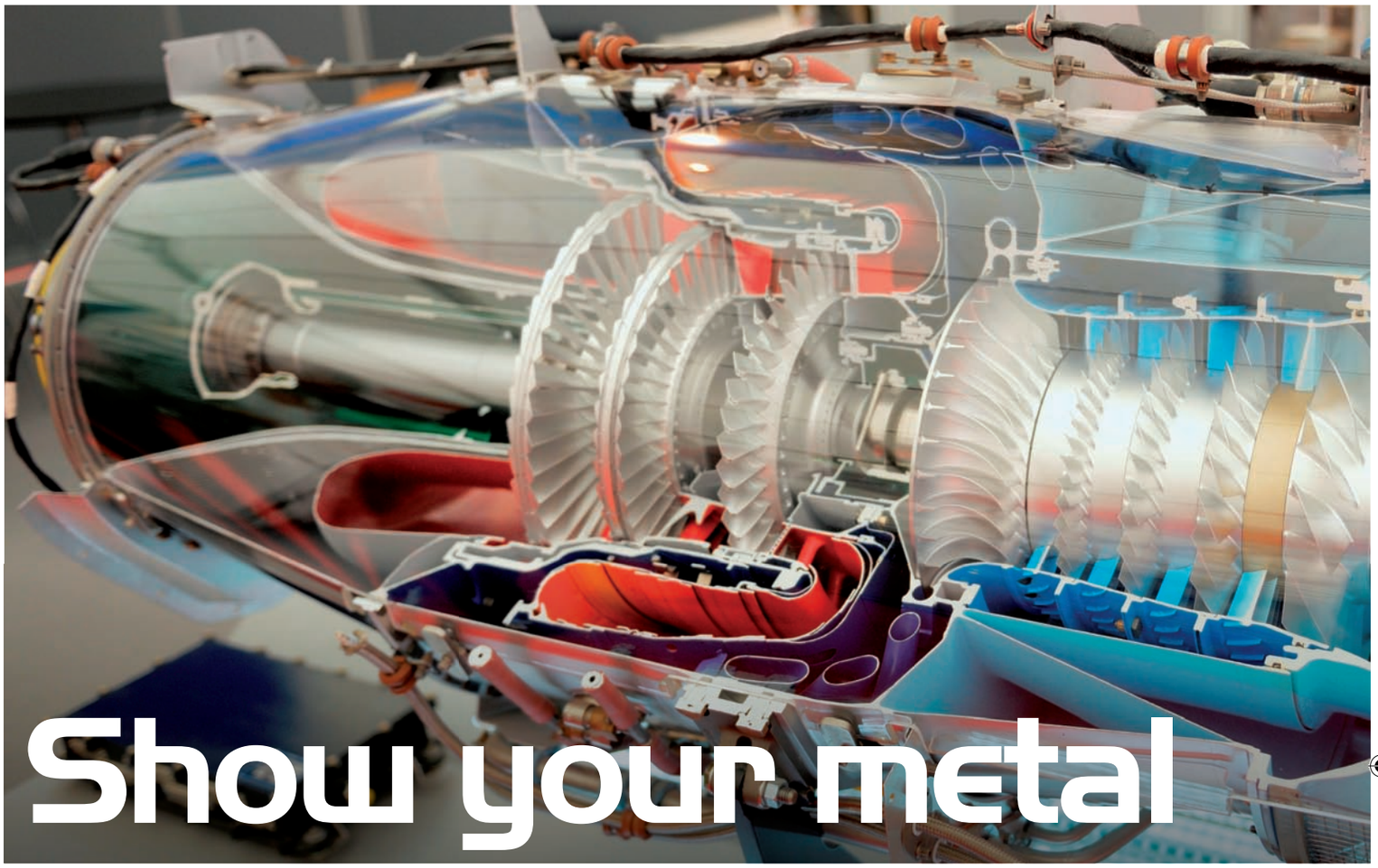


Show your metal

A NEW AND NOVEL QUALITY-CONTROL SYSTEM FOR THE INSPECTION OF TITANIUM COMPONENTS IN SAFETY-CRITICAL APPLICATIONS IN THE AEROSPACE INDUSTRY WILL HELP TO KEEP AIR TRAVEL SAFE

BY DR HARSHAD VIRJI PATEL

The inspection of titanium billets, for use in the manufacture of components such as engine turbine blades, is of particular interest in the field of aerospace non-destructive evaluation (NDE). This stems from the risk of component failure, induced by material defects in safety-critical components, with the potential for catastrophic consequences. Existing inspection systems can meet the prevailing requirements of production controls in terms of sensitivity to a minimum defect size.

However, the increasing demand on the performance of jet engines has created a need to inspect more thoroughly and detect ever-smaller defects. In addition, there is a distinct economic advantage in reducing the costs associated with manufacture and inspection. A drive now exists to develop advanced and reliable inspection technologies that support a defined specification for defect inspection, while minimizing costs.

Current production billet inspection systems are either 'conventional', using a single ultrasound transducer, or 'multizone inspection' (MZI), using a number of strategically positioned transducers to focus the ultrasonic beam at various depths in the material. The current approach relies on an ultrasonic transducer scanning across the surface of the component. This inspection technique takes place in a water-filled immersion tank, which provides an efficient ultrasonic medium between component and transducer.

A common drawback found in the use of ultrasonic transducers is the presence of a dead zone in the near surface of the material. This region receives unformed and incoherent acoustic energy, which results in a certain amount of material depth being uninspected. Conventional inspection systems achieve relatively low sensitivity, particularly on large diameter billets, whereas MZI achieves higher sensitivity but exhibits large variations in response.

These variations are attributed to the setup of the individual probes within the system and misalignment of the system with respect to the center of the billet. The challenge faced in detecting smaller defects is to increase the sensitivity while overcoming the variation due to misalignment.

Previous work has demonstrated that phased-array ultrasonic probes (PAUT) can better or equal the sensitivity achieved by MZI systems. The application of PAUT enables the steering and focus of the ultrasonic beam, offering advantages over conventional inspection techniques. The advantages include the inspection of larger areas without moving the probe while minimizing the size of the beam spot, which enhances inspection sensitivity.

Therefore, a PAUT, generating a number of ultrasonic sound beams that are designed to correct potential misalignments of the probe, can be introduced almost simultaneously at each sampling point on the billet. However, this approach does not automatically overcome the material losses due to the ultrasonic dead zone. An automated system that overcomes this loss, while maintaining the tighter specification for defect inspection in titanium billets, is a solution that is not currently available in the titanium billet manufacturing industry. The development of an automated system to address the challenges is being car-

Left: Aircraft engine cutaway, showing internal components, many of which are manufactured from titanium

Right: UNIBIG 5-leg eddy current transducer

ried out by a European part-funded consortium called QualiTi. Comprising several European companies and research institutes, the consortium is developing an integrated solution that brings together two complementary NDT techniques.

Concept design

A 2D Annular-Segmented Phased Array with Dual Concavity (ASDC) has been manuafactured, which will detect defects within the volume of the billet, employing beam steering to correct for variations in flaw response caused by misalignments. The ASDC system implements a 255 piezoelectric transducer elements array and has a center frequency of 5MHz. The probe has an elliptic shape with a long axis of 98mm and a short axis of 78mm, delivering a constant 2.5mm diameter beam spot at all inspection depths.

However, due to the strong interface echo from the front face of the sample, there is an ultrasonic dead zone of 5mm in the material when using the ASDC probe. To overcome this, a complementary multicoil eddy current (EC) inspection probe will detect surface flaws within the ultrasonic dead zone. The EC probe implements a novel configuration of five coils, which, when working in combination, can detect defects in any orientation. Combining the ASDC and EC inspection techniques in tandem should, therefore, help to attain 100% inspection coverage of the titanium billet.

Preliminary work

The project followed a comprehensive design plan that included a full simulation of the ASDC probe and performance analysis prior to manufacture. This indicated that the probe design did in fact match the requirements for inspection and confirmed that a 2.5mm beam spot size is achievable at the necessary inspection depths and for all required steering angles. Simulation also proved that the ASDC probe was capable of delivering consistent sensitivity levels, and showed compensation for the misalignment of the probe.

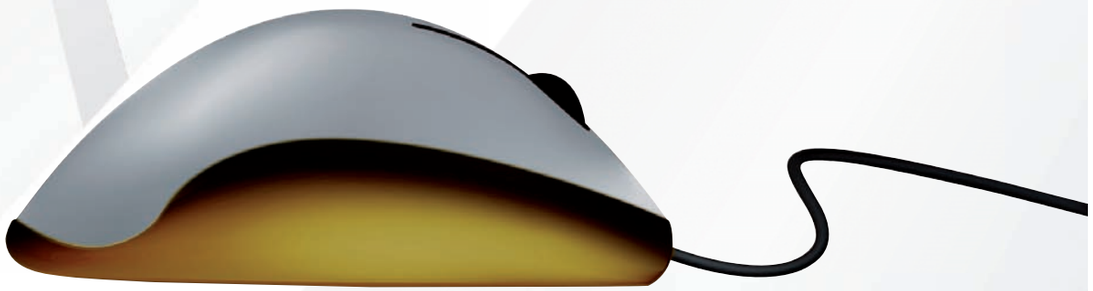
Preliminary measurements using the novel EC configuration have demonstrated the capability to detect small notches (5mm x 0.2mm) at depths of 2.8mm and 5mm. This shows that the configuration will deliver reliable detection of flaws in the ultrasonic dead zone.

