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AEROSPACE TESTING INTERNATIONAL

JULY 2012

Leading light
India's aerospace industry is taking off: some of the prime movers and shakers discuss progress

Driving force
Chief test pilots talk about the latest programs and the essential part they play

Bank right
A new generation of fast jet trainers is emerging and the Hawk T2 is in the vanguard

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Hardware-in-the-Loop Testing with dSPACE – For Certain Success

With the complexity of today's highly-integrated vehicle systems, testing is more important than ever. In "iron birds," integration test facilities, and model-testbed applications, dSPACE hardware-in-the-loop (HIL) systems, emulators, and model-driven testing tools are best-in-class when it comes to performance, quality, and value. dSPACE products have set the standard for quality for over 20 years. Whether the application is for air, land, sea, or space, dSPACE has provided world class support on programs as diverse as Joint Strike Fighter, the USS Makin Island, Future Combat Systems, and the Joint Polar Satellite System.

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Embedded Success dSPACE

This June I had the good fortune to attend the Cheltenham Science Festival, which spreads across the beautiful main square of the glorious Gloucestershire spa town and sits alongside the jazz, food and drink, and literary festivals. Although I was there with my family, I did wear my professional 'hat' because so much science is either steered by the aerospace development industry or has a direct impact on other industries. I was not disappointed.

Alongside stands showing jet engine technology and latest simulator systems, there was also a number of presentations on the science of flight. While my partner was busy, I dragged the kids off to see a presentation called *Fly Like a Bird*. They looked so bored at the prospect I thought I might have to stretcher them in with some oxygen, but after five minutes of listening to Garnet Ridgway and Sophie Robinson, both young aerospace engineers and academics from the University of Liverpool's Flight Science & Technology Department of Engineering, they were leaning forward, entranced.

The presentation was straightforward. Can humans fly using natural technology, ornithopter style? Many have tried, and many have died in the process, so it could have been a very short chat. But natural technology is seeping back into aeronautics.

Humans were never designed to fly; we escaped predators using legs and a larger brain. As the presentation pointed out, the power-to-weight ratio in humans makes us reluctant to leave the ground. I think I heard it right: the ratio for humans walking is 0.0007kW/kg; an F-22 is 12,000kW/kg. So no natural 'Ironman' flying…

There was another great fact about fuel efficiency: compared to 15 years ago, the passenger fuel usage is exactly the same, but passenger miles have expanded by 45%. Which does show that greener times are happening.

However, what I found most interesting was their discussion on 'aeroelasticity'. This is the science of inertial, elastic, and aerodynamic forces in fluid motion. This has been seen as a destructive force (we all know the film of the suspension bridge with this scientific law in absolute motion until the point of destruction). As far as aircraft have evolved, aeroelasticity has been a structurally unsafe phenomena, particularly when you bolt on missiles, extra fuel tanks, and wing upgrades. Now, with the use of composites and more flexible materials, it will be possible to return to nature, move away from fixed structures and solid flaps, but incorporate 'whole wing' flexibility, just as our feathered friends do. If you search online for 'Snowbird ornithopter' you can see first-hand how natural flying can be grasped by humankind… just really slowly and for no practical use on that level!

So fascinating were Ridgway and Robinson's insights that I have persuaded them to write a regular column for the magazine and website, starting next issue. Incidentally, Ridgway said that soon we'll be getting rid of engine nacelles as they are cumbersome to performance and restrictive to flight parameters…

This was not my only interesting day out of late; I was recently invited to a book launch in London to celebrate the publication of a tome entitled *Godfrey Hounsfield: Intuitive Genius of CT.* Sir Godfrey is a slightly distant relative of mine and the book celebrates his mind-blowing invention, the CT (computed tomography) scanner exactly 40 years ago (he was awarded a Nobel Prize shortly after). Although Hounsfield had no medical training and was almost entirely self-taught, he thought in unusual ways and with a certain 'intuition'. Until recently I thought the CT scanner was almost entirely devoted to medical health. However, I have learned now the actual extent of his exploratory endeavors.

The CT scanner is widely used across the NDT spectrum, numerous industries and its use is prolific in aerospace. Indeed, last month GE Measurement & Control business unveiled a new Speed Scan AtlineCT system, which introduces high-speed, 3D CT for the inspection and stringent quality control of light metal castings and composite structures. The system was before its time for aerospace as it suits the inspection of composite material flaws perfectly. Well done, Godfrey, it's all about composites now!

Incidentally, at the science festival I did have a chat with the eminent Professor Brian Cox, and asked him if he had any thoughts about spacecraft technology and the 'great voyage' beyond Earth. He responded by discussing his latest trip to Madagascar and the biological studies for his new TV series, before walking off mid-sentence. No quote from him, then.

Christopher Hounsfield, editor

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Watchkeeper hold-up continues

Efforts to bring the Thales Watchkeeper UAV into British Army service are still suffering from delays, according to a UK government, Ministry of Defence spokesperson.

The MoD had hoped to resolve issues concerning the Watchkeeper systems' release-to-service (RTS) certification by the end of March but this deadline passed without a solution.

Problems with software integration and flight trials have plagued the effort to deliver a new tactical UAV to the British Army and the in-service date has slipped on at least two occasions. It had been hoped to deliver the first system before the end of 2011 for use in Afghanistan to replace the leased Elbit Systems Hermes 450 UAVs currently being used in Helmand province by the Royal Artillery.

An MoD spokesperson said in May, "The delivery of Watchkeeper equipment is on track and over 200 hours of flying trials have taken place. The RTS process is taking longer than expected but as it is the first large UAV to fly in UK airspace, it is essential that the process is thorough. Until RTS is achieved, we cannot confirm an in-service date."

It is understood from British Army sources that maybe a questions are being considered regarding the deployment of the Watchkeeper to Afghanistan because the 2014 deadline for UK combat forces to leave the central Asian country is rapidly approaching. "With the clock ticking, the cost of sending a Watchkeeper to Helmand to replace the Hermes 450 might make it just worth doing, particularly if the problems with bringing the new UAV into service drag on into next year," said the source.

The UK's Defence Equipment and Support Minister, Peter Luff, hinted to parliamentarians in April that the Royal Artillery might end up running both the Watchkeeper and Hermes 450 in Helmand until British troops leave. Previously, the ministry had envisaged pulling all the Hermes 450s out of service by the end of 2012. "Between now and 2015, Hermes 450 will be replaced incrementally by Watchkeeper and will be withdrawn from service," said Luff. "These plans are under consideration as part of the current planning round, as is the future of capabilities acquired as urgent operational requirements (UORs) once they are no longer required in Afghanistan."

A ministry spokesperson said, "We cannot confirm the exact in-service date for Watchkeeper but the MoD remains committed to deploying it to Afghanistan at the earliest opportunity."

KEEPING A WATCHFUL EYE

A senior defense source said that the MoD's Major Project Review Board, which former defense secretary Dr Liam Fox set up in 2011 to "name and shame" failing defense projects and manufacturers, was monitoring the progress of the Watchkeeper project. "It has a watching brief on Watchkeeper but no decisions have been made yet," said the source. "The board next meets in the middle of the year."

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Five in formation

As the next-generation A400M continues its certification evaluations, all five of the program's flight test aircraft took to the sky this week for a unique formation flight performed by the Airbus Flight Test teams. The exercise originated from Toulouse, France. Once completed, each aircraft returned to its individual testing activities – which include evaluations for handling quality (performed by A400M test aircraft MSN1), wing pod hose stability (MSN2), engine performance (MSN3), pressurization and oxygen (MSN4), and function and reliability (MSN6).

E'X'perimental tour

The Eurocopter X3 hybrid aircraft toured the USA throughout June 2012 in order to demonstrate the advanced high-speed transportation system's operational capabilities for both civil and military operators.

Transported aboard a chartered cargo jetliner, the X3 arrived in Texas from France's Istres Flight Test Center. The hybrid aircraft will be based at the headquarters of Eurocopter's US subsidiary in Grand Prairie, Texas.

During its US tour, the X3 will visit five locations for presentations that will showcase its combination of a helicopter's full hover flight capabilities with cruise speeds of a turboprop-powered aircraft. Demonstrations will be completed with Eurocopter's test team, and the X3 will be available for flight evaluations by selected US armed services personnel and civilian operators.

In testing to date performed from the Istres Flight Test Center, the X3 has surpassed its original speed target of 220kts, reaching more than 230kts in level flight while using less than 80% of available power.

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BUILDING BLOCKS

Another aspect of flight testing is the progressive check out of the latest version of mission system software known as Block 2A. Until May 2012, more than 90% of Block 2A airborne software code is complete with more than 85% of that code currently being flight- or lab-tested. Block 2A flight test is being conducted at Edwards AFB and will continue throughout 2012. Block 2A is scheduled for 'ready for training' in the summer of 2013.

Hawker Beechcraft enters Chapter 11

One of the USA's iconic aircraft manufacturers, Hawker Beechcraft, filed for Chapter 11 bankruptcy on May 3, 2012. With debts of some US$2.5 billion and a downturn in the executive travel and general aviation markets hitting its core business hard, the company had been in financial trouble for several months. The high cost of financing its debt led to it delaying the development and test of its Hawker 200 jet in September 2011, and the problems did not stop there. The loss of a competition to supply the Pentagon with turboprop AT-6 ground attack aircraft for use in Afghanistan added to its woes. As part of its deal with its creditors, the company has had to make 350 staff redundant from its main production facility in Wichita, Kansas.

In the aftermath of the Chapter 11 announcement, the company's executive vice president, Shawn Vick, told a press conference in Geneva, "This is not chapter 7, this is not the break-up of the company." It is "highly likely" that the maker of Beechcraft King Air turboprops and Hawker 4000 and 900XP jets will exit Chapter 11 before the year end, Vick said, citing the firm's financial advisers. Vick also said other companies may be interested in acquiring Hawker Beechcraft.

The Goldman Sach Group Inc and Onex Corporation bought Wichita-based Hawker from Raytheon for US$3.3 billion in 2007. It had been owned by Raytheon since 1980. Beechcraft was founded in Wichita in 1932 by Walter H. Beech and his wife Olive Ann Mellor Beech. Its classic Model 17 Staggerwing first flew in November 1932 and over 750 Staggerwings were built, with 270 manufactured for the US Army Air Forces during the Second World War.

After the war, the Staggerwing was replaced by the revolutionary Beechcraft Bonanza with its distinctive V-tail. Perhaps the best-known Beech aircraft, the single-engine Bonanza has been manufactured in various models since 1947. The Bonanza has had the longest production run of any airplane, past or present, in the world. Other important Beech airplanes are the King Air/Super King Air line of twin-engine turboprops, in production since 1964; the Baron, a twin-engine variant of the Bonanza; and the Beechcraft Model 18, originally a business transport and commuter airliner that was built between the late 1930s and the 1960s.

GOOD BREEDING

In 1994, Raytheon merged Beechcraft with the Hawker product line it had acquired in 1993 from British Aerospace, forming Raytheon Aircraft Company. Since its inception Beechcraft has resided in Wichita, also the home of chief competitor Cessna and the birthplace of Learjet and Stearman. Stearman's trainers were used in large numbers during the Second World War.

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UK budget plans forces JSF variant switch

Plans for the UK to acquire the carrier or CV variant of the Lockheed Martin F-35 Joint Strike Fighter (JSF) were unceremoniously dumped on May 14, 2012, by Secretary of State for Defence Philip Hammond. His announcement did not come as a surprise after a month of media and parliamentary speculation.

The upfront costs associated with purchasing the necessary catapults and arrestor hook equipment of the Royal Navy's two new super carriers, HMS Queen Elizabeth and HMS Prince of Wales, totaled more than £2 billion (US$3.1 billion), said Hammond.

As a result, the UK has had to return to its original choice of the F-35B short take-off and landing variant. Hammond said the first F-35Bs would be delivered to the Royal Air Force and Royal Navy by 2016 and an operational capability will be ready at sea by 2020.

Unsurprisingly, such a dramatic policy about face has caused Ministry of Defence procurement officials and military planners to rethink their plans. Only in January this year the Royal Navy and the US Navy signed a cooperation agreement to allow some 200 UK personnel to train in the USA to gain experience in catapult and arrester gear operations.

The UK had a well-developed plan to transition its Harrier GR9 jump jet personnel to the F-35B until the 2010 Strategic Defence and Security Review ordered the switch to the F-35C CV variant. They are now having to be dusted off and put back into action. The UK is having to rebuild its relationship with the US Marine Corps to allow Royal Air Force and Royal Navy personnel to train in STOVL operations.

The Ministry of Defence had also funded a number of UK-specific elements of the JSF operational test and evaluation process, including a series of flight tests to prove and certify the aircraft for ski-jump operations. Unlike the US Marine Corps, the UK envisages using ski-jumps on its carriers to boost the performance of its F-35Bs by allowing so-called rolling take-offs. In 2010 a mock ski-jump had been built at the US Navy's main JSF test center at Patuxent River, Maryland, and this will have to be reactivated for future UK ski-jump trials.

The UK had to renegotiate its order for three low-rate initial production F-35B aircraft after its switch to the F-35C, buying two F-35B and one F-35C prototypes instead. It is unclear yet if the UK will try to switch this order book or just make do with the current mix and offer up the last aircraft as part of its contribution to the multinational operational test and evaluation effort.

The manufacturing of these aircraft is well advanced and in April, BK-1 (the UK's first F-35B Lightning II production aircraft) flew its inaugural flight. Lockheed Martin test pilot Bill Gigliotti took the STOVL jet through a series of functional flight checks during a sortie that lasted 45 minutes. The jet is now in the process of completing a series of company and government checkout flights prior to its acceptance by the UK Ministry of Defence. It will then be used for training and operational tests at Eglin Air Force Base in Florida later in 2012.

"Not only is this a watershed moment for the Joint Strike Fighter program, as BK-1 is the first international F-35 to fly, but it also brings us one step closer to delivery of this essential fifth-generation capability for the UK," said RAF group captain Harv Smyth, the UK National Deputy in the Joint Strike Programme office.