Ongoing work

The integrated NDT systems require a purpose-built mechanical mount that enables tandem operation. A mechanical collar has been designed that encircles the sample and therefore maximizes the inspection area coverage. Further work will verify the performance of the integrated system to maximize repeatability and positional accuracy. A complete inspection trial will be performed to assess the system's capability/suitability for deployment in a manufacturing environment.

Funding has been received from the European Community's Seventh Framework Programme managed by REA-Research Executive Agency ([FP7/2007-2013) under grant agreement no. 222476'. ▮

Dr Harshad Virji Patel is the senior project leader at TWI NDT Validation Centre in Wales. Project website: www.qualiti.eu Project partners also include: West Pomeranian University of Technology (ZUT), Poland; TIMET, UK; France; TECNITEST, Spain; and ISO Test, Italy



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Check, check, and check again

A metallurgical analysis system being used by support manager Len Stott

COMPONENT FAILURE CAN LEAD TO A CATASTROPHIC EVENT, AND IT HAPPENS A LOT MORE THAN MAY BE IMAGINED. THERE IS AN ESSENTIAL NEED TO RE-INSPECT MATERIAL CERTIFICATIONS

BY DEBBIE MELLOR

Critical component failures often make the headlines, whether they occur at sea, under ground, in mid-air or in production plants. Faulty pipes, valves, shafts, gears, couplings, and other engineered components give rise to safety, environmental, productivity, and financial issues, some catastrophic. These failures result from design, manufacturing or assembly errors, inadequate quality assurance or unforeseen operating conditions, but sometimes they relate to substandard materials and improper processing treatments.

Independent metallurgical specialist Keighley Laboratories, based in Yorkshire, UK, points out that with growing volumes of steel, alloys, and metal components being sourced in the Far East from comparatively unknown suppliers, and manufacturers being ultimately responsible for any component failures, there is now a pressing need to re-inspect, or overcheck, material certifications.

In support of this view, there is a recent US study in which 133 out of 220 samples of imported steel rod were rated as failures by a certified test laboratory – an astonishing 60% failure rate.

"If you have specified imported material to a particular grade or heat treatment process, then overchecking is the best way to ensure you are getting what you paid for," says Michael Emmott, Keighley Laboratories Heat Treatment commercial manager. "Often we find that the raw material is not as specified, even with the correct certification, creating potential problems down the line.

"The cost of a chemical or mechanical overcheck or a full in-depth metallurgical analysis might be tens or hundreds of pounds or dollars, but if that item is safety-critical or forms part of a product worth hundreds of thousands, then it's a small price to pay," continues Emmott. "Given the legal implications of a failure in the field, it's a question of verifying incoming material or possibly putting your own business at risk."

Techniques and methods

Through its in-house Technical Services laboratory, Keighley Laboratories is able to provide independent chemical analysis, employing spectroscopy or classical wet methods; microscopic sample examination using metallography techniques; and mechanical testing for impact resistance, hardness, ductility, tensile strength, and durability. In addition to overchecking certificated materials, these specialist techniques are also used in the allied fields of reverse engineering and failure investigation.

Reverse engineering refers to the process of duplicating an engineered component or assembly without recourse to drawings, CAD files, specifications or documentation, determining exactly how it was originally made and treated and from what material.

"Customers often ask us to re-engineer specific low-volume, high-value components, and we apply reverse engineering techniques to such projects, usually introducing design and material upgrades as part of the process to improve it to better than original spec," says customer support manager Len Stott. "Reverse engineering can also be invaluable for remanufacturing a vital replacement part, where the original manufacturer no longer exists or drawings have been lost.

"It is also useful for reclassifying mixed stock, where materials have been mishandled in storage and certification is missing," he continues. "On mixed batches like this, we can test the hardness profiles, looking at depth and quality of case and the microhardness, then the surface hardness, to determine which material is actually fit for purpose and which has been wrongly classified."

Aerospace industry

In the aerospace industry especially, the consequences of the failure of one critical component are virtually incalculable, when you take into account consequential loss liability and any damage to corporate reputation and customer goodwill.

The Keighley Laboratories service also covers problem and failure investigation, employing forensic analysis techniques to determine why specific components have failed in the field to prevent similar problems in the future. Its senior metallurgists, who have extensive experience across a wide range of materials, treatments, and product types in many different industries, can also suggest from what material the component should be made and how it should be processed. It's just another useful weapon in the fight against critical component failure. ■

Debbie Mellor is the managing director of Keighley Laboratories, UK

Making data simple

THE IMPORTANCE OF MANAGING THE COMPLETE MEASUREMENT CHAIN AND AVOIDING COMMON PITFALLS IN SOUND AND VIBRATION DATA COLLECTION AND ANALYSIS

BY NOEL BROWN

High-value acoustic and vibration testing requires tools and solutions that provide the test engineer with high-quality data in the shortest possible time. Test measurement set-ups are often complex, with equipment and systems ranging from highly sensitive sensors, cabling and data acquisition front-ends, through to complex real-time and post-process analysis and reporting.

To manage this complex chain of equipment, integrated solutions powered by 'intelligent' products are hugely beneficial, eliminating potential errors and providing intuitive ease-of-use. This enables the user to set up, validate, calibrate, record, manage, analyze, document and report effectively – increasing efficiency throughout the measurement process.

Interfacing with the object

Planning, setting up and performing acoustic and vibration tests can be very different from one scenario to another. A number of factors have to be taken into account, including the nature of the test object, the test environment, and the operating conditions.

Measurement scenarios often range from just a few channels to hundreds, and a versatile data-acquisition system must therefore be scalable, modular and easily reconfigurable. Measurements must be 100% sample-synchronous between all of the measurement channels. The same data-acquisition system that performs large multichannel measurements with several rack systems one day should be easily divisible into multiple systems the next day, to make many smaller measurements at different locations – all without compromising performance, ease-of-use, or cost.

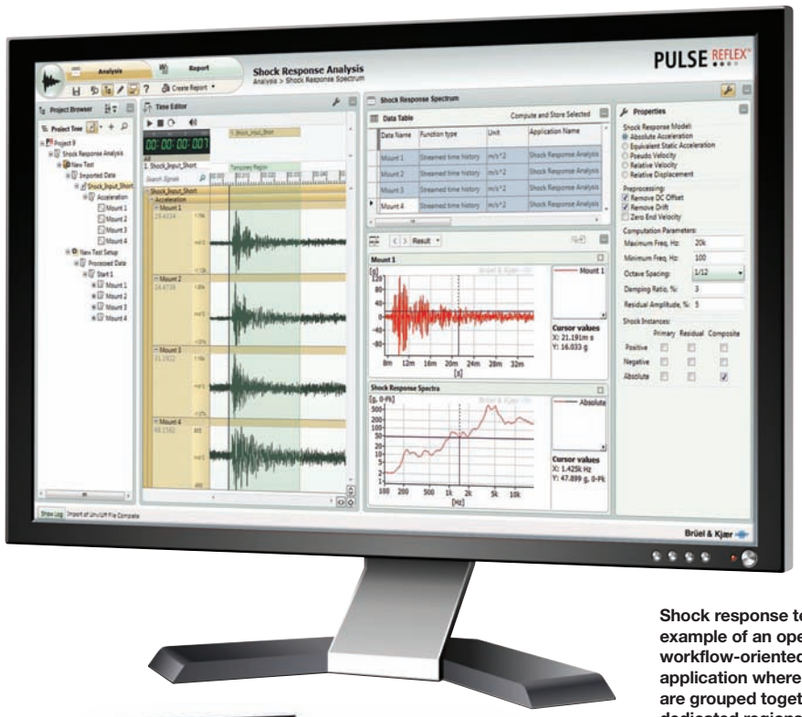
In general, it is advantageous to place the data-acquisition system as close as possible to the test object, to shorten the length of the transducer cables. Apart from significant cost savings on expensive high-quality transducer cables, and fewer set-up and measurement mistakes due to reduced cable infrastructure, short cables minimize the risk of adding noise to the data.

When choosing the sensor, Transducer Electronic Data Sheet (TEDS) IEEE 1451.4 Transducers will greatly help to improve set-up time. Even with just a few sensors, it can be a tedious and error-prone job to identify sensors and enter their specific data. The TEDS standard eliminates this by adding plug-and-play capabilities to analogue transducers, making it now an almost mandatory system feature.

Transducers with TEDS contain information about their sensitivity, serial number, manufacturer and calibration date. When a transducer with TEDS is connected to an input module supporting TEDS, it is automatically detected and its data is assimilated into the hardware and analyzer set-ups.