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Extra F-22 safety

To help ensure the safety of F-22 pilots, US Secretary of Defense Leon Panetta has instructed the US Air Force to implement some additional safety measures to the aircraft. Panetta directed the USAF to expedite the installation of an automatic backup oxygen system in all F-22s. This means completing the system's testing in November and beginning installations in December, according to Pentagon spokesman US Navy Captain John Kirby.

Starting in January 2012, retrofits are scheduled to occur to the rest of the USAF fleet at a rate of 10 aircraft per month, he said. The defense secretary ordered that, effective immediately, "All F-22 flights will remain within the proximity of potential landing locations to enable quick recovery and landing should the pilot encounter unanticipated physiological conditions during flight," said Panetta's spokesman, George Little, at a media briefing. Other fighter types will now perform the long-duration aerospace control flights in Alaska in place of F-22s, said Little.

However, Pentagon officials believe that the F-22s currently deployed to the United Arab Emirates "can safely continue that deployment given the geography of the region". Panetta also wants the USAF to brief him monthly on the progress it is making to determine the root cause of why some F-22 pilots have experienced hypoxia-like systems such as disorientation and dizziness in the cockpit. Little said that Panetta "supports the measures taken so far by the Air Force" to address this issue, but he wanted the additional steps because "the safety of our pilots remains his first and foremost concern".

The move by Panetta follows a whistle-blowing incident involving two USAF F-22 pilots who told a television station that not only are they afraid to fly the most expensive fighter jets in US history, but the military has attempted to silence them and other F-22 pilots by threatening their careers.

"There have been squadrons that have stood down over concerns. And there's been threat of reprisals," F-22 pilot Josh Wilson told CBS News' 60 Minutes program. "There's been threat of flying evaluation boards clipping our wings and doing ground jobs. And – in my case – potentially getting booted out of the air force."

OXYGEN MYSTERY

The saga of the F-22 oxygen system continues after a series of mysterious problems. Although the exhaustive investigation never did find a 'smoking gun' technical problem, the USAF has identified a series of fixes to mitigate the chance of any future problems with it. Many years ago during a weight-cutting exercise during F-22 development a back-up oxygen system was removed. The old system weighed 20 lb and the new one will weigh 10 lb. Software fixes are also in store, as well as new oxygen sensors.

Deep space power trial

NASA's Stennis Space Center broke its own record when it conducted a test on the new J-2X powerpack. The test lasted for 1,150 seconds, surpassing the previous record by more than a full minute.

The test marked a milestone step in development of a next-generation rocket engine to carry humans deeper into space than ever before. For Stennis, the 19-minute 10-second test represented the longest duration firing ever conducted in the center's A Test Complex.

"This is the longest and the most complex J-2X test profile to date," said Mike Kynard, NASA's Space Launch System liquid engines element manager. "By combining as many test objectives as we can, we aim to get the most out of every opportunity and work as affordably and efficiently as possible while maintaining a reasonable level of risk."

The powerpack is a system of components on the top portion of the J-2X engine, including the gas generator, oxygen and fuel turbopumps, and related ducts and valves. The powerpack system feeds the thrust chamber system, which produces engine thrust. By removing the thrust chamber assembly, including the main combustion chamber, main injector, and nozzle, engineers can push more easily the turbomachinery components over a wide range of conditions to demonstrate durability and safety margins.

The results of this test will be useful for determining performance and hardware life for the J-2X engine turbopumps. The test also enabled operators to calibrate flow meters on the stand, which measure the amount of liquid hydrogen and liquid oxygen delivered to the powerpack.

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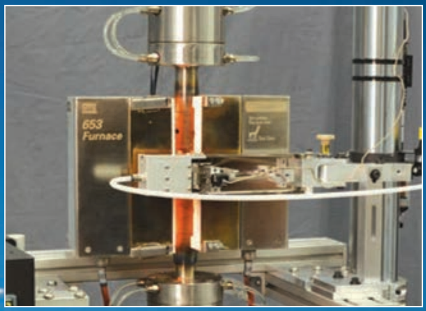

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Loss of control

THE FIRST INTERNATIONAL WORKSHOP TO ADDRESS THE ISSUE OF LOSS OF CONTROL IN FLIGHT WILL BE HELD IN SALZBURG, NOVEMBER 2012

BY DES BARKER

Latest statistics published by the Commercial Aviation Safety Team indicate that over the past 10 years, controlled flight into terrain (CFIT) accidents within the commercial jet fleet worldwide have decreased considerably with the advent of Terrain Avoidance and Warning Systems. However, in its place, the newest threat emerging from the analysis of aircraft accidents is 'loss of control in flight' – commonly abbreviated as LOC-I.

LOC-I was recently officially acknowledged as the largest contributor to hull losses in commercial aviation in the past 10 years – with a concomitant loss of life. In fact, more than 5,000 passengers have died in the past decade, when experienced, 'multi-thousand hour' airline crew lost control of their aircraft. Recent examples are the Boeing 737 stall on approach into Amsterdam, and a stall out of cruise flight by the Airbus A-330 that plunged into the Atlantic Ocean.

Strangely, this phenomenon has occurred both on conventional and fully protected aircraft. There are strong suggestions that the problem may not be so-called 'automation addiction', but rather an inadequate training regime; training programs have not adapted to aeronautical engineering innovation, while a regression in pilot handling skills adds another dimension to causal factors.

Pilot intervention

However, there is no easy solution to the problem. Data shows that LOC-I originates from many different sources, one of which is aircraft upsets, followed by improper upset recovery. The question being asked by accident investigators and test pilots is: "Why are pilots unable to regain control of their aircraft following loss of control? Is it loss of situational awareness, complacency, or lack of aerobatic training? What should the training industry do to solve this issue? How can the manufacturers support the industry? What is the role of the flight test community in contributing its knowledge and experience to ameliorating this phenomenon?"

The flight test community certainly has a competitive edge, being familiar with stalls and stall certification. Flight test pilots can and must share lessons with those pilots who are not that familiar with high-altitude buffet, stalls, and stall recovery.

To this end, an initiative that goes by the name 'Institut für Flugsicherheit' in Austria plans to host a two-day workshop in Salzburg, Austria, from November 19-20, 2012. The aim is to bring together scientists, researchers, training captains, regulators, and test pilots, to discuss the latest safety statistics, and deliberate on the causal factors, with a view to developing recommendations to regulators and the aircraft industry.

Great initiatives such as the Simulation of Upset Recovery In Aviation project and the work done by the International Committee for Aviation Training in Extended Envelopes will be addressed. Calspan will share its experience with inflight simulators, and regulators will present their views on regulation and simulator certification. The event is supported by the Society of Experimental Test Pilots. ∎

Des Barker is the former senior test pilot for the South African Air Force

Technology as the answer for LOC-I?

Most, if not all, of the previous accident areas that have been significantly reduced have been the result of newly introduced or improved technology. Windshear and CFIT incidents were mitigated through use of Ground Proximity Warning Systems, mid-air collisions through Traffic Collision Avoidance Systems, and CFIT further prevented through enhanced Terrain Awareness and Warning Systems. It appears that with regard to LOC-I there is not a new acronym on the horizon to save us. Although there are many factors that can result in the chain of events leading to an LOC-I accident, it appears that the most complex system onboard represents the best line of defense: the pilot.

A 767 rolls – something an airline pilot never wants to see - the ice of the Arctic seen upside down. Wake vortices have caused smaller aircraft to flip inverted and have caused roll upsets even in larger craft

"More than 5,000 passengers have died in the past decade, when experienced, 'multi-thousand hour' airline crew lost control of their aircraft"

The forward cockpit of the Hawk T2 would be familiar to any Typhoon pilot. The T2 instructor can choose to place 'markers' on the digital mission log, using these during debrief to illustrate teaching points

Personnel trainers

AN ENTIRELY NEW GENERATION OF MILITARY TRAINING AIRCRAFT IS FAST EMERGING – AND THE HAWK T2 IS AT THE FOREFRONT OF THE LATEST DEVELOPMENTS

BY PAUL E. EDEN

Clinging to the rocks of the rugged western shore of Anglesey, off the northwest coast of Wales, RAF Valley's remote location and weather-beaten approaches could easily fool the visitor into thinking that here lies a forgotten military outpost. But closer inspection reveals the brand-new Ascent complex, providing accommodation and ground training facilities for the Royal Air Force's No. IV (Reserve) Squadron, as well as hangarage for a fleet of 28 BAE Systems Hawk T. Mk 2 Advanced Jet Trainers (AJTs).

Ground school for the first Hawk T2 students began in April 2012. The training system is comprehensive, with three levels of simulation, plus an awe-inspiring range of post-mission debrief systems that have come into their own since flying training kicked off in May. By any standards, the RAF is entering into a new world of technologically advanced training – arguably the most advanced in the world. With several air arms, notably the US Air Force, looking for new training systems, all eyes are on Valley and its first student course, a course that represents the culmination of a flight test effort that began in 2004.

Test regime

Outwardly very similar to the legacy Hawk T1, the T2, known as Hawk AJT or Mk 128 to BAE Systems, features a modified wing and fuselage and uprated powerplant, and its avionics and cockpit are a world apart from those of the machine it replaces. In many ways it is a new aircraft and BAE Systems approached the flight test campaign as it would for any complex military aircraft, delivering progress through four phases: development, specification compliance, fitness for purpose, and release to service.

But there were additional test dimensions unique to the new trainer. Hawk T2 is effectively a flying classroom with a range of functionality designed to enable the instructor in the back to modify each student's training experience, interact with the student, or insert

Ascent JV

Ascent, a 50/50 joint venture between Lockheed Martin and Babcock International, won the UK MoD's 2008 contract to provide an industry-led, military-backed training system as part of the UK Military Flying Training System.

The company owns the T2 syllabus and courseware, and is responsible for the ongoing evolution of those components. BAE Systems and Babcock work in partnership to provide a contracted level of serviceability across the T2 fleet.

'markers' into the mission log for later analysis, for example, while all the time performing traditional teaching and safety oversight. This extra functionality had to be tested and demonstrated to operate correctly, safely, and intuitively while keeping the instructor's workload low so that he or she can continue to perform effectively.

The second dimension arises through the need to test an aircraft that represents the systems of another type entirely. Hawk T2 uses a datalink and INS/GPS-driven moving map among other systems, to emulate and simulate the complex avionics and sensors found on frontline combat aircraft.

According to BAE Systems, the cockpit layout is typical of a modern fourth- or fifth-generation combat aircraft, but while some of the critical moding and symbology is representative of the frontline functionality, it is not a slavish copy. The key is to provide the functionality, features, and systems (real or synthetic) that enable the student to gain the skills they will need for the frontline platform so that by the time they arrive at the operational conversion unit (OCU), they are far more capable and competent than they might otherwise have been. In other words, the test community needed to ensure that training could effectively be offloaded from the OCU (perhaps flying a Typhoon) to the much cheaper Hawk without compromising more basic skills, and minimizing the risk of a student 'helmet fire'.

Ensuring such functionality introduces a number of flight test challenges, since the requirements for a simulated/emulated system are often very different from those used in testing the equivalent real-world system, and any problems observed require careful consideration as to their possible causes. Interaction between the controls of the two cockpits also had to be considered (especially the instructor overrides), as did the requirement to build future growth potential into the design.

Given the extent and importance of the AJT's avionics, much reliance was placed on ground-based avionics rigs. These were not only used for ground testing of the aircraft hardware and software, but also provided aircrew and flight test engineers with the opportunity to familiarize themselves thoroughly with the mission system and to validate test scripts in advance of flying.

ABOVE LEFT: **These Hawk T2s were up from Valley in June 2011, during the initial instructor training and work-up phase of the type's introduction into service. The Sidewinder acquisition rounds on the wingtips add greater utility to the jet's missile simulation software**

ABOVE RIGHT: **The PC-21 cockpit features digital moving map displays, as well as a HUD upfront and a HUD repeater for the instructor 'in the back'. This Swiss machine is optimized for pilots moving onto the F/A-18**

Emulation/simulation

BAE Systems reports that the Hawk AJT's embedded simulation and emulation systems were developed in parallel with the flight test process. There was a flight test input from the initial requirements definition phase and an overarching strategy for test and evaluation was a necessity at an early stage. Throughout development, planned, incremental capability insertion was performed. The datalink supporting the simulated radar and RWR functions was introduced initially, followed in subsequent test phases by simulated air-to-air weapons, counter-measures and surface-to-air missile threats. Multiple test phases provided ample opportunities for bug fixes and system improvements to be introduced. By the final phase of testing, all elements of the systems were integrated, allowing fully representative training sorties to be performed.

Given the complex customer requirements for Hawk AJT, which needed to satisfy both instructor and student while fitting into an extensive training system, acceptance test and evaluation (AT&E) was considered from the beginning of the program, alongside development testing. As the manufacturer readily

Turboprop competition: Pilatus PC-21

Pilatus has long been a proponent of the turboprop trainer, through its hugely successful PC-7 and PC-9 series, but its current offering, the 21st century PC-21, is its most advanced yet. The company claims jet-like handling and performance with turboprop operating costs, while Pilatus-developed emulation/simulation makes the PC-21 ideal for training from *ab initio* up to pre-OCU levels.

Like Hawk AJT, PC-21 has avionics capable of emulating frontline equipment, as well as a suite of synthetic classroom training aids. It also provides a jet experience, which, Pilatus notes, "…is achieved through a specially designed power management system, which emulates the thrust-to-drag relationship of a jet aircraft and was tested throughout the flight envelope." The company focused on developing PC-21 as an integrated learning platform from the outset and reports: "The advanced training aids were thoughtfully incorporated into the complete training package. Aspects such as HMI, usability, ease of learning and teaching facilities were vital considerations during the development of the flying platform."

Consultation with end users was maintained throughout the test process, with constant consideration of student limitations to ensure that the aircraft provided as useful and cost-effective a solution as possible. Interestingly, although the detail design and refinement of the synthetic systems was conducted with reference to flight testing, the foundation of Pilatus' training concept was firmly in place before development work began. Nevertheless, as Pilatus is keen to point out, "Flight test pilots and engineers are a vital resource in all aspects of developing an effective training environment."

And with PC-21 firmly established in service, has the test effort ceased? Like BAE Systems, Pilatus says that is very much not the case: "The tailoring of customer-specific requirements, product refinement and continuous improvement are all aspects demanding flight test involvement for in-service customer support. Testing never stops."