Verifying and calibrating

Having installed and set up the system, each channel needs to be verified and calibrated. When dealing with a data-acquisition system with multiple sensors, it is important to check all of the channels before and after a test, and here software tools are very useful



Shock response testing is an example of an open workflow-oriented software application where operations are grouped together in dedicated regions on-screen

to ensure correct calibration while measuring directly in engineering units.

Calibration normally involves physically using a calibrator to apply a calibration signal to the sensor. This can be a very time-consuming exercise, that is highly prone to human error, especially when operating with sensors in locations that are difficult to access, such as in wind tunnels, on large test objects, and in widely distributed systems.

For acoustical systems, Brüel & Kjær's Charge Injection Calibration (CIC) technique system enables a complete measurement chain to be verified, including the microphone. As the name implies, the method uses frequency-independent injection of a charge into the microphone and preamplifier input circuit technology.

Used in the right way, the CIC technique has the advantage that it can be used to increase the interval between costly acoustical calibrations. It enables the verification and diagnostics of hundreds of channels in just a few seconds.

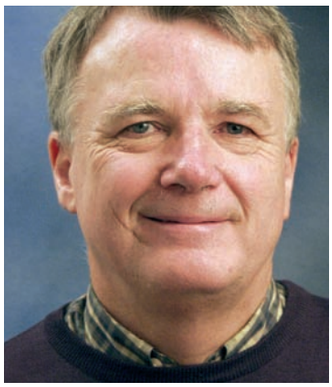
Setting up the measurements

With each channel verified and calibrated, measurements can now be taken. Time is often of the essence meaning there is typically little to ensure that input ranges are correctly set for each measurement channel. Dyn-X is a range of state-of-the-art input modules with a single analysis range exceeding 160dB. This means that there is no need for trial runs to ensure correct input ranges for the various input channels, so the certainty of getting the measurements right the first time is significantly increased.

To date, high-quality transducers and preamplifiers have outperformed measuring equipment with regard to linearity and dynamic performance, being able to deliver a noise- and distortion-free signal over a signal range of 120-130dB broadband and 160dB narrowband. With Dyn-X technology, the entire measurement and analysis chain matches or outperforms the transducer used for measurement. With no setting of input ranges, and with no need to be concerned about overloads, under-range measurements and measurement accuracy, the ease and safety of measurements are drastically increased using Dyn-X technology.

During a measurement it is important to avoid overloads that result in clipping of the signal and thereby ruining the information it contains. The vast dynamic range of the Dyn-X technology goes a long way to removing the problem of overloads, but intelligent data acquisition goes one step further by also managing so-called out-of-band overloads. Normally, if any overload occurs outside the measurement band of interest, the signal will be clipped.

Response equalization (REq-X) is a technique that enables the flattening and stretching of the frequency response of microphones, accelerometers and couplers in real time. This extends the frequency range of transducers, improves the accuracy of the measurement, and expands the uses of existing transducers. This means that the same microphone may be used for different sound fields: free-field, pres-



Left: Noel Brown is project manager, Brüel & Kjær, Sound & Vibration Measurement A/S

Measuring, recording and analyzing

Making measurements in real time provides an up-front feeling about whether a test is proceeding according to plan. Here, multi-analysis and parallel recording provide a very powerful combination. Exactly the same data is analyzed in multiple dimensions, such as FFT, CPB (nth Octave) and order-tracked, and at the same time recorded to disk. This saves a considerable amount of time compared to using post-processing to validate data. Even if the final results are to be achieved by performing post-processing, it is important to verify straight away that the data to be processed is good data.

With today's modern workstations, performance yields are reaching new heights that are capable of handling the high data throughput required. For example, using a Dell T7500 Westmere workstation - with a 6-core Intel Xeon X5670 processor, continuous data recording of ~600 channels @ 25.6kHz analogue bandwidth can be achieved. Simultaneous to the recording of data, all channels can be analyzed with a 400 line 25.6kHz FFT analysis. This generates some 150MB/s sustained data writing to RAID 0 configured hard drives.

With the data now verified and recorded to disk, test results must be filed. A typical test scenario then continues with post-processing to achieve the final analysis results. Full integration between the real-time analysis/recording system and the post-processing system provides the efficiency of a seamless flow of data.

However, it is still important to provide openness using an import browser to other systems to make comparisons and to merge data. A project browser is an essential data management tool, to include data search, filter, selection and editing of data descriptors. A display manager sets up and manipulates multiple pages of displays, and includes facilities for quickly sending selected graphs to a report. A time editor allows the review of imported time data and the selection of time ranges and subsets of channels for subsequent processing.

The process chain provides the heart of the post-analysis tool to set up and carry out the analysis using a graphical representation of the process, including filtering, analysis, display, and storage of results. A chain is made up of these elements, connected together, to form an analysis process. A scratchpad calculator is used to perform standard mathematical and statistical operations on single functions or groups of functions. Finally, a report organizer gives a complete overview of available templates and generated reports.

"The dynamic range of the Dyn-X technology goes a long way to removing the problem of overloads, but intelligent data acquisition goes one step further"

High-value acoustic and vibration testing requires tools and solutions that provide the test engineer with high-quality data in the shortest possible time

sure-field, and diffuse-field, independent of the type of microphone. What's more, the microphone can be corrected for angle-of-incidence in steps of 30˚, that is for 0˚, 300˚, 600˚, 900˚, 1,200˚, 1,500˚ and 1,800˚ angles-of-incidence, thereby improving the measurement accuracy by a further 5-10dB.

For a correctly mounted accelerometer you can expect REq-X to increase the highest recommended usable frequency range from 33% of the accelerometer's resonance frequency to 50% of the resonance frequency – an increase of 50%. This leads to better quality measurements all round. ▮

Noel Brown is project manager, Brüel & Kjær, Sound & Vibration Measurement A/S, based in Denmark

Filling the gap

THE GAPMAN GEN3 ELECTRONIC GAP MEASUREMENT SYSTEM FOR AIRCRAFT APPLICATIONS HAS HIGHER RESOLUTION, LONGER BATTERY LIFE, AND AN EASIER-TO-USE INTERFACE THAN ITS PREDECESSOR

BY BRYAN MANNING AND ROBERT L FOSTER

For years aircraft assembly and structural component manufacturers have been using traditional contact methods (plastic shims, feeler gauges, and step gauges) to measure gaps during production and final assembly of commercial and military aircraft.

Hundreds of gaps between metal/metal, metal/carbon fiber reinforced polymer (CFRP) and CFRP/CFRP surfaces must be measured and controlled during production to determine whether liquid or solid shimming is required. These gaps can be found in a variety of applications throughout the aircraft structure, from the front passenger doors to the vertical stabilizer. Figure 1 shows typical applications.

Control drives gap measurement

Due to increased standardization of process improvement methods such as SPC and Six Sigma, aircraft structural component manufacturers from Alenia to Lockheed are adjusting output specifications from their measurement instrument suppliers.

The new standards require the measurement, data capture, and documentation of an ever-increasing number of physical measurements, such as gaps, holes, and parallelism in their manufacturing and assembly processes. Traditional gap measurement methods, such as feeler gauges and plastic shims, cannot meet the new quality specs for accuracy and repeatability and are not able to automatically record and store error-free data.

Engineers have also found limitations and major reliability problems with these old methods. Shims and feeler gauge suffer from inadequate accuracy. Plastic shims can vary in thickness by 7.6µm and both these and feeler gauges cannot meet required operator-to-operator repeatability levels. In addition, accuracy is reduced over time due to shim wear from constant rubbing against hard surfaces, which can also cause damage to the target surfaces.

It is now common for these users to perform analysis of variance (ANOVA) between groups and gauge repeatability and reproducibility studies (Gauge R&Rs) to compare the capability of traditional measurement methods versus more modern methods, such as digital capacitive non-contact gap sensor instruments. A leading aircraft structure manufacturer recently tested and concluded that feeler gauges could not meet their Six Sigma requirements. Specifically, their Gauge R&R concluded that mechanical gauges totaled 45% measurement dispersion versus 20% or better for Capacitec gap gauges. Since feeler gauges showed a measurement dispersion of greater than the required 30% minimum for Six Sigma, they were forced to change. The solution was to use Gapman's capacitive gap measurement system, known as the electronic feeler gauge.

Sensor selection

The capacitive gap sensor wand model selection is application-driven and is chosen in reference to the following factors: minimum gap, gap range, target material combinations (metal/metal, metal/CFRP, CFRP/CFRP), difficulty of access to target, and so on. There are dozens of standard models of flexible wands and spring contact sabres along with the option of developing custom models according to customer needs.

Flexible wands

Kapton flexible wands are typically used to measure the thinnest gaps where the flexibility of the wand improves accessibility to the target. The thinnest gap measurement available can be found in Model GPD-(3X1)I-A-225, which offers a range from 0.15mm (0.006in) to 1mm (0.0394in). The popular Model GPD-4.5 (.0075)-A-250 has a range of 0.2mm (0.0075in) to 3mm (0.118in). Other models can be specified to have a range up to 10mm (0.394in)

Spring contact wands are typically used in applications where one or both targets are non-conductive, a target size is less than 2mm, or

"The new standards require the measurement, data capture, and documentation of an ever-increasing number of physical measurements..."

Left: Gapman Gen3 with flexible gap sensor wand

the surface or shape of the target is irregular. These are also the most popular choice for CFRP/CFRP applications where the minimum gap is greater than 0.64mm (0.025in). The Spring Contact wand Model GPD-5 (0.22)-A-150 has a range of 0.64mm (0.025in) to 3mm (0.118in) and the range of the GPD-10 (.034)-A-350 is 0.86mm (0.034in) to 10mm (0.394in).

For larger gaps such as the gaps between trailing edge flaps and the wing where the gaps typically run 20mm ±5mm, a custom wand can be offered. In this case a non-contact or spring contact wand is built onto a 15mm shim with a set of GPD-10 sensors giving a range of 15- 25mm.

The selection of integral or remote wand mounting configuration to the Gapman is according to customer preference.

Gapman Gen2

The Gapman Gen2 model was introduced with flexible wands in 1996. The remote versus integral configuration and availability of spring contact wands were introduced later. Today, most commercial and military aircraft manufacturers worldwide use the Capacitec Gapman Gen2 to measure and control gaps that typically range from 0.2-3mm (0.0078-0.118in). In the assembly of tail sections, a Gapman Gen2 with flexible wand is used to measure gaps 20cm (7.87in) inside the subassembly. A flexible wand can also be used for difficult-to-access targets.

The self-grounded spring contact sabre is often used to measure gaps between targets where one or both sides are composed of CFRP. In another application example, gap readings from the Gapman Gen2 are sent to a CNC machine, which manufactures custom shims that fit perfectly in the void between two structural components of the aircraft.

Gapman Gen3

The Gapman Gen3 was introduced in late 2010. Among the main design enhancements of the next-generation Gapman Gen3 are higher resolution output (0.00001in/0.254µm) with +/0.5% FS (12.7µm) typical accuracy with a GPD-5F wand; 10,000+ datapoint logging and storage capabilities; battery life doubled (now 22 hours minimum with 3AA lithium batteries); simplified PC user interface software to allow control of the outside button functions and storage of gap measurement data through USB or Zigbee wireless transfer.

With a compact form factor measuring just 56 x 220 x 28mm (2.2 x 8.7 x 1.1in) and weighing less than 1 lb (454g), the Gapman Gen3 features the same high-precision dual capacitive sensing technologies for position-compensated measurements as its predecessor, with components housed in a factory-floor-tested, highly rugged enclosure. Using standard and custom sensor probes that are backward compatible, Gapman Gen3 enables easy insertion into gaps as thin as 0.150mm (0.006in).

The Gapman Gen3 records and stores datapoints for easy transfer to SPC, in support of Six Sigma and other quality systems. Other next-generation enhancements include a bright blue alphanumeric Active Matrix OLED display; external menu selection buttons for millimeters/inches; a calibration button, to adjust to the standard of a known gap; and inclusion of an industry-standard USB Type A combination data output and external power port. With its user-friendly design enhancements, the Gapman Gen3 can be used to effectively measure gaps within a wider range of aircraft applications, including aircraft manufacturing and assembly operations, metal and rigid composite surfaces (CFRP), and aircraft engine build and rebuild. Other applications include flexible solar panel lamination, coater roller-to-roller parallelism, film production, and any other non-contact gap measurement application characterized by minimal gap tolerances and complex assemblies. ∎

Bryan Manning is commercial director for Capacitec Europe. Robert L Foster founder and president of Capacitec.

Margins of flutter

AIRBUS DISCOVERS THE ROUTE TO A STREAMLINED FLUTTER ANALYSIS PROCESS

BY JENNIFER SCHLEGEL

Modal identification methods used during flutter testing, along with the aircraft characteristics, have evolved to assure correct parameter identification. Frequencies and damping value estimations have to be as accurate as possible to define the aircraft fluttering margins used during those first mission-critical inflight test campaigns.

In a nutshell, flutter testing can be broken into three segments: real-time, near real-time, and offline. Inflight real-time test campaigns acquire live data during the test flight mostly as a safety check to continue the flight envelope. Near real-time testing focuses on rapid modal estimation to determine the overall safety of the flight and the flutter test program. Offline deals with the finer analysis of the recorded flight data and final report production.

To validate data efficiently and effectively offline, Airbus has chosen LMS Test.Lab Modal Analysis. It offers all the required functionality, such as data pre-processing, modal parameter estimation, mode shape animation, and result validation.

Bigger craft, new requirements

The Airbus flutter team in Toulouse, France, faced some challenges working on the Airbus A380 campaign, but there were issues they had faced before with the Airbus A340 flutter campaign: high modal density and similar mode shapes, both placed in a low, narrow frequency band.

In terms of modal identification, these new precise requirements called for a better-defined and better-equipped testing installation. This meant digging a bit to find the right kind of process. Measured data had to be recorded at enough locations, with sufficient quality, to improve power spectra and transfer function estimates and avoid spatial aliasing when working out aircraft deformed shapes. This required some innovative thinking and serious process validation in terms of current techniques.

Since 2001, Airbus France and LMS International have been cooperating on several EUREKA projects called FLITE (Flight Test Easy). An intergovernmental initiative to support market-oriented European R&D, the EUREKA FLITE projects focus on bringing new and powerful tools to structural engineers and aircraft designers, improving the quality and usefulness of data gathered during flight testing. The FLITE consortium gathers world-ranking aircraft manufacturers and technology providers from France, Belgium, and Poland. The FLITE projects offered a good opportunity to confront new advanced algorithms with challenging real-life aircraft data.

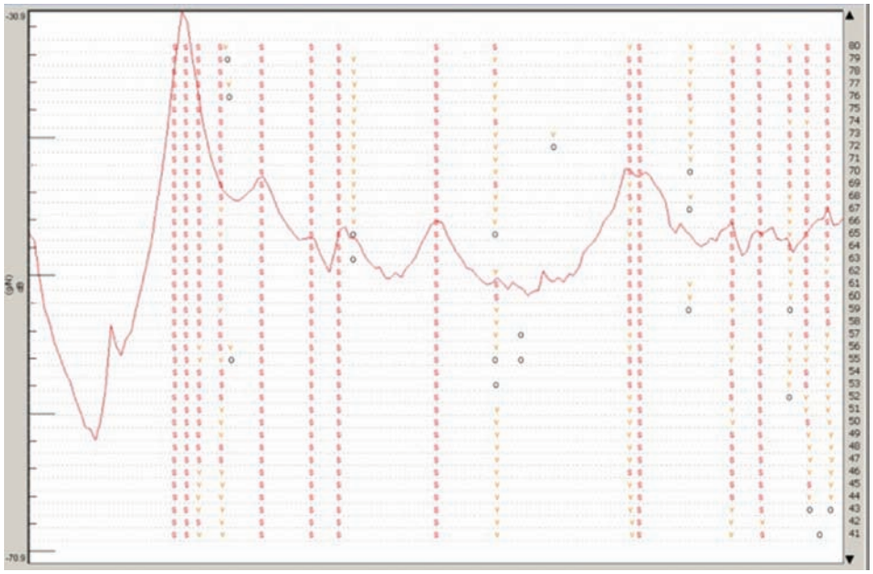
Finding the right data

In late 2007, LMS and Airbus agreed to start a project to evaluate LMS PolyMAX, an integrated part of the LMS Test.Lab Structures suite, as a key solution to achieve high-quality offline inflight data processing for flutter testing. The LMS Test.Lab Structures suite is a complete solution for modal analysis, combining high-speed multichannel data acquisition with a suite of integrated testing, analysis, and reporting tools. LMS is renowned for its modal testing experience and scalable solutions, from supporting impact testing on small structures up to large test campaigns using multiple shakers and hundreds of measurement channels.

In the past, the flight test departments of Airbus France performed data analysis using an in-house near-real-time analysis package and transferred the results, together with the raw data, to Airbus Germany where the numerical flutter predictions were correlated with actual flight tests. However, Airbus France felt the need to carry out some more in-depth data processing, so that they could transfer more complete results to Germany.

The LMS SCADAS data acquisition systems

"Clearly, we needed a solution that would improve the alignment between online inflight analysis occurring in Toulouse and the post-processing completed in the design center at Airbus, Germany," states Jean Roubertier, the flight test department aeroelasticity expert at Airbus. "At this stage, we are very pleased with



The clear LMS PolyMAX stabilization diagram allows easy identification of the many modes in the frequency band

the results. LMS Test.Lab is able to provide us with the right type of results."

Record-breaking data acquisition

Considering that the 525-seat Airbus A380 is the largest commercial passenger aircraft in the skies today, it isn't surprising that the acquired inflight testing data also breaks records.

"With more than 100 sensors, this was one of the largest setups for an in-flight flutter test campaign I have ever seen," explains Bart Peeters, LMS Research project manager. "Also, the number of tests under different flight conditions is impressive and the resulting database is immense, and so efficient processing and report generation capabilities are required."