New-generation jet: AleniaAermacchi M346

AleniaAermacchi evolved its M346 from a joint development program with Yakovlev. As such, it takes a radical approach to trainer design, offering Alpha and maneuverability limits similar to those of a fourth or fifth-generation fighter, albeit without the power or outright performance of the frontline type. In essence, the company's test program – which was nearing its conclusion in late May 2012 – has addressed all the test requirements of an advanced combat aircraft, plus the needs of an advanced trainer with comprehensive simulation/emulation capability.

Company sources note: "Since the M346 is a completely new aircraft, all aspects of flight test have been encompassed: structural static and dynamic load survey; flutter and buffet; aerodynamics at low and high AoA; handling qualities and performance; FCS integration; avionics; system operations and interactions; stores management systems; and stores integration.

"More than 1,600 test flights have been completed to date, and we are in the final stages of flight test in support of the 'full trainer' type certification for the Italian Air Force and the Republic of Singapore Air Force."

The Italian manufacturer took a similar approach to BAE Systems and Pilatus in developing its embedded emulation and simulation systems, known as ETTS (embedded tactical training system). Development was incremental and began on the test rig, before moving onto the flight simulator and ultimately to the jet itself. AleniaAermacchi's approach to classroom systems has been a little different to that of BAE Systems, for example, in that its integrated training system (ITS) has been developed and used during the flight test campaign. Indeed, ITS elements have been used in support of flight testing, particularly the mission planning and debriefing station, the real-time monitoring station, and the ground-support station.

Flight data has been fed back into the part task trainer and full mission simulator to ensure that both accurately reflect the performance and capabilities of the M346, while the test pilots and flight test engineers have been heavily involved in ITS development, review and testing.

Unlike the Hawk AJT and PC-21, the M346 is also offered as a light-attack platform, expanding the requirements of the test program (AleniaAermacchi)

admits, it is easily possible to design a system that satisfies a functional requirements specification, but it is not fit for purpose if it does not satisfy the needs of the customer.

AT&E requirements were therefore considered upfront and integrated into the joint development test and evaluation (DT&E) plan and flight test programs for each phase of testing. Performing AT&E in parallel with DT&E realized several other benefits in terms of overall efficiency, as well as allowing the customer to have early visibility of the product and issues to be identified early on in the test process. Indeed, many of the DT&E activities satisfied the data-gathering needs of AT&E, resulting in a shorter, combined test program.

Customer involvement

A group of the RAF's most experienced qualified flying instructors (QFIs) was involved in the T2 project from the outset. Representing the customer and its needs, their approach to the test process was somewhat different to that of the manufacturer. BAE Systems worked through the final stages of the test effort with consideration to key test points: Is the product safe for use? Is all the 'advertised' functionality present? Is that functionality working as expected? Is the system logic satisfactory? Are there any obvious human machine interface issues? Are there any obvious deficiencies or limitations?

For the QFIs, the issues were: How am I going to use this system to teach my students? Does it meet my needs as an instructor? Will it meet the needs of my students?

The Lockheed Martin/CAE-developed simulators use re-targeted mission computers from the Hawk T2, while Al Shinner, Ascent's station manager at Valley, reports, "An extensive data-sharing agreement also ensured that the full mission simulators accurately reproduce the flying characteristics and aerodynamic performance of the aircraft."The classroom aids were developed separately to the flight test program, but the test pilots and customer aircrew who had conducted the mission systems testing were closely involved in their verification and validation.

In-service testing

Six QFIs were originally involved in the preparations to bring the Hawk T2 into service. They created a customer framework for the syllabus, with input and overview from the Harrier, Tornado, and Typhoon communities, as well as their fellow Hawk instructors at Valley. This framework was then developed by Ascent into the syllabus now in use at Valley, although Al Shinner notes that it will only be baselined after feedback from the first two instructor and student courses has been collated and agreed upon. There was always a realization that such a radical system would continue to evolve and this was borne out as soon as T2 instructor training began.

Early system exposure to student pilots fresh from intermediate training on the Tucano was also important to the test and evaluation process. These young pilots soon proved that the synthetic training aids were indeed intuitive, working out for themselves how to progress through the cockpit display menus and options to 'release weapons' and explore other possibilities beyond their initial instruction.

At the end of May, Saudi Arabia signed for a combined fleet of 22 Hawk AJTs and 55 PC-21s. The BAE deal alone is worth more than £1.6 billion (US$2.5 billion). ∎

Paul E. Eden is a UK-based writer and editor specializing in the aviation industry

The Indian Light Combat helicopter

Star profile

INDIA HAS ONE OF THE FASTEST GROWING AEROSPACE INDUSTRIES IN THE WORLD. *AEROSPACE TESTING INTERNATIONAL* EXAMINES ITS CURRENT AIRCRAFT TEST AND DEVELOPMENT PROGRAMS

BY AIR MARSHAL PHILIP RAJKUMAR AND CHRISTOPHER HOUNSFIELD

By far the most important ongoing aircraft development in India is that of the Tejas light combat aircraft (LCA). It was originally envisaged as a MiG-21 replacement, and the program being run by the Aeronautical Development Agency in India had an ambitious goal of closing the technology gap that had opened up between the domestic aeronautical industry and the developed nations in the West.

Since fly-by-wire flight controls, a glass cockpit, composites in the airframe, and microprocessor-controlled subsystems were being attempted for the first time in the country, the program was split into two phases: a technology demonstration (TD) phase, and a full-scale engineering development (FSED) phase. Formal sanction and full funding for the tech demo phase was received in 1993 and the phase was completed after flying 210 sorties on two aircraft by March 2004.

Wing Commander Rajiv Kothiyal was the test pilot on the LCA's maiden flight. He says, "The flight itself was not without its share of the unexpected. After take-off the telemetry auto-tracking system failed and all screens in the Monitoring Room started showing erratic readings. However, the telemetry locked again when I was on final approach, to everyone's immense relief."

At the time of writing, the FSED phase has completed 1,845 flights on 12 aircraft, of which one is a two-seater trainer version.

"The envelope cleared so far is Mach 1.6/15km and 6g. High AOA testing is being planned using an anti-spin chute," says Kothiyal. "New avionics systems such as HMDS are being integrated. Many more indigenous modules have been manufactured and tested, and are functioning well on the LCA, and the first phase of hot and cold weather trials has been completed."

The Indian Air Force (IAF) has ordered 40 aircraft, which will all be powered by the General Electric F404-GE-IN20 afterburning engines delivering 8.5kN of thrust. The IAF feels the aircraft falls short of performance in some areas and has therefore asked for a Mk2 version, which will be powered by the GE F414 engines delivering 9.5kN of thrust. The initial preproduction batch of about eight aircraft are set to enter IAF service this year.

The Indian Navy has part-funded the development of a naval Tejas, which will be optimized for carrier operations. The aircraft will use a ski jump for take-off and carry out an arrested landing on the deck. The naval prototype NP-1 did its first flight earlier this month. The type is expected to see service by 2017 on board the first Indian aircraft carrier, which is under construction at the Kochi shipyard.

Trainer aircraft

Meanwhile, an intermediate jet trainer (IJT) is under development at Hindustan Aeronautics, Bangalore. Intended to replace the aging Kiran fleet of the IAF at the IAF Academy, the first prototype IJT flew in March 2003, powered by a Safran Larzac engine delivering 1.4kN of thrust. The second prototype was lost in a crash during flight testing in 2011. After investigations were completed, flight testing has resumed but with a Russian engine, AL 55I, delivering 1.7kN of thrust. This engine will power the production series and the IAF has ordered an initial batch of 16 aircraft.

Saras light utility aircraft

National Aerospace Laboratories (NAL), Bangalore (home of the Indian aerospace industry), has undertaken the design and development of a passenger-carrying civil aircraft for the first time in the country – the Saras 14-seater light utility aircraft. The first prototype flew in May 2004. It was powered by two rear-mounted Pratt & Whitney PT-6 turboprop engines delivering 850shp each. Because performance fell short of design goals, a second prototype powered by a PT-6 engine delivering 1,200shp was first flown in April 2007, but was lost in a crash in March 2009.

Meanwhile, the first prototype has been fitted with 1,200shp engines and flight testing

Birth and growth of the first Indian helicopter

In the early 1980s, the government of India tasked Hindustan Aeronautics Limited to design and develop the advanced light helicopter (ALH), a state-of-the-art, multirole, multimission, medium-weight-class helicopter for the Indian Armed Forces. The helicopter was required to operate both by day and night, in all weather, at high altitudes, in extreme cold and hot weather conditions, in hot and high desert conditions, and in a saline atmosphere in offshore environments. India is a land of environmental extremes: temperature, humidity, and elevation. The helicopter had to fly in one of the toughest environments in the world.

The ALH has been designed to survive in the battlefield with all the above, along with low infrared and noise signature; redundant critical systems; ballistic hit-tolerant fuselage; main rotor and tail rotor blades; self-sealing fuel tanks; sophisticated electronic warfare suite; good auto-rotational characteristics and excellent single-engine flyaway capabilities; and crashworthy structure.

The test program

When prototype testing of the ALH started, it was soon realized that ways and means of overcoming the constraints would be needed. The first constraint was that the whole team had no past experience in prototype testing. The internal team consisted of HAL designers from the Rotary Wing Research & Design Centre, the flight test instrumentation center, field service personnel, and the rotary wing test pilots and flight test engineers from the flight operations department of HAL.

The external team had representatives from military certification authorities; the Directorate General of Civil Aviation; and rotary wing test pilots and flight test engineers from the army, navy, and air force. It was learning on the job. No test pilot school in the world teaches prototype testing, so knowledge application was the mantra.

As the military certification was nearing completion, it was decided that ALH would be rechristened as Dhruv – the North Star, which has been showing the way to explorers for centuries. It is hoped that the Dhruv helicopter will show the Indian helicopter design, development, and manufacturing industry the way forward in times to come.

Flight phase

There were a lot of achievements during the flight testing phase. The first 35 hours saw the operation clearing the envelope of ALH up to 3km, and by the time 65 hours was completed, the whole of the envelope up to 6.5km was cleared. All the FADEC and engine response tests up to the maximum altitude were completed by the time 80 hours was achieved. At 120 hours, testers could claim to have cleared the ALH for landing on a 10° slope in any direction, plus single-engine landings, and the helicopter was cleared for 5,500kg all-up weight (4,000kg was initially planned for army/air force variants).

Full military certification was obtained at 1,400 hours of flight testing. DGCA of India awarded the certification at 1,800 hours after all the required additional tests for the civil certification, as per FAR Part 29, were completed. This included Cat 'A' performance testing up to 3km altitude.

HATSOFF to simulation

A fully fledged, world-class simulator training facility called HATSOFF has been established to train customer pilots. The JAA & DGCA certifiable Level-D full motion simulator has been commissioned for the Dhruv. For the first time in the history of the Indian Aviation, an indigenously designed, developed, and manufactured flying machine has got military and civil certification, and is being exported abroad. The lessons learned from the Dhruv program are enabling HAL to quickly complete the program for the light combat helicopter, and the design and development of the light utility helicopter (LUH). HAL is also looking forward to designing a 10,000-12,000kg multirole helicopter.

Wing Commander Chandra D. Upadhyay, former CTP rotary wing at HAL and CEO at HATSOFF, was largely responsible for certification of the Dhruv in all its different versions

The Dhruv program today

The Indian Coast Guard was the first service to make the Dhruv operational, followed by the Indian Army, Indian Navy, Indian Air Force, and the Border Security Force. The Indian Air Force also created a dedicated display team of Dhruvs, called 'Sarang', and frequently demonstrates the agility and maneuverability of Dhruvs at air shows.

In total, more than 140 Dhruvs are currently in the military inventory. In addition to the original five prototypes, 56 aircraft had traditional cockpits with mechanical gauges, the TM 333-2M2 engine, an anti-resonance vibration isolation system, and Frahm dampers, developed by Lord Corporation. The Mark II, with 20 aircraft delivered, features an integrated architecture and display system (IADS) glass cockpit, which was developed with IAI (Lahav Division), to integrate all the avionics, weapons, and mission systems.

Since much of India's northern borders are at very high elevation, the Dhruv was designed and tested for good performance at altitude, and the military demonstrated high-altitude operations of the Dhruv in the hot summer of Leh and in the cold weather of the Himalayas. The Dhruv has an integrated dynamic system, high power-to-weight engines, and rotor blades designed with good hover capability up to very high altitudes.

HAL intends to continue to increase the Indian content of the Dhruv, with the expectation of reducing costs. In addition to the engines, the glass cockpit, autopilot, vibration monitoring

is expected to resume later this year. The aircraft will be certified to military airworthiness standards first and the IAF has issued a letter of intent to buy 15 aircraft.

NM-5

NAL and Mahindra Aerospace, a private sector aerospace company, have jointly designed the NM-5 five-seater utility aircraft powered by a 300hp Lycoming piston engine. Mahindra Aerospace has bought a 75.1% stake in an Australian aircraft company, GippsAero, located at the Latrobe Regional Airport, Morwell, Victoria. One prototype was built by GippsAero and its first test flight was in September 2011. Flight testing is now in full progress.

Advanced light helicopter

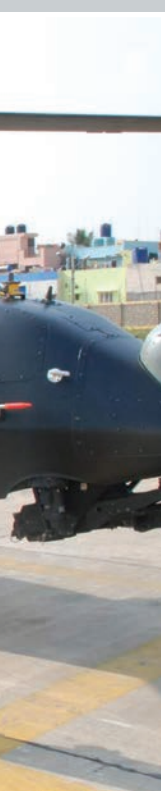
The advanced light helicopter (Dhruv) project was started in the early 1980s by Hindustan Aeronautics Limited (HAL) with Messerschmitt-Bölkow-Blohm (MBB) of Germany acting as design consultant. It was to be a twin-turbine-engined helicopter in the 5 ton class. The high tail boom design enabled introduction of rear-loading ramp doors. The helicopter featured a revolutionary concept called an integrated dynamic system (IDS), rigid rotors, and a tail rotor made of composite material.