The Airbus flutter team in Toulouse performed a variety of excitations including control surfaces sine sweeps and pulses. Pulses are currently used to assure crew and aircraft safety, whereas sweeps are used to work out more accurate results and enable an update of theoretical FE models. Due to integrating pulses into the process, flutter flights' duration time has been considerably reduced.

Technically speaking, the basic concept behind the project was to compare classical experimental modal analysis (EMA) with LMS Test.Lab's Operational Modal Analysis (OMA) technique. With classical EMA, the control surface excitation and aircraft response signals are converted to frequency response functions (FRFs). During the actual flight, other excitation sources are present, such as turbulence. Sometimes, this results in noisy FRFs. For example, an aircraft tail response sensor receives a rather limited contribution from the wing excitation. Therefore, the idea arose to neglect the excitation signal and apply OMA to the aircraft acceleration signals.

"We actually achieved better results using OMA than with classical EMA," reveals Miquel Angel Oliver Escandell, a member of the Airbus flutter team who was dedicated to the project for a year. "We found more modes. The synthesis was better with higher correlation and fewer errors. And the in-flight mode shapes looked much nicer, due to the number of sensors we used and the OMA capabilities of LMS Test.Lab."

Even with projects of this scale, there is always noise in the data that needs to be managed. LMS Test.Lab paints a really clear picture with techniques that produce clear analysis results even from rather noisy data. This feature really offers clients such as Airbus a true competitive advantage in terms of offline test processing.

"We found that the exponential window, which enabled cross-correlation calculations, was a good de-noising tool for our inflight data," says Escandell. "And the validation tools such as correlation levels, MAC matrix, and mode shape complexity (MPD and MPC criteria) are very complementary in terms of real-time identifications performed during flutter tests."

During the comparison testing, the flutter team at Airbus used LMS PolyMAX during sweep excitations of the aircraft. Results, using an exponential window of 5%, appear to be good, supplying high synthesis correlations (98% using just two references) and clear stabilization diagrams.

"We've been extremely impressed by the flutter analysis results and the way that the LMS Test.Lab software can handle the challenges of processing the immense amount of Airbus A380 inflight data during the offline analysis," says Roubertier. ▮

Jennifer Schlegel is the copywriter for LMS

Measured mode shapes estimated from in-flight sensor data. A wing-bending mode (top) and fuselage bending mode (bottom) are shown

Avionics for high flyers

AN INTEGRATED DEVELOPMENT PROCESS USING STRAIGHTFORWARD INTERFACE BOARDS IS IN ACTION ON THE JSF PROGRAM

BY DR ANDREAS HIMMLER

The MIL-STD-1553, ARINC 429, ARINC 717 avionics databuses are widely used in areas such as engine management (FADEC), flight surface actuation, guidance, and navigation. The control systems in these applications are extremely complex.

To reduce the manual workload of developing and testing the systems, and to avoid expensive mistakes, an integrated development process is essential. It can be achieved with dSPACE interface boards for hardware-in-the-loop (HIL) testing and rapid control prototyping (RCP). The boards are being used in the Joint Strike Fighter F35 program, the NPOESS program (a US environmental satellite), and other projects.

Integrated development process

The solutions for MIL-STD-1553, ARINC 429 and ARINC 717 are based on modules that are integrated into dSPACE's Peripheral High-Speed (PHS) bus by special carrier boards. They ideally combine the short latencies of dSPACE hardware with industry-proven bus system boards, and help to set up seamless development processes from model-based development to release tests on HIL simulators.

To connect the bus interfaces, there are special blocksets that provide access to the real-time (plant or controller) model plus a graphical environment for intuitively configuring communication. Bus-specific real-time interface (RTI) blocksets are used to transfer the functionality to the buses. Another advantage is that the bus communication is configured into specialist files, so the models can be parameterized in Simulink.

MIL-STD-1553

The interface board for MIL-STD-1553 has four doubly redundant channels that comply with MIL-STD-1553 A/B Notice II. Each channel can be configured independently as a bus controller, a remote terminal, or a bus monitor, so the interface board is perfect for developing components and testing networks.

The associated RTI blockset contains a library with send and receive blocks for remote terminals. The blocks in it give users access to the channels' functional behavior, their physical level, the transmitted messages, and status information. The outputs of the receive blocks also make time stamps, commands, status messages, and message counts available within the real-time model. The blocks enable 32 remote terminals to be simulated on a MIL-STD-1553 bus, and users can set sub-addresses, the word count, mode codes, and broadcast messages for each remote terminal.

Both the physical bus level and the transmission behavior can be manipulated to perform error testing. The bus output voltage can be either predefined or fed in from the outside. The times for no-response and late-response timeouts can be set for transmission behavior tests. Messages to be monitored with a bus monitor are not only available in the real-time model, but can also be sent to a PC via Ethernet.

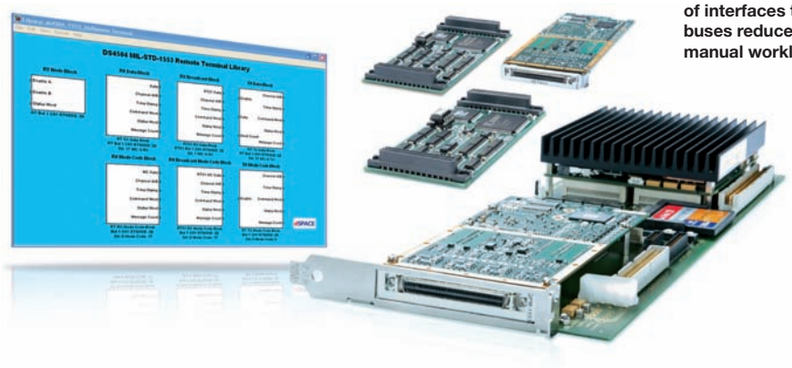
ARINC 429 and ARINC 717

The interface board for ARINC 429 has 32 send and 32 receive channels for testing avionics networks, including the communication between a large number of bus nodes. The configuration files define all the properties of the ARINC labels: data format, start bit, data length, scaling factor, and SDI filter. This makes it easy to change the labels. With the data from the configuration files, the ARINC messages are generated automatically by Encode and Decode blocks in the real-time models, and payload data can also be extracted from the received ARINC messages. To perform tests for erroneous bus transmission, errors can be inserted for bit-count, inter-message-gap, and parity errors.

There is now also a dSPACE interface board for ARINC717, offering the same network-testing features as the ARINC 429 interface. ▮

Dr Andreas Himmler is the product manager for dSPACE GmbH in Germany

Many aerospace applications use MIL STD-1553, ARINC 429, and ARINC 717 buses. JSK picture courtesy Lockheed Martin.



Graphical programming of interfaces to avionics buses reduces manual workloads

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Puma reborn

DESPITE SWEEPING DEFENSE CUTBACKS IN THE UK, THE RAF IS STILL GOING AHEAD WITH ITS PROGRAM TO UPGRADE ITS FLEET OF AGING PUMAS FOR THE SUPPORT HELICOPTER FORCE

BY DAVID OLIVER

The RAF's long-serving Puma support helicopters are currently undergoing a life extension program that will see a number of integrated modifications made to the aircraft to enable it to cope more effectively with the intense heat and increased altitudes of current operational theaters.

Originally developed to meet a French Army requirement, the Aerospatiale SA 330 was selected for the RAF Tactical Transport Program in 1967, with 40 Westland-built SA 330E Pumas being delivered. The Puma HC.1 first entered service at RAF Odiham in 1971, and the RAF currently has a fleet of 34 aircraft available to the frontline Support Helicopter (SH) Force. The aircraft are operated by Nos 33 and 230 Squadrons, both based at RAF Benson.

As support helicopters within the Joint Helicopter Command (JHC), the Pumas are used in the classic support roles of tactical troop transport and internal and underslung load movements by day or night. The aircraft can accommodate up to 20 troops or up to 2 metric tons of freight and another of its major roles is that of casualty evacuation for which six stretchers can be fitted. The normal crew of two pilots, or a pilot and a weapons systems officer, plus a

RAF aging Pumas are operated in the challenging terrain and climatic conditions of Kenya to support British Army training exercises (Photo David Oliver)

crewman, is trained in procedural instrument flying and tactical low flying by day, and by night using night-vision goggles (NVG). The aircrew and supporting ground crew are also trained to operate from remote and inhospitable areas in all conditions, ranging from desert to arctic environments.

Since entering service the Puma has been involved in numerous worldwide military and humanitarian operations, including those in Northern Ireland, Zimbabwe, Yugoslavia, and Iraq. The extant fleet currently supports army exercises in the UK and Norway, and since RAF Puma SH force was withdrawn from Iraq in 2009, it has provided a permanent detachment of Puma HC Mk1s under the umbrella of Joint Helicopter Force (Kenya) (JHF(K)) to provide air support to British Army units taking part in the regular brigade-size Askari Thunder exercises.

After nearly 40 years of continuous service, the Puma fleet had accumulated airworthiness, safety, and obsolescence issues and was in need of refurbishment, and if possible an upgrade of its powerplants, avionics, and defensive aids systems. In September 2009, Eurocopter was awarded a £300 million (approx US$484.7 million) Puma helicopter life extension program (LEP) contract to upgrade 28 Puma HC Mk1s plus two options.