The IDS combined several key rotor control functions into a single transmission system conveying power to the rotors. The first flight took place in August 1992, and after an accident-free flight-test phase, deliveries to the Indian Army and Air Force started in 2002. Currently, around 100 Dhruvs are in service and seven have been sold to the Ecuadorian Air Force in South America. A civil version has been certified and the army has also asked for an armed version.

Wing Commander Chandra Upadhyay was the chief test pilot, rotary wing, for HAL and is CEO at HATSOFF (Helicopter Academy to Train by Simulation of Flying; see *Birth and Growth of the First Indian Helicopter* box). He says, “The design standards given were that the new helicopter was to be designed and developed as per FAR Part 29/JAR requirements. In addition, it was also supposed to meet all the other stringent requirements of DEF STAN 970, MIL-STDs, and also the specific requirements of the Indian Armed Forces. The helicopter has since met all these certification requirements.”

The original powerplant chosen was the French Turbomeca TM 333-21B, developing 1,000shp. This engine was not able to meet the stringent requirement of being able to carry a payload of 200kg at 18,000ft altitude. A more powerful engine – the Shakti – was tested and developed by HAL in collaboration with Turbomeca. This engine fitted with a dual-lane digital engine control unit (DECU) developed 1,400shp. The Dhruv, when fitted with Shakti engines, was able to carry a payload of 600kg at 18,000ft, therefore meeting the requirements of the army and air force to operate in the high Himalayas. Dhruvs are in service in India with a number of civilian operators, as well as the Indian Coast Guard. A further 160 Dhruvs are on order.

Upadhyay notes, “The HAL flight testing team completed the sea-level trials and the full g envelope was cleared from sea level to 6.5km, which included +3.2g to -1g and demonstration of the integrity of the helicopter up to 1.5g at Vd (maximum designed velocity), which was 367km/h at sea level. The first flight of the



systems, and other components are also intended to be in-sourced from India, for increased indigenization.

Light combat version

The HAL Rotary Wing Research and Development Centre (RWRDC) created a dedicated work center for a light combat helicopter (LCH) design, co-locating the designers and outsourcing partners, using Siemens’ Unigraphics NX4 computer aided design (CAD), product data management/team center, and finite element method (FEM) software. The digital development of the LCH allowed the model to be used for manufacturing of components and tooling for high accuracy and ease of fabrication and assembly. Design of the assembly jigs was launched concurrently with the aircraft development; the desired inputs for the fixtures were extracted and tracked during the aircraft design refinement in order to keep the jig design continuously updated.

Flight trials

The first LCH prototype, TD-1, began its first ground runs on February 4, 2010, and completed ground check-out testing over the next six weeks. HAL’s chief rotary wing test pilot, Wing Commander Unni Pillai, and test pilot Group Captain Hari Nair, made the first flight at the HAL facility in Bangalore, India on March 29, 2010. HAL is in the process incorporating a number of minor aerodynamic changes to improve flight performance.

The second development aircraft, TD-2, is now planned for weapons and mission systems testing. This prototype debuted with a digital camouflage scheme and is presently undergoing extensive flight testing.

The third prototype, TD-3, will be built to production standards and used for operational testing. The flight evaluation of the prototype is planned to include more than 700 flights and up to 500 hours of testing.

Light utility helicopter

The Cheetah and Chetak helicopters operated by the Indian Air Force and Indian Army are nearing the end of their useful life and need to be replaced. The military requirement for a reconnaissance and surveillance helicopter was issued in February 2008. It calls for 384 helicopters, of which 197 will be procured from abroad, with the remaining 187 helicopters to be indigenously developed by HAL as the light utility helicopter (LUH). The LUH requirement calls for a light (3 metric ton) single-engine utility helicopter capable of seating six passengers, in addition to the two pilots, and operations up to 6.5km (21,300ft) altitude.

The design features a four-bladed, composite, hingeless main rotor and a four bladed, composite, bearing-less tail rotor, a composite airframe, a glass cockpit, and an automatic flight control system. The Indian Ministry of Defence is considering engines from Pratt & Whitney, Honeywell, and Turbomeca, with the power range just below that of the HAL/Turbomeca TM333 that powered the early versions of the Dhruv.

Wing Commander Unni Pillai (retired) is the current chief test pilot for rotary wing with HAL, based in Bangalore, India naval variant with a different engine was carried out when 250 hours of flight testing had been carried out on the ALH."

It was feedback from clients and a war that led to modifications to the Dhruv, as Upadhyay comments, "A lot of improvements/modifications have since been carried out on Dhruv as a result of feedback from the operators. The Kargil War required for the weaponized Dhruv to be used at higher altitudes, which led to the re-engining of the Dhruv with a more powerful Shakti engine, jointly designed and developed by HAL and Turbomecea of France. The weapon system's integration with the full glass cockpit and EW system has placed Dhruv in a class of its own."

The design and development of Dhruv took just as much time as any other such program in the world. Whereas other manufacturers had the advantage of testing the major components on their earlier models, every component of Dhruv was tested for the first time on a flying machine.

Light combat helicopter

An armed helicopter is being developed based on the same rotor system and engines as the Dhruv. It features a low frontal cross-section fuselage with tandem seating for two pilots and a stub wing to carry weapons. Eight anti-tank missiles, four air-to-air missiles, or four 68mm rocket pods can be carried for the close air support mission.

This version made its maiden flight in March 2010 and a second prototype flew in June 2011. Flight testing is in progress, with deliveries to the Indian Air Force and Indian Army expected to commence in 2014. When development is completed, the light combat helicopter will have a chin-mounted turret gun system coupled to a helmet-mounted sight, an electronic warfare suite, and a datalink so that it can operate in a net-centric environment. Its sensor suite will feature a forward-looking infrared (FLIR) system, a charge-coupled device (CCD) camera, and a laser range finder.

Wing Commander Unni Pillai is the current chief test pilot for rotary wing with HAA. He says, "An LCH cockpit mock-up was built early in the program to study ingress/egress, refine the door configuration, improve the field of view, and develop the cockpit display arrangement and user interface. Wind tunnel testing, landing gear drop tests, shake tests, and improvements in swash plate control margins, were all successfully concluded during the LCH development.

"Since the propulsion system and most of the weapons system development and qualification has already been completed on the Dhruv, HAL hopes to achieve Initial Operational Clearance by 2014," Pillai concludes.

The Kaveri turbo

This program to develop an indigenous jet engine to power the LCA was launched in 1989, but has moved very slowly. This slow progress was due to the lack of jet engine development experience in the country. The Kaveri's design aim was to produce an afterburning low bypass (0.2%) engine in the 8kN class, with full authority digital engine

The light combat aircraft (Tejas)

BY WING COMMANDER RAJIV KOTHIYAL

January 4, 2001 heralded an important beginning in Indian aeronautics when the first prototype of the LCA, later renamed Tejas, took to the skies with me at the controls for a memorable first flight lasting 18 minutes.

The last fighter prototype in India was manufactured and test-flown way back in 1961. Therefore, the expertise, technical know-how and data infrastructure needed to design and develop a state-of-the-art digital fly-by-wire aircraft was virtually non-existent. Team LCA was compelled to design and develop the aircraft while simultaneously setting up the design and developmental processes and systems to do so successfully. In such a situation the test pilot's role became all the more crucial. This aspect was recognized by the US Society of Experimental Test Pilots (SETP) when they conferred on me the prestigious Iven C. Kincheloe Award in September 2001 for 'outstanding professional achievement in flight testing'.

Initial flight tests

The LCA Technology Demonstrator 1 (TD1) flew 12 flights using Fixed Gain Control Law. Some of the new technologies incorporated included the Quadruplex Digital Flight Control System, a glass cockpit, and a composite airframe (apart from a large number of indigenous system modules). Testing during the flights consisted of assessing HQ, checking of system functions, and calibration of the air data system. A few problems observed in the functioning of the brake management system and nose wheel steering system were quickly rectified. The TD2 first flew in June 2002 and was fitted with an

Anecdote from a test pilot

BY WING COMMANDER PADMANABHA ASHOKA

It was 1975 and at the HAL Kanpur site the HS748 production line had just started deliveries to Indian Airlines. As well as carrying out production test flights I was also appointed as an examiner on the aircraft for Indian Airlines. In 1970, Indian Airlines pilots expressed doubts about single-engine climb performance of the aircraft. To prove that the aircraft met the requirement, I ended up carrying out 20 single-engine take-offs at maximum weight, where the right engine was shut down at decision speed and the take-off continued on one engine, getting airborne and climbing to 1,500ft. The aircraft met the requirement. I also carried out extensive paratrooping and supply-dropping trials on a modified HS748 with a large side door. Supply-dropping trials involved drops at remote pockets in the Himalayas; the highest pocket was at an altitude of 16,000ft! The trials were fully successful.

As part of the probe into single-engine performance, I had to carry out glides with both engines switched off. This enabled accurate calculation of airframe drag in a descent and was very useful. After the last such test I decided to carry out a dead stick landing with both engines switched off and feathered. It was the easiest thing, as the aircraft had wonderful glide ratio.

During the early 1980s I was involved in production test flying of various versions of MiG-21 aircraft. Some exciting tests ended up in engine flameouts at 65,000ft at Mach 1.8. This led to extended glides at supersonic speeds. Relights were done at around 25,000ft, mercifully successful every time.

We also had a problem with aileron flutter at supersonic speeds at altitudes below 10,000ft. I experienced flutter on many occasions but fortunately no failures. The problem was sorted out by the introduction of more stringent production standards. On one flight I had a turbine failure at 43,000ft at Mach 1.5, producing massive vibration. I had to throttle down to near idle speed and managed to carry out a near dead stick landing.

During the early 1990s there were some interesting experiences. Before certification, we had to carry out inverted spins on Kiran Mk2 to prove safe recovery. I tried the usual techniques but it refused to enter an inverted indigenous HUD but still used Fixed Gain Control Law. Meanwhile, the LES and air brakes on the TD1, which had been grounded after the first 12 flights, were made functional using Scheduled Gain Control Law. The modified TD1 flew again in February 2003. In one of the high-speed taxi tests on this TD1 the elevons started to flap violently, causing the aircraft to bounce up and down on the runway. This was later discovered to be caused by the unnecessary bobbing up and down of the nose wheel while rolling on the uneven runway surface. Flutter testing was conducted on TD1 and the first supersonic flight was achieved in August 2003.

Phase 1 of the program was completed by March 2004. This marked the successful end of the technology demonstrator phase. The main targets achieved were, firstly, bridging the technological gap in terms of FCS, glass cockpit, and use of composites, and, secondly, the manufacturing technology was upgraded with indigenization of a large number of critical components.

Present test status

The LCA has so far logged more than 1,800 flights with no major incidents or accidents. The initial operational clearance (IOC 1) of the aircraft was achieved in December 2010 and mainly involved the basic weaponization of the aircraft in terms of both air-to-air and air-to-ground capability. Phase IOC 2 is intended to resolve issues pending in IOC 1 and, according to sources, is likely to be completed by end of this year. It is also understood that the Indian Air Force has placed an order for about 40 aircraft.

National civil aircraft program

With 10 years' experience in flight testing (including prototype testing) and 10 years' experience in the airline industry, I was found to be most suitable to be nominated as the Pilot Consultant by the National Aerospace Laboratory (NAL) in Bangalore, in early 2011, for the proposed National Civil Aircraft (NCA) program. The NCA is planned to be a 90-seater jet aircraft powered by two turbofan engines designed for regional operations. An NCA Design bureau has been set up in the premises of NAL, Bangalore. The present status of the project is that a feasibility report was submitted to the Indian government in May 2011. The report includes studies in market assessment, aircraft configuration design and system definition, road map for design, development, joint venture (JV/PPP) series production, funding aspect and business model. A JV committee is working on the modalities of JV partnerships with the private sector for the development of the aircraft. A series of meetings between major industrialists in India have been held in 2012.

The maiden flight of the LCA was carried out by Wing Commander Rajiv Kothiyal. He was the only man on the project from its inception through its initial progress past the first flight. He is now the chief advisor to NAL

spin. Finally, I tried to enter immediately following recovery from an erect spin, pushing the stick hard and fully forward, and lo and behold it entered an inverted spin. Recovery was easy and immediate. I also carried out erect spins on the Ajeet Trainer with a certain amount of apprehension as I had earlier (in Gnat handling flight) had to eject from a spin as it would not recover. The Ajeet trainer spins were entirely different from spins in the Gnat, and recovery was fairly good but with lots of yaw oscillations. During some other tests on the Ajeet trainer, I had jamming of the elevator at 10,000ft and, of all conditions, at 6.9*g*. I had to split the elevator to recover! They found a mechanical fouling of a cable to be the cause.

As I said earlier, the HTT34 was a delightful machine with excellent aerobatic capability. I demonstrated it at Farnborough International Airshow in 1984 and at Paris Air Show in 1985.

Wing Commander Padmanabha Ashoka is the former CTP and executive director (Flight Operations & Safety, HAL). He is the only test pilot to have worked with all three aircraft-producing divisions of HAL. He continues to advise National Aerospace Laboratories in India

control developed indigenously. Testbed runs indicated a shortfall in the design goals for thrust, and the program was detached from the LCA Tejas. The government, however, decided to pursue the program to develop expertise. In 2011, a prototype engine (K9) was flown in an IL-76 flying testbed at the Gromov Flight Research Institute near Moscow in Russia. An 85-hour flying testbed program has now been planned.

Kothiyal gives little away. "The LCA Mk2 is being planned and seeks to correct the deficiencies observed in Mk1. A more powerful engine is being considered to compensate for the increase in weight of the Mk2."

Meanwhile, India's Defence Research and Development Organisation (DRDO), which is steering the program, is on the verge of entering into a joint venture with the French engine manufacturer, Snecma. This JV will build on the Kaveri program and produce an engine in the 9.5kN class using the Indian 'cold' section and a French 'hot' core. ∎

Air Marshal Philip Rajkumar (retired) supervised the flight testing of the LCA. He was integral to the setup of the National Aerospace Laboratories (NAL), where he designed and manufactured Saras commuter aircraft. He is also part of the latest NAL-Mahindra Aerospace five-seater aircraft now being manufactured in Australia

Blimp on the horizon

THE DEVELOPMENT AND TESTING PROGRAM FOR THE ZEPPELIN LZ N07 AIRSHIP WAS UNVEILED TO THE READERS OF THIS MAGAZINE MORE THAN SEVEN YEARS AGO. NOW THE COMPANY IS SET TO UNVEIL THE LZ N07-101 VARIANT – COMPLETE WITH EXTENDED RANGE KIT

BY JUERGEN FECHER

Since 2005, four LZ NO7 airships have been in active service worldwide in a variety of roles. The airships, operated by the Deutsche Zeppelin-Reederei, the operating arm of Zeppelin Luftschifftechnik, have so far safely carried more than 120,000 passengers on sightseeing flights. Just recently, a fifth airship was assembled in Friedrichshafen, southern Germany. This rebuild took to the skies for its first functional check on April 27, 2012.

One year ago, in May 2011, Zeppelin landed its biggest marketing coup so far. The Goodyear Tire & Rubber Company ordered three of a new LZ N07-101 variant. These airships, which are now massively modified versions of the current LZ N07-100, will be built in Friedrichshafen, and jointly assembled in Akron/Ohio, USA, the base of the Goodyear airship operation. Within the next few years, they will replace all current Goodyear airships operated in the USA.

Zeppelin began building lighter-than-air vehicles a few years before Goodyear. However, Goodyear has the longest continuous history of building and operating airships, and no manufacturer has built more than the company. Goodyear produced its first airship envelope in 1911 and its first airship on contract for the US military in 1917. Between the military and Goodyear's own public relations blimps, it has built more than 347 airships.

The first public relations airship of their own design and for their own purpose was built in 1925, and named The Pilgrim. Since then, with the exception of war years 1942-1945, Goodyear has continually operated a fleet of blimps for its own purposes: advertising for Goodyear tires, filming and televising live sports events from the air, carrying VIP passengers, and appearing over special events.

Turning full circle

It was in 2008 that Zeppelin decided to start development of an improved version of the airship Zeppelin LZ N07 – the -101 variant.

Experience in building and operating the previous airships had shown that, within the overall dimensions of the airship, an airship could be designed that offered more payload by optimizing the envelope cut, therefore offering more aerostatic lift as a result of weight-reduction measures. It would also offer more versatility by incorporating from the start provisions that had been found useful during non-passenger missions performed by the airships.

The new variant would have a slightly larger passenger gondola with two more seats, more electrical power available for mission equipment, an avionics interface for mission equipment, provisions for a mission platform for 450kg of scientific equipment on top of the airship, and structural modifications for easier production and longer fatigue life. To increase the operational flexibility of the airship, an extended range and endurance kit had been designed and tested. Pilots' duty times permitting, this kit would enable the airship to be flown for more than 36 hours, giving it a no-wind range of approximately 1,400 nautical miles.

Around the same time, Goodyear and Zeppelin began negotiations on possible replacements for their current airships and it was decided to join forces to design and build the -101 variant with additional changes that Goodyear wanted to have in its new airships. Such a cooperation was not new. In 1923, Luftschiffbau Zeppelin and the Goodyear Tire & Rubber Company created a joint venture, the Goodyear Zeppelin Corporation, which built the two giant rigid airships, USS Akron and USS Macon, for the US Navy. This time it was not a joint venture, but a joint effort of two

"All in all, the LZ N07-101 will be an improvement in all three marketing segments of the airship"

BELOW: **Zeppelin at sunset (Picture: Mende)**

INSET: **LZ N07-101 with extended range kit: two special fuel tanks installed in the gondola increase fuel capacity from 825kg to 1,790kg**

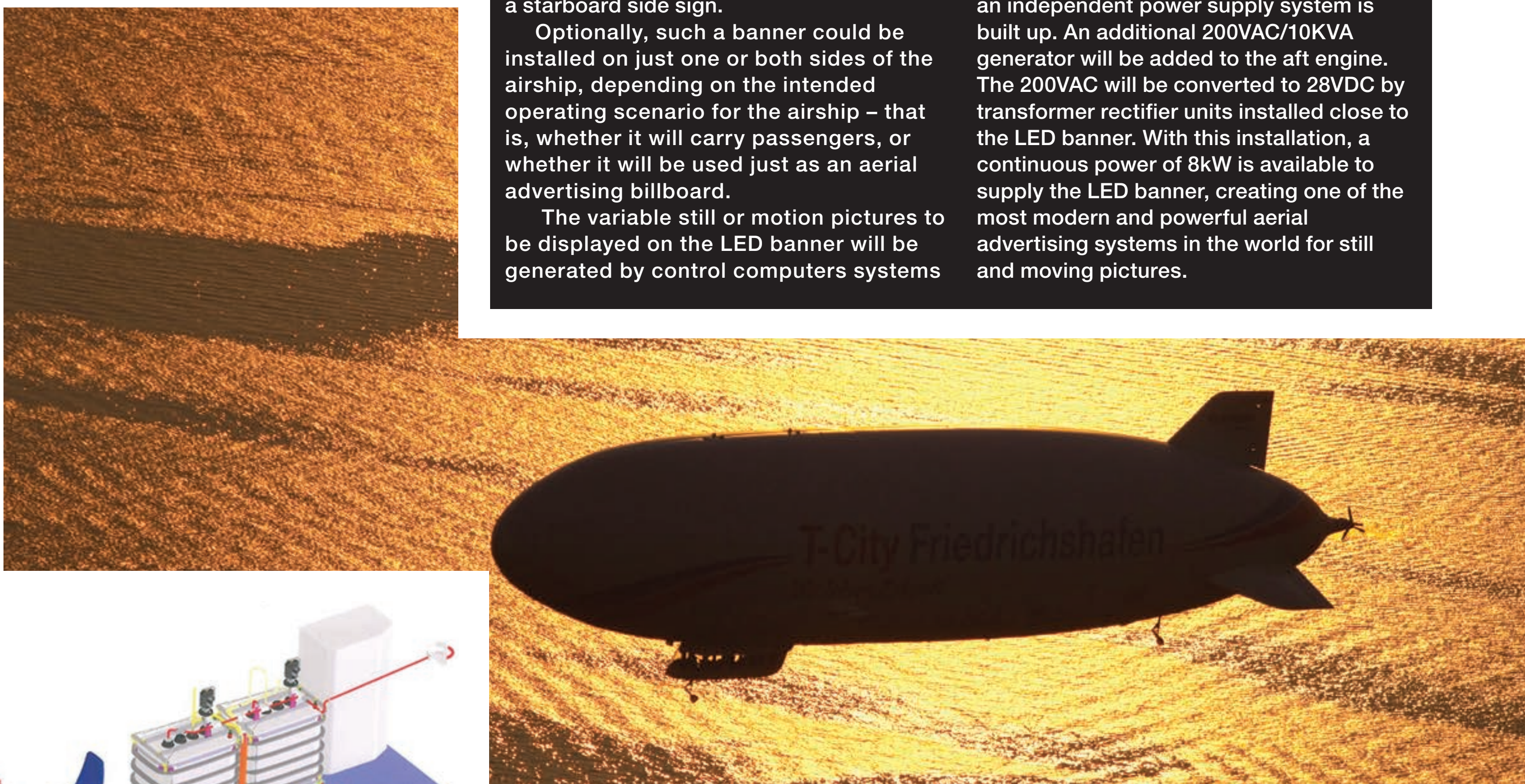
LED electronic advertising banner

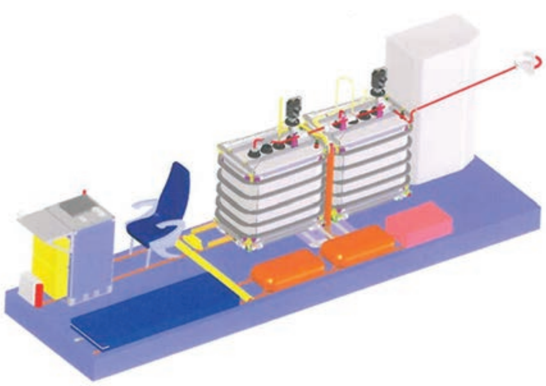
Goodyear has designed an active LED advertising system and, with the help of Zeppelin, is applying it to the new airship. Goodyear plans a full electronic sign on the port side and is in the engineering stage for a starboard side sign.

Optionally, such a banner could be installed on just one or both sides of the airship, depending on the intended operating scenario for the airship – that is, whether it will carry passengers, or whether it will be used just as an aerial advertising billboard.

The variable still or motion pictures to be displayed on the LED banner will be generated by control computers systems that are housed in the rear of the passenger gondola.

It is also possible to display the advertising image on one of the new EICAS displays. For the LED advertising system, an independent power supply system is built up. An additional 200VAC/10KVA generator will be added to the aft engine. The 200VAC will be converted to 28VDC by transformer rectifier units installed close to the LED banner. With this installation, a continuous power of 8kW is available to supply the LED banner, creating one of the most modern and powerful aerial advertising systems in the world for still and moving pictures.





companies synonymous to airships. The task was to combine the design experience of Zeppelin with the operational experience of Goodyear, and to design and build one of the most modern and versatile airships.

Among other features that were now added to the design of the -101 variant were a new cockpit display system and avionics suite that, once approved, will permit LPV approaches with the airships, a daylight-readable, high-resolution LED advertising system, an improved envelope material and air system, and improved ground support equipment. All in all, the LZ N07-101 will be an improvement in all three marketing areas: passenger operations, special missions, and advertising.

Cockpit display and avionics

When the Zeppelin NT was designed in the mid-1990s, a glass cockpit was standard from the beginning. At that time, individual ADIs and HSIs were still the standard inflight displays, with mechanical back-up instruments. Airship systems information was displayed on a two-screen integrated instrument display system. A lot has changed in the field of cockpit displays since then. It is, however, still very difficult to find suppliers that are willing to adjust their display systems to the needs of an airship, where the number of units sold will not go into the hundreds. Nevertheless, the new airships of the -101 series will get a new cockpit display system.

In designing the new cockpit, special emphasis has been put into designing a state-of-the-art 'airship-to-crew interface' for system and flight parameters, by using multiple large active matrix liquid crystal display (AMLCD) color screens. The cockpit display system is divided into the engine indicating and crew alerting system (EICAS) in the central section and the electronic flight instrument system (EFIS) on the left and right side of the instrument panel, plus the necessary standby instruments and back-ups. To provide sufficient redundancy, two EICAS computers and screens and two EFIS units with multifunction display (MFD) for enhanced situational awareness will be employed.

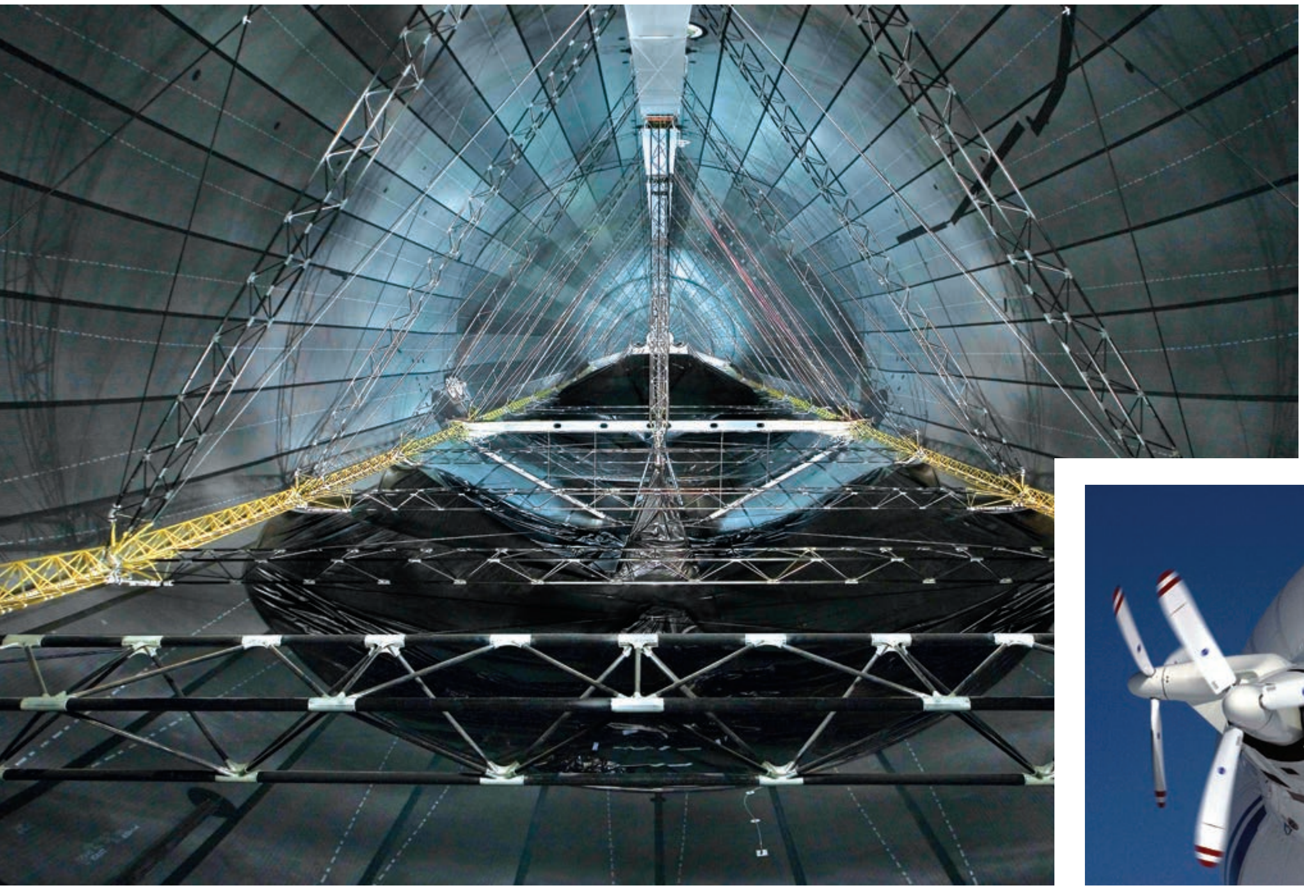
EICAS technology

The EICAS will indicate the various system parameters (most of them very specific to airships, such as envelope system data), parameters of the three engines of the thrust vector propulsion system (there are few aircraft out there with three piston engines), and warning and alert messages to the flight crew. The EICAS is designed to provide clear, safe, and fast access to airship parameters required for flight, preflight checks, or maintenance purposes.