"In September 2009, Eurocopter was awarded a £300 million Puma helicopter life extension program contract"

Following the 2010 UK general election, the new coalition government announced a far-reaching Strategic Defence and Security Review (SDSR) and the Puma LEP was one of many defense programs that was under threat. Much to the surprise of many pundits, and the relief of the RAF Puma community, the UK government confirmed the Puma helicopter upgrade program in October 2010 at a total cost of £339 million (US$547.6 million).

New installations

As part of the UK government's Future Rotary Wing Strategy, the Puma LEP includes replacing the two 1,435shp Turbomeca Turmo IVC turboshaft engines with 1,877shp Turbomeca Makila 1A1 turboshafts, and the installation of a Eurocopter EC 725-style glass cockpit. The Puma HC.2 will have a new flight management system (FMS), Bowman and Thales tactical communications and information systems, and a Selex Galileo integrated Defensive Aid System (DAS). A fifth internal fuel tank will also be fitted plus a composite tail rotor.

The first helicopter to be converted to HC Mk2 arrived at Eurocopter's UK base at London Oxford (Kidlington) Airport on October 19, 2010 prior to being stripped down and transported to Eurocopter Marignane, which holds the type's

Right: RAF Puma aircrew are trained to operate from remote and inhospitable areas in all conditions ranging from desert to arctic environments (Photo David Oliver)

Below: The Puma HC Mk2 production line at Eurocopter's Marignane facility, where the first four aircraft will be upgraded (Photo Eurocopter)

design authority. It is currently being reassembled for a first flight in April 2011. Eurocopter and QinetiQ test pilots will be involved in the program, which is being overseen by the MoD's Puma Project Team, based at Yeovilton, part of the Helicopters Operating Centre within Defence Equipment & Support (DE&S). It is responsible for delivering the Puma helicopter LEP to provide helicopter capability to the frontline by addressing the safety, airworthiness, and obsolescence issues currently facing the Puma HC Mk1 throughout the upgrade program.

The Rotary Wing Test & Evaluation Squadron (RWTES), a tri-service unit based at MoD Boscombe Down, is part of the Air Warfare Centre alongside QinetiQ within the air test and evaluation collaboration. It is primarily responsible for assisting with the provision of 'release to service' recommendations for helicopters and their equipment.

Trials involving new major modifications to the Puma aircraft will be conducted with combined test teams with representatives from Eurocopter, RWTES, QinetiQ, and the Operational Evaluation Unit (OEU) of the RAF. For regulatory purposes the QinetiQ-MoD partnering arrangement that is approved to conduct flight testing is referred to as the Aircraft Test and Evaluation Collaboration (ATEC). The commanders of the two Puma squadrons, both graduates of the Empire Test Pilot's School (ETPS), have been involved in devising the training program for the OEU at RAF Benson.

Overseas outsourcing

Four Pumas will undergo conversion at Marignane, while the remaining helicopters will be transported to IAR SA Brasov in Romania. Having manufactured some 150 Pumas under license, IAR was selected for the program by virtue of it having produced upgraded versions with Makila turboshafts and glass cockpits for the UAE Air Force. Final assembly and initial test flying of the upgraded aircraft will take place at Oxford. Initial operational capability (IOC) for the Puma HC Mk2 is scheduled for December 2012. The life of the upgraded Pumas has been extended to 2025. In June 2010, the MoD awarded CAE a contract to upgrade the Puma helicopter full-mission simulator located at the company's medium support helicopter aircrew training facility (MSHATF) at RAF Benson to ensure concurrency with the new Puma HC Mk2 helicopter by mid-2012.

The DE&S Puma Team has signed an amendment for the through-life support contract with Eurocopter, the first phase of which included the repair, overhaul, and provision of spares with the team. A transitional period will enable the company to develop a tailored program for DE&S. ▮

Below left: Puma HC Mk1 support helicopters were deployed to the deserts of Iraq until 2009 (Photo RAF Benson)

Below right: Two Puma HC Mk1 helicopters being stripped down at Eurocopter's UK base at London Oxford (Kidlington) Airport prior to HC Mk2 conversion (Photo Eurocopter)

Bottom right: A pair of Puma HC Mk1s recover to their base at RAF Benson (Photo David Oliver)

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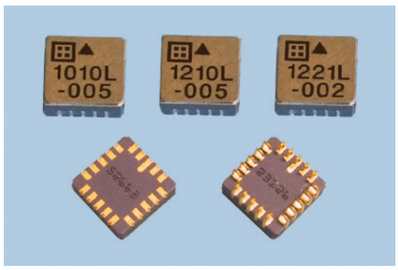
Versatile MEMS capacitive accelerometer modules and chips

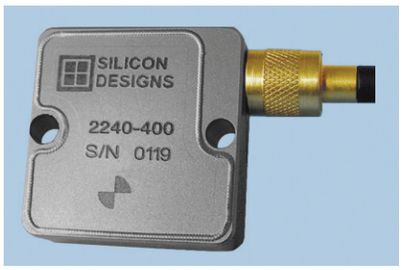
Based in Seattle, Washington, Silicon Designs (SDI) specializes in the design and manufacture of highly rugged industrial grade MEMS capacitive accelerometer modules and chips with integrated amplification to support the rigorous testing requirements of military and commercial aircraft OEMs and associated test facilities, as well as government customers in the USA, Europe and Asia.

SDI accelerometer modules are available in ranges from 2*g* to more than 20,000*g*. Within standard range (2–400*g*), most models continue to reliably operate after sustained exposures of up to 10,000*g* shock and limited temperature exposures above +200°C. Carefully regulated in-house manufacturing processes ensure that each sensor is made to be virtually identical, allowing users to swap modules with minimal modifications, saving time and resources, and providing a quick plug-and-play solution for almost any application, with total trust in sensor accuracy when used within published specifications. More than 300 SDI product models are also available at specially discounted rates to US government customers under the 2011 GSA Advantage program.

The versatility of SDI modules and chips for aerospace testing can be illustrated by the wide variety of supported applications found among just a few standard models. For example, SDI 2220 and 2240 series single-axis MEMS capacitive accelerometer modules are offered in ranges of 50*g* and 100*g*, respectively, and can be specified for aircraft engine vibration monitoring due to their measurement stability, ability to respond to both AC and DC acceleration, reliable operation in high and low temperatures and low power consumption. These low-noise sensors are +9 to +32VDC powered and offered with either buffered ±4V differential or 0.5V to 4.5V single ended output with an internal voltage regulator and reference. The SDI 2220 series is housed in an anodized aluminum case, while the 2240 series features a hermetically sealed titanium case with removable plug and cable. When ordered in ranges of 5*g*, 10*g* and 25*g*, the same modules offer necessary DC response capabilities to make required low-frequency precision measurements of aircraft flutter. At 50*g* and 400*g* ranges, modules can also offer necessary shock and vibration capabilities to support high-impact landing gear monitoring and testing. Units of these specified ranges may also be used to support payload testing, as well as the testing of externally mounted accessories, such as drop tanks, weapons and radome. Series models are available with custom low-pass filters and optional higher temperature versions to +150°C. They feature a simple four-wire connection and a low weight of 10g with low-impedance outputs that will drive 15m of cable.

As the OEM of its own high-quality, low-cost, LCC and JCC accelerometer chips, SDI can offer highly rugged, compact and lightweight, hermetically sealed units for aerospace shock and vibration testing, combining a MEMS capacitive sensing element, custom integrated circuit and a sensing amplifier. These chips are frequently used for the testing and evaluation of critical aerospace safety systems, such as the monitoring of aircraft seat ejectors. SDI 1010 series accelerometer chips, with digital pulse density output, and the 1210 series, with analog ±4V differential output, are both used to monitor seat control after ejection and parachute deployment in both military and commercial aircraft. The SDI 1010 series is available in measurement ranges from 2*g* to 200*g*, while 1210 series chips are offered with measurement ranges from 5*g* to 400*g* to support higher shock and vibration levels. Both offer ±5V operation and measure just 8.89mm^2 x 2.54mm, with a total weight of just 0.62g. The units are ideally suited for zero-to-medium frequency instrumentation applications and offer reliable operation in temperatures up to +125°C. The analog, low-noise, differential output alternative to the 1010 and 1210 series, the 1221 series, is often effectively combined with a GPS and gyroscope to offer high-performance shock and vibration monitoring within aerospace-related inertial navigation systems. For more information about these and other products available from Silicon Designs, visit www.silicondesigns.com.





Above left: Low-cost MEMS capacitive accelerometer chips are used to monitor critical aerospace safety systems

Above right: Silicon Designs 2240 series modules have the necessary versatility to be used across a diverse range of aerospace testing applications

Left: When specified in ranges of 5*g* to 25*g*, 2240 series modules offer necessary DC response capabilities to effectively measure aircraft flutter

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Go to online reader enquiry number 101

Airborne accelerometers

For more than 30 years, Dytran Instruments has been a global industry leader in the design and manufacture of sensors for dynamic acceleration, force and pressure sensing. The company's rapidly growing military and aerospace portfolio includes piezoelectric, variable capacitance and DC response sensing technologies, with numerous models now flight qualified to meet even the most demanding flight test, ground vibration testing, UAV, modal and structural analysis and health and usage monitoring systems (HUMS) applications.

Sensors specified for airborne applications must offer a wide frequency range, exhibit great temperature stability and be able to reliably perform over many hours of service. The accelerometers must be highly rugged; typically, hermetically sealed for reliable operation in harsh and dirty environments; and either base or case isolated, to avoid electromagnetic or ground loop interference. Certain applications also call for miniature or teardrop styles, which minimize mass loading effects and can be installed in hard-to-reach areas of the aircraft; higher temperature versions for engine monitoring; specialty mounting styles, allowing for 360° cable orientation or other easy installation measures; or custom designs to support specific customer program requirements.

Of the available off-the-shelf airborne sensing technologies, IEPE accelerometers are some of the most popular, due to their integral electronics; availability in various styles, sizes and sensitivities; and overall versatility and ease of integration across multiple types of aerospace testing environments.

Three examples of the most popular Dytran standard airborne accelerometer models include: for flight and flutter testing, the Dytran model 3220M6 is a miniature, low-profile IEPE accelerometer with a 10mV/g sensitivity, incorporating the use of high-stability quartz shear technology and packaged in a highly rugged stainless steel housing. Electrical connection for the model 3220M6 is achieved via integral wires soldered to two terminals on the unit. Sensors are both hermetically sealed and base isolated, with the anodized base bonded to the lower mounting surface, in order to achieve proper electrical isolation from structure ground, a typical requirement of this installation environment.

For commercial and military aircraft vibration monitoring, the Dytran model 3168F is a ring-style IEPE accelerometer, incorporating a high-stability quartz shear sensing element, packaged in a stainless steel housing. The accelerometer is offered with a sensitivity of 10mV/g and features a miniature 'thru-hole' mounting configuration, allowing the sensor to be turned 360° prior to securing for ease of installation. Units are hermetically sealed for reliable operation within high-humidity and dirty environments, as well as case isolated to avoid ground loop interference. The model 3168F also features a rugged integral molded Viton cable, terminating in twisted shielded pair flying leads. This high-precision accelerometer is expressly designed for aircraft gearbox and transmission measurements; rotor, track and balance in HUMS applications; and airframe vibration measurements.

Rotorcraft and fixed wing aircraft vibration monitoring, as components of an aerospace customer's predictive maintenance strategy, is a particularly strong application area for Dytran in the HUMS marketplace. To meet these requirements, Dytran offers a number of accelerometer types, including the 3062A series of IEPE accelerometers, which has been expressly designed to cover the most critical frequencies for points of rotor, track and balance; airframes; and fixed wing aircraft. The industry has commonly referred to the sensors as "spark plug-type", due to their similar appearance. Available in two models with sensitivities of 10 and 25mV/g, Dytran 3062A series units feature hermetically sealed stainless steel construction and case isolation. Both models feature a top mounted military-style 3-pin bayonet connector, 1/4-28 mounting threads and lockwire holes.

In addition, Dytran offers vertically integrated custom manufacturing capabilities that include its own design and machining operations. At its AS9100 and ISO9001:2008 certified facility in Chatsworth, California, USA, the company offers the necessary expertise to design and package nearly any sensor, connector or cable type to precise customer or program specifications with short lead times. Calibration services are also A2LA accredited to the ISO 17025 standard, ensuring the quality and uniformity of sensors and instrumentation, all tested according to rigorous in-house standards.

Right: 'Spark-plug type' accelerometers, such as the 3062A series, cover the most critical frequencies for points of rotor, track and balance, airframes and fixed-wing aircraft

Below: The Dytran model 3220M6, a miniature, low-profile IEPE accelerometer

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Hydraulic services

Austrian company Test-Fuchs will soon complete its first major project for an airline program. It will provide hydraulic services for four of seven production stages at its customer's final assembly line at a facility in Charleston, South Carolina.

The customer requires four sets of Test-Fuchs' Hydraulic System and Flushing System (HSFS787), which have the ability to supply aircraft with a pressure of 5,000psi. Each set consists of a hydraulic power unit (HPU), a flushing unit (FU), and a human machine interface (HMI).

This hydraulic set with integrated pressure, temperature, and flow sensors will fill, flush, and test the hydraulic system at the same time as observing the contamination level of the aircraft hydraulic system. The requirement for high pressure (5,000psi) and high flow rate (50gpm) on three separate outlets (left, center, and right systems), plus six separate outlets for flushing means that a bigger rig is needed, approximately 12.5ft long and weighing about 6,000kg.

A highlight of the project is an efficient purification unit, which has been developed to remove water, gases, and solvents from oils such as lubrication fluids, coolants, and synthetic fluids. The usage of this purifier increases the equipment's reliability and performance and therefore leads to a reduction in maintenance costs.

The Test-Fuchs system was designed to meet the ergonomic requirements for easy operation, and in order to reduce the noise level all doors are sound isolated.

The integrated measuring and control system, operated using a touchscreen, enables individual software adaptation and therefore guarantees very easy handling. Therefore it is possible to switch between preset pressure values by just one click, or to start the rig at the push of a single button.

To make operation and maintenance as easy as possible the interface has a separate mode for each task.

The remote control HMI (human machine interface) provides the operator with further possibilities. The customer can place the hydraulic power unit (HPU) in a separate room and with the external hoses and pipes in a trench, the accessibility of the working area can be improved. As a consequence, the user interface handling does not require any special training.

The flushing unit completes the test system. This unit has six separate outlets with a maximum pressure of 1,750psi at a flow rate of 30gpm and is used to flush all hydraulic pipes in the aircraft.

After-sales service is in the form of remote maintenance facilities. Test-Fuchs can access the control and measuring system and is therefore able to assist during any troubleshooting (the system is of course protected against unpermitted access).

With the installation of this special test system, Test-Fuchs is proud to participate again in the production of a new aircraft.

Test-Fuchs flushing unit

Hydraulic power unit and human machine interface from Test-Fuchs

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Go to online reader enquiry number 103

Rugged data recording

Brüel & Kjær's modular data acquisition system, PULSE LAN-XI, has become even more like a 'Swiss Army Knife' since the debut of a standalone data recorder option for sound and vibration measurements, called the Notar. The PULSE LAN-XI Notar technology uses firmware to take any existing PULSE LAN-XI module and convert it into a battery-powered data recorder.

With its small form factor and rugged design, the versatile LAN-XI range provides an assortment of solutions to suit all sound and vibration applications. The modules' removable front panels provide a range of connector types and channel inputs that contain built-in power and conditioning for all relevant sound and vibration transducers, including ICP sensors, microphones, accelerometers, charge, voltage inputs, and tachometers systems.

Channel counts up to 12 channels per module are available, and frequency ranges up to 100kHz (262.4 ksamples/s). Control is via a built-in LCD screen or remotely via web browsers and smartphones. Battery operation provides more than seven hours of measurement time storing data to a solid-state memory card.

Brüel & Kjær's patented Dyn-X technology provides a huge dynamic range for Notar, while intelligent inter-connectivity is built into the system with TEDS transducers being automatically configured.

For further information contact
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Secure, miniature GPS for the military

Rockwell Collins has unveiled its MicroGRAM GPS receiver, which is 90% smaller than the earlier version of its miniature precision lightweight GPS receiver engine SAASM (MPETM-S). The extraordinary size reduction means that equipment such as handheld radios, ruggedized field computers, laser range finders, gun scopes and small unmanned aircraft can be equipped with secure GPS capability.

"Today's warfighters must be prepared to find their way in unfamiliar environments, along with having precision accuracy in their weapons systems. Our new MicroGRAM opens up a whole new world of secure, military GPS technology for equipment that previously could not have it," said Bob Haag, vice president and general manager of Precision Strike and Navigation Products for Rockwell Collins. "Before now, this equipment could only use commercial GPS technology, which does not have the required military security features that warfighters need to avoid enemy threats." The MicroGRAM has also been optimized to allow rapid acquisition of the GPS satellites when the power is first supplied.

For further information contact
www.rockwellcollins.com

Proven sensing designs

For more than 60 years, Meggitt's Endevco® accelerometers, acoustic, vibration and pressure sensors have been widely used in aerospace testing applications such as flutter testing, ground vibration testing, high-temperature jet and turboprop engine monitoring, aerodynamic studies, turbulent flow measurements, landing gear response testing, static airframe testing and aircraft carrier qualifications.

These highly rugged, field-proven designs offer precision amplitude, frequency and phase response, as well as stable performance over extreme in-flight speeds and temperatures, with precise data matching from multiple sensors. In addition, high-output, ground isolated, low-noise piezoelectric HUMS accelerometers are used to measure low-frequency phase and vibration in rotor-tracking and balance applications. High resonance frequency models offer linear response to 10kHz for rotating part diagnostics, gearbox bearing assessments and shaft monitoring. Sensors feature low base strain sensitivity, as well as a reliable hermetic connector and integral cable, essential for use in harsh environments, with 'thru-bolt' designs for installation in space constrained areas.