The architecture designed by Zeppelin for the EICAS uses two Barco PU-2000 display management computers (DMCs) and connects them with two Barco CHDD-268 displays in a way that allows each PU-2000 to drive both screens. Should one of the PU-2000s fail, then the other can drive both screens. Should one of the displays fail, then the other display can display the complete information needed by the crew in composite mode.

The CHDD-268 displays have the inherent capability to display additional analog and composite video pictures as main image or as picture-in-picture. The PU-2000 unit has been chosen because it provides a modular and open system architecture with sufficient growth capability, so that future upgrades or temporary changes for special missions are possible. The EICAS is able to perform logical operations with input parameters to provide visual and aural alerts to the crew.

The application software for the EICAS is generated by the Belgium software house (UN) MANNED and certified through Zeppelin. The software must generate all airship-specific illustrations, display parameters, and text messages. It must also be able to process signal data to physical data for the displays (i.e. non-linear fuel quantity data or discrete inputs into warnings and cautions) and check for limitations.



LEFT: Inside the envelope with carbon fiber frames, aluminum longerons and ballonets with a volume of 8,450m³ (Picture: Bernhard Gering)

BELOW: The airship is powered by three independent engines, two lateral and one rear engine, each with 200hp and a swiveling propeller, to a maximum speed of 78mph

A maintenance menu provides provisions to adjust and calibrate input parameters in a wide range without having to change hardware (actuator and rudder positions, etc). The displays supplied by Barco are already certificated and will come with an European Technical Standard Order (standardized equipment qualification requirements). The processing computers PU-2000 are also off-the-shelf units with a basic certification, but the application software for the Zeppelin N07-101 must be developed and, of course, certified according RTCA DO-254.

Three engine data acquisition units, one for each engine, and one cabin data acquisition unit (C-DAU) provide the two processor units (PU-2000) with systems data. Whereas the old IIDS (Integrated Instrument Display System) had the capability to handle several analog signal inputs directly, modern computers prefer digital inputs only. Zeppelin therefore developed a new C-DAU in cooperation with BMC-Messtechnik to sample 28 different analog signals and more then 50 discrete signals, and to send them to the DMCs via an ARINC 429 bus. The new C-DAUs will be developed and certified according RTCA DO-254 / DO-178B and DO-160 from scratch on.

EFIS functions

The EFIS provides the pilot with all the necessary flight (IAS, VAS, pitch and roll attitude, rate of turn indicator, barometric altitude, radar altimeter, decision high, wind vector) and navigation data (CSR, HDG, NAV #1 and #2, DME, ADF, MB, GS, LOC).

For the EFIS, Zeppelin selected the Garmin 600 in a dual-installation version. It contains a primary flight and navigation display, and a multifunction display. It is an approved off-the-shelf system with all necessary TSO (Technical Standard Order) and it is IFR-capable. Each system has a dual 6.5in diagonal color AMLCD display in portrait orientation and provides sufficient redundancy through dual installation. An interface to display video pictures from a TV camera (one of the missions of the airship is to provide high-definition TV footage of sports events, and it is very helpful for situational awareness if the pilot knows what is to be filmed), satellite downloaded weather data, and map data is also provided. Although the airship currently has no Traffic Collision Avoidance System (TCAS), Terrain Awareness and Warning System (TAWS), weather radar, or FPI system (Flight Path Indicator) installed, these options are possible in future. Some other add-ons are will depend on operation and mission requirements.

The G600 systems get their navigation data from two Garmin GTN 650 units. The GTN 650 is a GPS/NAV/COM system with touchscreen control. Because the Zeppelin airship often operates at low altitude, especially during scientific or TV missions, a radar altimeter is an integral part of the avionics suite.

Envelope and air system

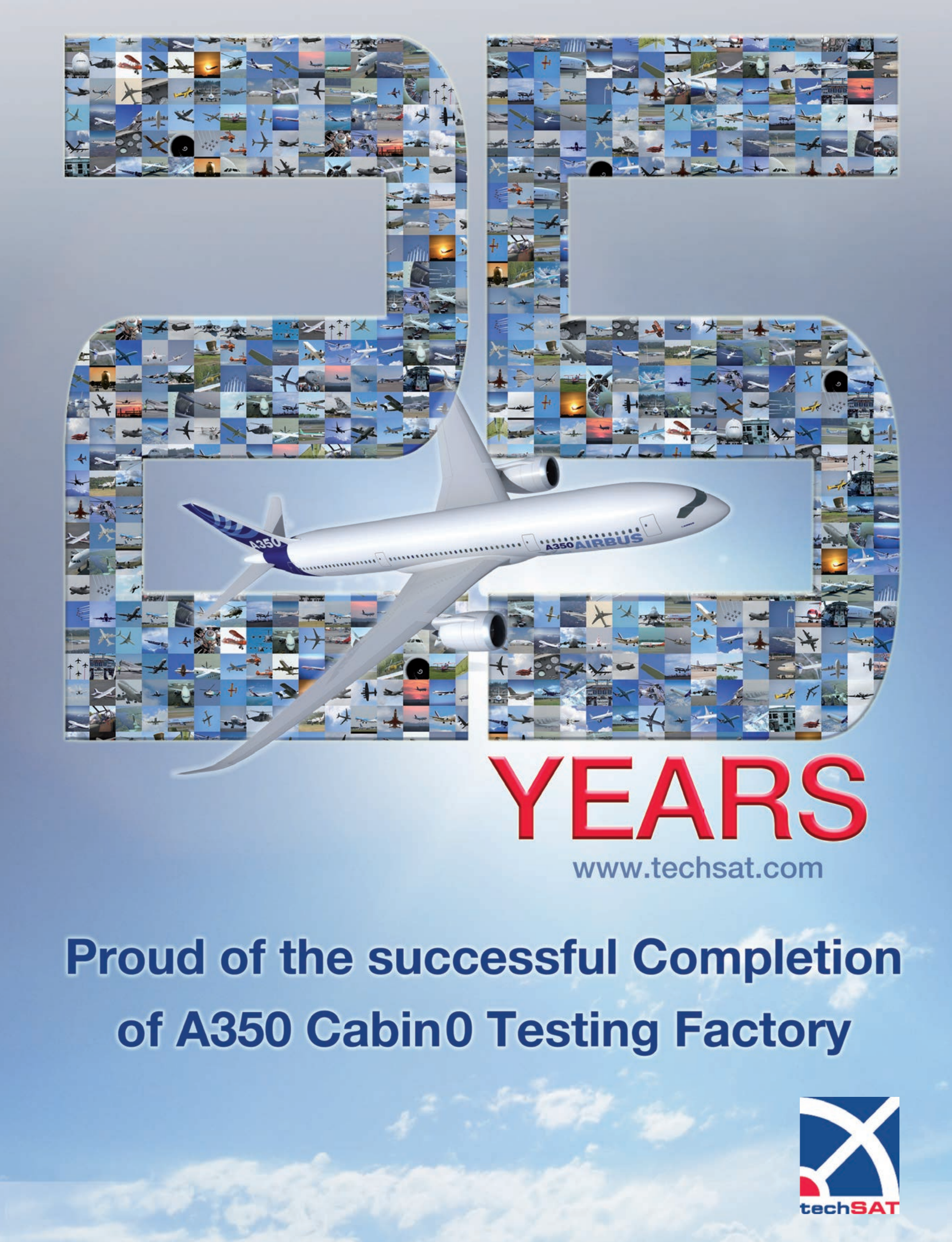
One of the most demanding changes required by Goodyear came about as a result of the addition of the new electronic sign technology. Because of the many uses Goodyear puts on its airships, it was necessary to give the Zeppelin NT an increase in its rate of climb.

In airships, climb rate is not limited by engine power, but by the outflow performance of the ballonet valves (Note: In pressure type airships, such as blimps and also the Zeppelin NT, air filled ballonets inside the envelope serve the purpose of maintaining a constant envelope pressure. They are needed as a compensation volume when the lifting gas inside the envelope expands or contracts due to changes in altitude and/or temperature.). Outflow tests in a special test rig at Zeppelin showed what had to be done to improve the outflow characteristics. In the end, the required outflow could be achieved without increasing the number of air valves. Adding the LED electronic advertising banner to the airship moves the empty weight center of gravity to the rear. If not compensated by passengers in the gondola, the inflight center of gravity must be brought forward by other means. In airships, one of the main tools to trim the airship is using the two ballonets. The Goodyear airships will therefore be equipped with a special ballonet configuration, adapted to optimize trimming the airship with LED banner installed.

The envelope of an airship such as the Zeppelin NT is a pressure vessel. The pressure envelope is constructed of a high-strength, multilayer laminate that has low gas permeation. The long service life of the pressurized skin is achieved by a combination of the different materials used in the laminate.

The envelope strength is achieved by a strong base fabric designed specifically for airship use. The outermost films must be resistant to environmental aging. The Goodyear blimp is one of the most recognized corporate symbols in the world and its paint scheme is based on a silver/gray background. The standard white color of the Zeppelin envelope would have required a lot of paint or adhesive foils to provide this background color, so an accommodation to the envelope material was developed by DuPont. DuPont has provided a special gray Tedlar as the outermost layer for the envelopes manufactured for Goodyear. ▮

Juergen Fecher is head of flight test and flight physics for Zeppelin, based in Germany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THE OPTIONALLY MANNED FIREBIRD GIVES NORTHROP GRUMMAN A RAPID INTEGRATION PLATFORM AND ARCHITECTURE TO TEST SENSORS, SYSTEMS, AND WEAPONS FOR UNMANNED AIRCRAFT

Pictures courtesy Northrop Grumman

> "We didn't carry a lot of dead weight or test weight in the aircraft. It was designed to be operationally relevant from the beginning"

BY FRANK COLUCCI

Although it has yet to identify a launch customer, Northrop Grumman Aerospace Systems is staffing a system design and development effort for its Firebird multi-intelligence aircraft. The optionally manned demonstrator, meanwhile, gives the maker of unmanned aircraft systems (UAS) a rapid prototyping platform to integrate and test UAS payloads.

"We haven't advertised ourselves as seeking to be a test asset," clarifies Firebird Systems program director Rick Crooks. "We will test capabilities and payloads for Northrop Grumman and others." The medium-altitude endurance platform has so far flown with more than 15 different intelligence, surveillance, and reconnaissance (ISR) sensors. Crooks explains, "Our fundamental principle is we integrate in one day."

Speedy payload integration saves time and money. Firebird, for example, joined the US Joint Forces Empire Challenge exercise at Fort Huachuca, Arizona, in May and June last year on 90 days' notice. In 30 sorties, the demonstrator flew with eight different payloads, five of them brand new to the aircraft. Firebird played unmanned air vehicle (UAV) in the distributed intelligence-sharing exercise with a safety pilot on board. "The soldier on the ground didn't care if there was a pilot in it or not," notes Crooks. "Had we planned to fly unmanned, we would have had to have started a year in advance. The complexities associated with that exercise for an unmanned vehicle would have been onerous."

In one sortie, Firebird employed a FLIR Systems Star Safire 380HD high-definition electro-optical payload, Northrop Grumman STARLite imaging radar, Northrop Grumman CSS-1500 Signals Intelligence (SIGINT) payload, and a Harris High-band Network Radio. Another mission mixed the electronically scanned direction-finding SIGINT system with Star Safire III, HD, and 380HD gimbals. Time to switch payloads ranged from 28 to 57 minutes. "Would it have been nice to fly unmanned?" asks Crooks. "Sure, but it wouldn't have changed any of those other elements."

By May 2012, the Firebird had logged about 400 flight hours in company testing and user evaluations, all with the safety pilot aboard. The unmodified aircraft can fly unmanned under line-of-sight ground control. Over-the-horizon operations would replace the pilot's seat with a 30in satellite communications antenna and SATCOM modem. According to Crooks, "The pilot who sits in that seat is effectively flying an unmanned vehicle management system in every action he takes. The level of maturity on that architecture and the flight controls is very high, but we haven't taken the man out of it. It doesn't further our fundamental capability, and it's a cost that we'd have to take."

Plug and play system

Firebird is notable for its large fore and aft payload bays. According to Crooks, "One of the key design parameters was a very large internal bay that could use commercial off-the-shelf 19in racks that are used in flight and bench testing." The quick-change racks can be supplemented by two 18 x 69in payload pods on underwing hard points. A synthetic aperture radar has been packaged in a centerline pod. Total payload is 1,420 lb.

The network-enabled Internet Protocol architecture accommodates MIL-STD 1553 and 1760; ARINC 429; RS-232, 422, and 485; Gigabit Ethernet; Synchronous Serial, TTL, Digital Discrete; and RS-170 and HD-SDI-SMPTE 292M video inputs and outputs. Northrop Grumman and the payload suppliers make joint decisions about how best to integrate payloads with the air vehicle.

Standard racks disconnect rings make mechanical installations straightforward. According to Crooks, "If you can stay in the 19in racks with the apertures needed, we're integrated in one day, tested, and ready to fly." He adds, "Even the communication links are sort of plug-and-play. We have the Tactical Common Data Link in the Ku-band, and can communicate in L and S bands to provide alternate paths and simplify frequency clearance." Suppliers are given interface control documents to assess signal, power, and mechanical compatibility. "Usually, it involves a block diagram assessment of what the payload looks like," explains Crooks. "What we're finding is that payloads designed to fly on UAVs are designed around the platform – it's got to have its own processor, its own communications link. It may be faster and more efficient to host the software on our existing processors rather than in a pod."

ABOVE AND LEFT: **At the Empire Challenge exercise last year, the Firebird flew with a Northrop Grumman CSS-1500 Signals Intelligence (SIGINT) payload and Star Safire III, HD, and 380HD electro-optical gimbals**

The safety pilot frees the Firescout from restricted airspace and FAA Certificates of Authorization. Crooks observes, "The key part of that is the ability to fly in National Airspace becomes much, much easier." Optional manned or unmanned capability pays off in both development and operational scenarios. "From a test and envelope perspective, it means the development team can operate just like any other experimental aircraft within FAA guidelines anywhere in the National Airspace," says Crooks. "It simplifies each and every time you add a new capability.