In addition, Endevco impact sensors are widely used in ship-to-air and air-to-air missiles testing and have remained the sensing technology of choice for the US Navy for more than 20 years. Piezoresistive pressure sensors are also used in altitude and airspeed measurements within these systems.

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F-35 to use robotic paint system

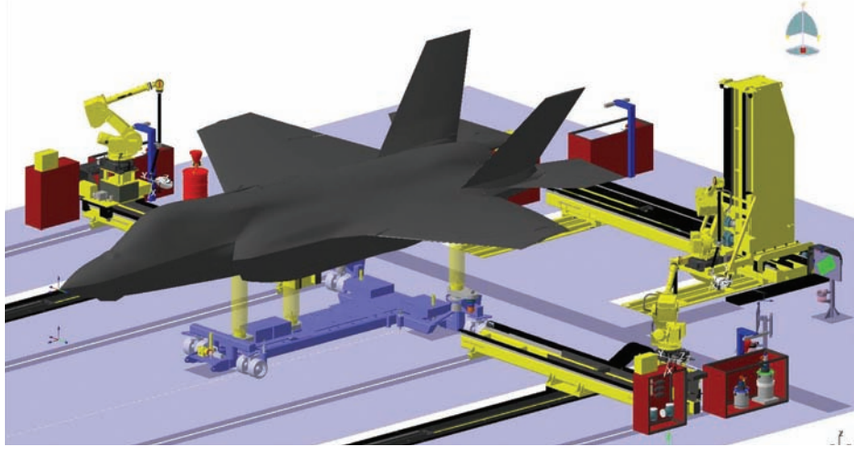
Dassault Systèmes has announced that Lockheed Martin has migrated its F-35 Lightning II robotic painting workcells to Dassault Systèmes' Delmia Robotics. A long-time user of Delmia manufacturing simulation solutions, Lockheed Martin's new implementation of Delmia Robotics has made the company's manufacturing processes more efficient, leveraging a common interface across its Catia design authoring and Delmia digital manufacturing solutions.

Lockheed Martin uses simulations to verify that the robots will reach all the painting positions while avoiding any collisions. Automating the paint and coatings process provides significant time savings, as well as better process control. Additionally, protecting workers from potentially harmful paint fumes is an added benefit of robots. The company had already experienced success with the previous generation of Delmia Robotics simulation. Since they are already familiar with the Catia interface, Lockheed Martin NC programmers easily move into robot support roles, pick up the software and produce programs.

Lockheed Martin currently employs the robotic solution in two different automated paint cells, both configured on moving rail systems. A three-robot cell is dedicated to painting the aircraft exterior and a two-robot cell is configured to handle a variety of F-35 components. Both the physical cell and the robot programming have been designed for flexibility through optimization and verification of the programs in the virtual Delmia environment so that the company can paint different mixes of components at different times.

Enhancements within the Delmia Cenit Fastsurf solution make it easier to modify existing robot programs for significant time gains. Previous solutions required extensive rework any time a component design changed.

With Fastsurf, adapting to a part change can be as simple as plugging a new parameter in the setup strategy. Additionally, this solution allows Lockheed Martin to monitor the thickness of coatings, a critical factor in ensuring that aircraft meet design requirements, through a query option at any point in the application. "Lockheed Martin was quick to understand the benefits to be gained by having all engineers working with the same user interface paradigm across Catia and Delmia solutions," said Steve Milliren, executive account manager, aerospace industry, Delmia, Dassault Systèmes. "With the Delmia Robotics solution, there is a common structure for easy communication and elimination of data translations for improved data integrity."



"Working with a visionary company such as Lockheed Martin has allowed Cenit to verify the value of our Fastsurf solution," stated Cenit account manager, Niall Cullen. "Their in-depth experience in Robotic OLP was key in shaping a production-hardened solution with aerospace accuracy."

In addition to the Delmia Robotics solution, Lockheed Martin also uses Dassault Systemes Virtual Ergonomics and DPM Assembly solutions.

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Index to advertisers

"Never turn with a Zero"

BY FRANK MILLARD

The Mitsubishi Zero was one of World War II's most formidable warplanes, credited with destroying 1,500 US aircraft. It outclassed and out-fought any allied fighter in the air when the Pacific War began and continued to be a dangerous adversary even when new tactics and updated aircraft were introduced by the US and British air forces. However, it paid for its early advantages over allied aircraft with an extreme vulnerability to hit-and-run fighter attacks and ground fire.

To comply with next-to-impossible specifications demanded by the Japanese Navy for an extremely maneuverable long-distance fighter-bomber, designer Dr Jiro Horikoshi had to make the aircraft as light as possible. He introduced a secret light aluminum alloy (T-7178) to its manufacture, and then omitted the usual protective armor for the pilot and did without self-sealing fuel tanks. The result was an extremely efficient flying incendiary bomb.

The aircraft first distinguished itself in the Chinese theatre in 1940, but its deadly strike rate went unnoticed by the USA's chiefs of staff who were not only unaware of the Zero's abilities, but succumbed to Japan's disinformation suggesting that its aircraft were slow, old-fashioned, and inferior to US warplanes. From China, in 1940, Flying Tigers commander General Chennault was impressed by the new Zeros in action, but his reports were not taken seriously.

The only way to down a Zero was to hit it on the climb or on the dive with 'boom and zoom' single bursts of fire, and pull away without engaging it in a dog-fight, where the odds would be stacked in the Japanese pilot's favor (hence the phrase 'Never turn with a Zero'). Allied pilots also developed the 'thatch-weave', involving two aircraft working together to bring down their prey. The Zero was also vulnerable to ground fire.

Mitsubishi Zero's creator, Horikoshi, was born near the city of Fujioka in 1903. His interest in aircraft grew out of a schoolboy fascination with World War I military flying machines. He studied aeronautical engineering at the University of Tokyo, graduating in 1927 from its Aviation Laboratory and joining Mitsubishi. Horikoshi designed and built the Mitsubishi A5M (it was given the name 'Claude' in the USA) and in 1937 was asked to design a 'prototype 12' to mark the 12th year of the Emperor's reign. It became known as model 00 (Type 0 Carrier Fighter), or Zero (Zero-sen) after Imperial year 2600.

The Japanese Navy issued its requirements for a new carrier-based monoplane fighter in May 1937, inviting both Mitsubishi and Nakajima to tender. The specification included: a wingspan of less than 39ft; a speed of 300mph at 13,000ft; a climb of 9,840ft in three to five minutes; an endurance of two hours on normal power or six to eight at cruising speed with drop tanks; two 20mm cannons and two 7.7mm machine guns, with 70 lb or 130 lb bombs; a radio long-range direction finder; and a complete cockpit radio.

Nakajima pulled out of the project, declaring it impossible, but Horikoshi's Mitsubishi team took it in their stride. Unfortunately, the only way the requirements could be met was through a sacrifice of pilot safety. The prototype, 12-Shi, fitted with a Mitsubishi Zucei-13 engine, first flew on April 1, 1939. This was followed by the A6M1 and the A6M2, equipped with a 950hp 14-cylinder, air-cooled radial Nakajima Sakae-12 engine.

This version became the production Zero Type 00 Model 11 adopted by the Japanese Imperial Navy on July 31, 1940. During the war in China not a single Zero was lost over enemy territory. The extremely agile light aircraft had a very low wing loading and high lift, which, with its consequent low stalling speed, contributed to its ability to turn more sharply than any other aircraft in the air at that time. The surprise attack on Pearl Harbor on December 7, 1941 displayed the awesome power and remarkable agility of the Mitsubishi Zero to a stunned world.

By 1943, Allied aircraft had been continually improved whereas the Japanese were slow to update. New US aircraft, such as the F4U Corsair and the F6F Hellcat overtook the Zero in performance. As a consequence, the Zero lost its edge. The loss of too many experienced pilots, who could not be replaced fast enough, did not help.

Horikoshi later built the Mitsubishi J2M Raiden and A7M Reppu, but he will always be remembered for the iconic Zero. ▮

Aces high

Japanese aces who flew the Mitsubushi Zeros during World War II include Hiroyoshi Nishizawa (104+ victories), Saburo Sakae (64 victories), and Kinsuke Muto (35 victories). In one encounter with US forces, Saburo Sakae shot down one Wildcat and one Dauntless and damaged two Avengers before returning to base and safely landing his aircraft, despite being badly wounded by machine gun bullets in the head, arms, and legs.

In February 1945, Kinsuke Muto's lone Zero closed on 12 Corsair fighters and engaged them in a dog-fight. The Japanese ace shot down four Corsairs before breaking off only because he had run out of ammunition.

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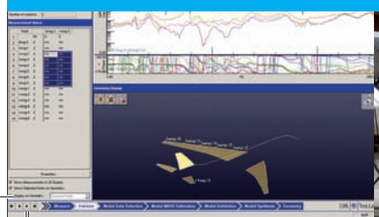

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