"From an operator's point of view, an optionally piloted system reduces the cost of user operations. He can base it at more locations than a UAV. He can use it as a training asset with a safety pilot. The ability to integrate new payloads is much easier."

Architectural exercise

The idea for an open unmanned aircraft system architecture readily integrated with different sensors, communications links, and ground-control stations began in 2000 with block diagrams and a software concept. According to Crooks, "The genesis of that was in Firescout, UCAS, Global Hawk, Hunter, and target drones, each of which occurred in different time periods, and each of which had a fundamentally different architectural basis. All were autonomous by design; what was different about them was the software and hardware glue – the architectural framework – that was driven by customer requirements."

Crooks explains, "We began a process of redesigning, taking the capabilities in all those platforms and how we put the pieces together in a modular way so that we wouldn't have to redesign each time we built a UAV to go forward." By 2003, Northrop Grumman engineers had the architecture on a laboratory bench aimed at future UAS products. The company palletized the system in 2007 and flew hardware and software on a general aviation aircraft in 2008.

In February, 2009 Northrop Grumman Aerospace Systems in San Diego started talks about a purpose-built, optionally manned platform with

LEFT: The Firebird is designed for 24 to 40 hours maximum endurance unmanned and can downlink imagery and data from multiple sensors

BELOW: The Firebird made its first flight in February 2010 – one year after initial discussions regarding a purpose-designed aircraft to carry a common UAS architecture

"The war fighters don't care what the aircraft looks like or flies like. They care what it does for them"

another Northrop Grumman subsidiary – Scaled Composites, in Mojave, California. Crooks says, "There is no one in the world like Scaled Composites in terms of the ability to think out-of-the-box and to meet the requirements for what we call 'the wrapper' – the architectural principle."

The UAS manufacturer gave the renowned design and prototyping house some 42 requirements for the new aircraft. "Persistence was the key driving design requirement that we issued," says Crooks. Also essential was the ability to accommodate multiple sensors and their infrastructure internally. "The business of mounting sensors and podding them to mount on the wing is an expensive proposition because of the extra weight and cost of airworthiness testing."

Northrop Grumman told Scaled Composites engineers the desired speed and altitude parameters, and specified that their new platform could be disassembled to fit an ISO shipping container. "Beyond that, we gave them some cost numbers, cost targets, weight numbers, and weight targets," says Crooks. The Firebird flew exactly one year later. "We were able to conduct the first flight with the architecture of the Northrop Grumman design in a platform designed by Scaled Composites."

The Firebird demonstrator, now based at the Scaled Composites facility in Mojave, California, is a 5,000 lb airplane with a 350hp Lycoming TEO-540E turbocharged reciprocating engine. "We spent the better part of 2010 expanding the envelope, conducting aircraft and integration testing, and moved immediately into testing multiple payloads and multiple capabilities," says Crooks. Projected Firebird endurance is from 24 to 40 hours, depending on configuration. Maximum sortie length so far has been about seven hours. "That's a pretty long flight for a guy in the seat." The first Firebird wears some flight test instrumentation, strain gauges, accelerometers, and pressure and temperature sensors. However, the vehicle control and management system itself provides more data than is typically generated by a test aircraft and, according to Crooks, "It's not designed *per se* as a development aircraft…we didn't carry a lot of dead weight or test weight in the aircraft. It was designed to be operationally relevant from the beginning."

A scalable solid state storage system records payload information, command and control signals, health status, and engineering data onboard. A Tactical Common Data Link with omni-directional antenna telemeters everything to the ground. "At the end, we can remove the storage device," says Crooks. "We can do forensic investigations. It's a well-crafted strategy to integrate test and operational data… there's a tremendous dataset in the white wire in our operational vehicle that would help a user understand what's going on in his airplane. It's a blend of white [operational] wire and orange (test) wire."

Flight testing progressed from low- and high-speed taxi, through general handling qualities evaluations, to three months of envelope expansion. "Fundamentally, we were expanding the envelope to create a stable, well-characterized platform that Northrop Grumman could implement sensors in," says Crooks.

Keeping elements apart

The Firebird demonstrator likewise uses a wide-open ground control station with a NATO STANAG 4586-compliant communications interface. Different UAS users have different interpretations of ground stations, and unique Firebird features such as an onboard weather radar require special controls and displays. Crooks explains, "What we use today is a blend of a ground control stations consistent with our network-based implementation, but it uses a lot of screens and interfaces that are common with Global Hawk, the US Army One System, and some new things that don't exist in those platforms." In addition to the sensors acknowledged so far, Firebird has flown with unidentified communications and electronics packages. "Each time we do that, we build our library of integrated capabilities," says Crooks. "We're aren't necessarily seeking payloads to provide a test service. The priorities are for customers with a specific need or problem, and how we can address that problem."

Cost concerns in the US Department of Defense canceled the Empire Challenge exercise for 2012, but other opportunities are continually being evaluated to demonstrate the Firebird as the optionally manned system continues development. Crooks concludes that air vehicle and payload changes will be driven by user requirements and says, "The war fighters don't care what the aircraft looks like or flies like. They care what it does for them." ■

Firebird facts

1. The Firebird system was designed around an accessible network enabled IP architecture to mix multiple internal sensors

2. Firebird works with a flexible ground control station in a mobile demonstration that provides payload integration and test facilities

3. The Firebird architecture demonstrated real-time cuing between multiple sensors at the Empire Challenge exercise last year

Frank Colucci has written about the helicopter industry for 30 years. He routinely covers rotorcraft design, civil and military operations, test programs, materials, and avionics integration

In the driving seat

AEROSPACE TESTING INTERNATIONAL TALKS TO THE TEST PILOTS WHO ENSURE NEW AIRCRAFT PROGRAMS REACH A SUCCESSFUL CONCLUSION

BY TIM RIPLEY AND CHRISTOPHER HOUNSFIELD

Demand for test pilots and their unique expertise is closely related to the level of work on new aircraft or the modification of aircraft with new weapons or systems. What is certain is that there remains the ongoing need to include a pilot to get into an aircraft and fly it again, again and again.

The test pilots are involved in all phases of planning and executing of any test program on the ground and in the air.

In Europe, for example, in the 1990s and the first decade of the 21st-century development work on the Eurofighter Typhoon was at its peak and as a result the four partner nations invested considerably in flight test activity. The UK, Germany, Spain, and Italy all shared the development work on the Typhoon, and each country maintained flight test facilities with large staffs. The nature of this work has now evolved considerably as the Typhoon program has moved wholesale into the production phase.

Test pilots at Warton in Lancashire, Manching in Bavaria, Cassele in Italy, and Getafe in Spain are now heavily engaged in weapon integration trials as new, enhanced capabilities are developed for the Typhoon, and testing each production aircraft as they come off assembly lines. The partner nation air forces now have their own operational test and evaluation units to bring new capabilities into frontline service.

The largest concentration of military test pilots and flight test engineers in the world are currently working on the Joint Strike Fighter (JSF) project in the USA, which is tasked with ensuring that the Lockheed Martin F-35 Lightning II is fit to enter service with the US armed services and export customer air forces.

At its peak the JSF Integrated Test Force (ITF) will comprise some 1,500 US and international personnel based at several sites across the USA. The test and evaluation (T&E) process is intended to identify technical or operational deficiencies for resolution prior to final production and deployment of the aircraft. The F-35 T&E effort is divided into two areas: verification and test (V&T) and flight test. Both V&T and flight test areas overlap in terms of methods, responsibilities, results, and products.

F-35 case study

When Jon Beesley, the original chief test pilot for the F-35, retired, Alan Norman took over as head CTP for the entire program and has extensively flown all variants.

"One of the keystones for the design of the F-35 is its commonality," says Norman, speaking exclusively to *Aerospace Testing International*. "So, what we've done is make all the variants as similar as possible. Really, the only difference between the airplanes is how you take off and land. Up and away, they're very similar; so similar, in fact, that once you're in the cockpit,

One man, three F-35 types

Alan Norman is chief test pilot for the F-35 program

Few people know the F-35 as well as Alan Norman does, and he for one is impressed by the aircraft's advanced mission systems, which take a large workload off the pilot. "The 5th-generation mission systems give us the ability to do things we've never been able to do before," he says. "They free up a lot of our brain so we can plan ahead and execute."

With these mission systems, pilots no longer have to worry so much about being the technician who in the past had to manipulate sensors and tweak things on board the airplane. "Now, we can step back and take the broader view of being a tactician.

"We have the total view of the battlespace with the advanced sensor fusion mission systems," he continues. "We have complete situational awareness, which gives us the flexibility and adaptability to respond appropriately. And because of the communications suite on board the F-35, we can share all that information with our allies in real time."

Norman rates the engine highly, too, and says it has been very reliable. "What a lot of people don't realize is that the core of the F135 is basically the engine that's in the F-22," he explains. "So, we do a lot of testing on it and spend a lot of time on it. We have a lot of information about how this core engine works. The Pratt & Whitney guys have talked to me about the engine. They said, 'You know that 119 engine you liked in the F-22 so much? Well, this is basically the same engine, only better.'"

This reliability can be seen in air-start testing. "The engine performance is matching and exceeding our predictions. The next big stressing thing we'll do is high angle of attack (AOA) testing. In high AOA, we put the airplane in positions where the airflow is limited so the engine is stressed to keep up with demands. But, I have no doubt that our engine will be robust in that situation."

So is there one single element that impresses Norman most? "The F-35 concept as a whole continues to amaze me in the sense that we have this commonality and oneness. We've taken three different airplanes and three different service requirements and combined them in a way that is easy and seamless for the pilots. Although the F-35 is one of the most complex and advanced aircraft ever made, it's also one of the simplest to fly.

"It has the phenomenal capability to fly 'well above the Mach'," he continues, "and also conduct vertical landings. I just think it's incredible we can do something like that. We've taken vertical landings and made them commonplace, simple, and easy. On legacy aircraft, hovering took three or four hands and mind-bending acrobatics. Now we use the computer to make things much simpler. That frees us up to concentrate on the task at hand – taking the aircraft into the fight."

Turning a fighter into a glider

Major Steven Speares is the operations officer for the 461st FLTS (Flight Test Squadron Air Force Flight Test Center), JSF. He is a USAF pilot who independently tests the F-35A and has his own specialities

As one of the initial cadre of F-35 developmental test pilots, Major Steven Speares currently flies the F-35A at Edwards AFB, and is the government-led test pilot for mission systems and air-starts. He flew the F-15E operationally before becoming a test pilot.

The enormity of his job is not lost on him: "I get the once-in-a-generation opportunity to fly the first test flights for a new fighter aircraft," he says. "From a fighter pilot's perspective, I get to influence the jet that will be the free world's frontline fighter for decades to come."

The data collected by Speares and his test force is constantly fed back to the contractor and F-35 Joint Program Office (JPO), which in turn use it to impact both the design and development of the jet. This includes data that shows systems are working as planned as well as data that details unexpected events or anomalies that potentially drive changes to the jet.

Speares says the program is unique from a concurrency perspective, where jets are rolling off the production line much earlier in the life of the program than previous platforms. "This can make it challenging from a testing perspective, because any new discoveries made during test flights inherently have a greater impact on aircraft design," he explains. "This means it is imperative that we test as efficiently as possible and communicate our lessons learned in a clear and concise manner so that the leadership at the JPO can make the most informed decisions for the program."

The technology used is similar to that of many other programs, where data is telemetered down to a control room and recorded on board the aircraft. "The difference with JSF is the sheer volume of data recorded. The difference between the data flow from an F-35 and a legacy platform is the difference between a dripping faucet and a firehose at full blast."

Within the past two years, the JSF Integrated Test Force at Edwards has taken the F-35 to the limits of its design, vetted basic operational features, and provided a safe flight envelope for the pilots at the training center in Eglin AFB to fly within. "We've executed flight test at unprecedented rates," reveals Speares, "solved issues when we've encountered them, and documented deficiencies for future focus, all while under the scrutiny of both national and international policy makers."

The most daunting challenge for Speares so far has been balancing the two main objectives of the F-35 test program while maintaining a schedule that is driven by concurrency. "How do we execute a thorough test program that provides the warfighter with the most capable combat system and finish it in the minimum amount of time so that it doesn't hold up the production line? It is a challenge that changes as the program progresses, which makes it that much more difficult to solve. It comes down to the quality and character of the folks who work on the program to meet that challenge, and although it will be difficult, I think we'll get there. This aircraft will most likely be the last bastion of manned fighters, so it needs to be done right."

One of Speares' most memorable flights involved conducting air-starts for the first time with a production F-35 engine. "It is a truly unique experience to turn off your only engine while a few miles up in the air and become the world's most complex glider," he enthuses. "The sound goes quiet and you're just soaring above the world below. Focusing on the various test parameters, it's easy to forget you've got 50 people in a control room listening to your every breath. Then the engine restarts and all's right with the world. The best thing about the air-start testing was that it was so uneventful, a fact due primarily to the well-prepared team of experts we had on the ground during the flights."

everything the pilot sees and does and interfaces with is essentially the same from the A model to the B to the C."

The ITF is engaged simultaneously with developmental test and evaluation (DT&E) and operational test and evaluation (OT&E), although as production ramps up over the coming decade the latter will take on more prominence.

So what is the best aspect of the 5th-generation fighter from a test pilot point of view? "5th generation is unprecedented. It gives us an edge in the fight, and in an air combat scenario or inside enemy territory I want that advantage on my side. I don't want just to win 51 to 49. I want to win 100 to nothing," enthuses Norman.

"Unless you've been fortunate enough to fly a 5th-generation fighter or had the misfortune of flying against one, then you don't realize how important all these advances are when they come together. The very low observable stealth aspect of 5th generation makes us hard to see. As a pilot, that frees me up to operate in places where I couldn't before and to operate with the knowledge and confidence that I don't have to worry about hiding all the time.

"Combine that advanced stealth with extreme performance and maneuverability like that of legacy fighters, add in the increased capability of sensor-fused avionics and incredible mission systems, and you've given the pilot an unmatched multirole fighter and an unprecedented advantage over the competition," continues Norman.

The ITF has a personnel and operating budget of US$1.8 billion, which gives some indication of its scope and scale. Flight test operations take place at China Lake Naval Air Warfare facility and Edwards Air Force Base in California, Patuxent River Naval Air Station in Maryland, and Lockheed Martin's Fort Worth plant in Texas, and is conducted according to the JSF test and evaluation masterplan (TEMP).

According to Norman, the test flight plan is ahead of schedule. "We've already taken the A-model out to its top Mach of 1.6 and its top g-rating of 9g. We've already started air-start testing on it, and we're getting ready to start high alpha or high angle of attack testing. We've seen the B model land and take off from sea, and we've done catapult launches with the C model. We've demonstrated how the mission systems work and talk together, and we exceeded our flight test goals last year."

All the flight test activity feeds into the deficiency reporting program to identify problems and issues with the aircraft, as well as contributing to the US certification and UK safety case work. The flight test program is gradually evolving and will ultimately move toward the live fire phase involving the deployment of live weapons on test ranges. The US and export customer air forces are now in the early stages of standing up their operational test and evaluation facilities to develop the tactics and procedures of how to use the aircraft in combat.

Norman explains, "Over the calendar year of 2012, we'll see a lot of new things in testing. We'll round out the full envelope of the F-35 in terms of speed and altitude. We'll do weapons separation, and we'll expand the high angle-of-attack envelope."

Best of British

Andy Blythe is a graduate of the Empire Test Pilot School. He has 20 years' experience flying Tornados and Jaguars in the RAF

Andy Blythe is currently working on the ongoing Tranche 2 Typhoon development, Tornado datalink integration, and testing the Hawk for the USAF and the RSAF. "I am looking at how we develop cockpit layout, all in an effort to create a clean cockpit environment in front of the pilot," he says.

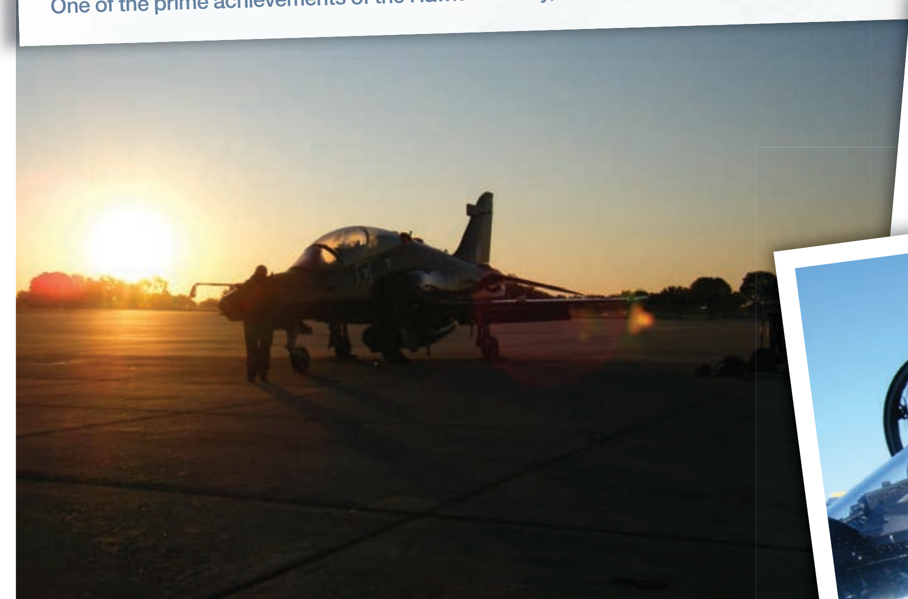
The flight operations division at Warton in Lancashire, UK, has four test pilots who between them have experience of over 20 different fast jet aircraft types, including Tornados, Harriers, Jaguars, F-16s, A-10s, JSFs, F-15s, and Gripens.

Blythe explains more about the part he plays in the design: "The test pilot provides a lot of guidance and advice on HMI (human machine interface) both in the design phase and development phase once flight trials begin. During the design phase the test pilot is pivotal in explaining the customer requirements to the software engineers. Drawing on previous experience and knowledge of current aircraft design developments, the pilot can then offer possible solutions to a given problem. Once the engineer has a proposed solution it will be assessed by the test pilot either on a computer-based model or on a dedicated aircraft rig. The test pilot usually identifies the problem and doesn't try to find a solution, leaving that to the engineer who understands his present design."

The aircraft at Warton are equipped with FTI (flight test instrumentation) that can record data bus traffic, control column inputs, and voice. Most development aircraft are equipped with real-time datalinks so that all the data can be viewed in real time by the engineers on the ground. One of the prime achievements of the Hawk T2 was the software load of OC2. Blythe is keen to point out the importance of the test pilot's role in the upgrade: "OC2 software was the load to introduce full operational capability of the sensor simulation. The initial software load proved to be very good, which vindicated all the previous rig testing and development work. Flying the trial sorties with the customer pilots in the aircraft allowed them to feed the development team with their initial thoughts, rather than telling them once the software had been delivered. Also, the initial software load was already very robust and there were only a few very minor comments from the customer that allowed time to change the software to correct the few deficiencies.

"Our biggest challenge has been explaining to potential customers that the Hawk T2 is a new aircraft," he continues. "The aircraft has a similar silhouette to all previous marks so – rightly – potential customers question what has changed. The aircraft physical design is sound and an excellent lead-in trainer to 4th- and 5th-generation fighters. The avionics are key to the Hawk's capabilities, and open architecture computer systems and a bespoke datalink have enabled the team to design a future-proof training system."

The new system makes the aircraft effectively a flying simulator, allowing the instructor to introduce basic and advanced air-to-air, air-to-ground, and electronic warfare scenarios both pre-planned and in real time while airborne. "The emphasis in future flying training will shift toward sensor management, and Hawk is there and ready," concludes Blythe.



On a special mission

Magnus Fredriksson is an experimental test pilot with Saab Support Services, Aircraft Services Divisions

Magnus Fredriksson began his flying career as a fighter pilot with the Swedish Air Force in 1983, flying the Saab Viggen. In 1993 he left operational flying and began working with test and evaluation of new projects with the Swedish Defense procurement agency (FMV). He completed test pilot training with EPNER in 1995 and has since worked within the flight test community. He is now part of Saab Support Services.

Many of his assignments today are Special Mission Projects. "That means tailoring an aircraft for a particular mission – Maritime Patrol, Border Patrol, SAR, AWACS, etc.," he says. "As well as understanding all technical issues of the aircraft you also have to have a good in-depth operational knowledge on how the customer will run their operation. So it is not just a question of JAR/FAR 25 certification issues; we also have to make sure our design team understands the operational environment and the mission. We support the design organization in matters concerning MMI, operational issues, cockpit layout, operator consoles, and issues about crew resource management."

Fredriksson says that much of the company's recent success is due to the way it works. "By assigning a project team with involvement of design, development, and operational personnel (i.e. test pilots and mission specialist) early on we are usually able to identify areas of concern before the final design is chosen. In all, the relationship works well, with respect for each other's profession.

"From day one we try to put the operational aspects into everyone's mind," he continues. "What are the product objectives and how will pilots and operators work? By continuously asking ourselves these questions we hope to have the right focus throughout the project."

Acknowledging the need to fully understand a problem before even starting to try to solve it, Fredriksson says they are usually able to choose simple and effective solutions. "We had one such problem on a recent project where we ended up trying numerous quick fixes before realizing that we had to do a complete redesign of a system. Had we done a proper problem analysis early on we would have saved both time and money. The basics for the problem analysis is to have the entire design and test team involved."

Early on in his career Fredriksson was asked to do a VHF range certification test. Certification criteria required a 160 nautical mile radio range capability for a pass result, but at 100 nautical miles the radio contact with the test center was lost. "When, during the debrief, I asked why we reached only 100 nautical miles before losing radio contact," he says, "the design engineer responded that he was impressed and had expected only a 50 nautical mile range capability. So I asked why we did the certification test!

"Well, I guess it is all about having a good and continued dialog with the design team. Eventually the antenna on this particular aircraft was moved and we were able to certify the new VHF comm system."

Beyond JSF and Eurofighter

Outside the JSF and Eurofighter projects, only a few nations can afford to run flight test facilities for advanced combat aircraft. France and Sweden have test centers that are heavily involved in the development of the Dassault Rafale and Saab Gripen respectively.

In China, the Chengdu Aircraft Design Institute (or 611 Aircraft Design Institute) is leading the effort to field the J-20 stealth fighter. Photographs of the aircraft suggest its design closely resembles the USAF JSF or F-22 Raptor. It underwent high-speed taxiing tests in 2010 and made its maiden first flight on January 11, 2011.

Russia is also working on a 5th-generation fighter, dubbed the Sukhoi T-50, and the first production models are supposed to be ready for frontline in 2014/2015. Flight test work on this new aircraft is split between the state-owned M. M. Gromov Flight Research Institute at Zhukovsky, 25 miles southeast of Moscow, and the Komsomolsk-on-Amur Aircraft Production Association (KnAAPO), where the aircraft are currently being manufactured.

The global demand for military test pilots might not be at the levels of the 1970s and 1980s when new aircraft programs were running at levels four or five times those of today, but few nations want to lose this vital expertise. The UK, USA, France, Brazil, India, and Russia all currently maintain test pilot schools where domestic and foreign students are taught the skills necessary to become a test pilot.

The introduction of advanced modeling and simulation has taken out much of the danger from flight test work and it is now very rare for modern experimental aircraft to crash or suffer major mishaps. There is still a requirement for a human to test aircraft to limits of their flight profile to make sure they work as advertised. As Norman says, "That's why we test. We can try to wring out everything in a lab and wring out everything in a flying lab like the CATB, but there's just something about putting it on an airplane and going out and doing the open air testing on the platform itself.

"The CATB is a go-between in software development. There are only so many things we can do in a ground laboratory. CATB enables us to take things from that ground laboratory to an open-air environment where we can make adjustments on the fly because we have engineers on board. We learn a lot of lessons from the CATB that we can put in the software before we release it to the F-35s. So, CATB is integral to our success." ∎

Tim Ripley is an aerospace and defense expert based in the UK. He regularly comments to the international media about a variety of issues and is a prolific defense author

Sound advice

THE EVER-INCREASING NEED FOR QUALITY AND IMPROVED PERFORMANCE IN AEROSPACE APPLICATIONS IS PUSHING THE INDUSTRY TO SEARCH FOR MORE AND MORE NVH SOLUTIONS

BY JOHN CHALLEN

As new airplane series enter the market, passengers and crew are expecting marked improvements on comfort levels and the overall environment. The introduction of these new airplanes has lead to a desire to cut noise, vibration, and harshness, and this trend shows no sign of stopping. Products and services provided by a number of companies involved in NVH development are concentrating on improving the quality and reducing the noise of numerous components, to the benefit of aircraft manufacturers.

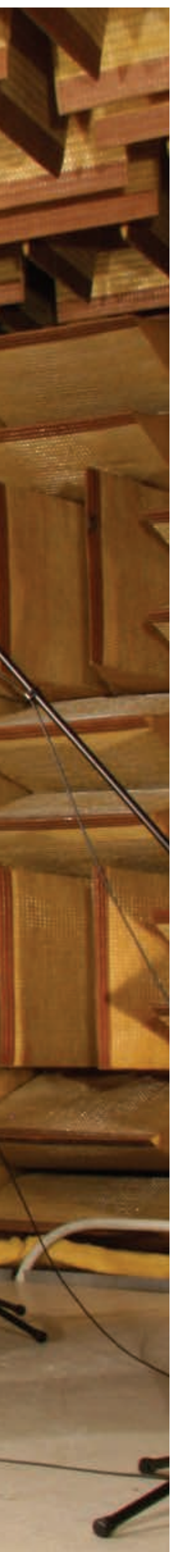
A recent development in North America is the investment by Technicon Acoustics in an acoustics lab to offer product development and testing services, as well as analysis of materials evaluations. The North Carolina-based company's president, Tyler Keeley, believes that the addition of the lab will "allow us to stay on the leading edge of sound technology. The space provides fine-tuned scientific measurements of sound, giving us greater accuracy in our sound solutions".

The main areas of the lab are the hemi-anechoic chamber, measuring 18 x 29 x 10ft, and the reverberation chamber (22 x 26 x 12.5ft), which has been constructed with reflective sound materials to create a diffuse sound field. Technicon Acoustics' technical director, John Gagliardi, admits that while the facility does have its limitations, there are plenty of evaluation opportunities for the aerospace industry. "We can't test all of our customers' products there, but we can test a good number of them," he explains. "For aerospace, it's not big enough to test a large fuselage section, for example, but we can test most smaller components, and also analyze the acoustical performance of a wide range of materials, in terms of how much they absorb, and block, noise."

Gagliardi says airplane parts that could be tested range from fuselage walls and a section of the outer skin, down to landing gear-mounted actuators, airfoils, and generators. "We can work with any parts that make a noise," furthers Gagliardi. "If the manufacturer wants to know how much noise the seats make, for example, it can also be done in the lab."

Equipment-wise, there is a variety of systems and tools available. "We have a couple of four-channel measurement systems; one

Technicon Acoustics has recently invested in a test lab that houses hemi-acoustic (far left) and reverb (left) chambers. The facility allows a broad range of aerospace products to be evaluated there



from Brüel & Kjær, the other is manufactured by Sinus," explains Gagliardi. "We also have a binaural torso – an anthropomorphic item with a speaker in the mouth, and microphones in the ears. These allow us to test speech intelligibility of crew or passengers when they communicating while sat next to each other." The product, called the KEMAR, and produced by G.R.A.S., can also test headsets used in the air, and Gagliardi claims not many labs have the ability to undertake such testing.

Good vibrations

Another Brüel & Kjær product deployed in the Technicon Acoustics lab is a vibration damping test rig. "If a surface is vibrating, the rig acts like a speaker cone, and generates a sound, so when a material is applied to flexible panels it can cut down the vibration displacement that creates sounds," explains Gagliardi.

Elsewhere, more vibration testing technology for the aerospace world comes courtesy of Hanse Environmental. The company has recently introduced a new generation of its random shock 6DoF vibration system, which offers a vibration range from one to $100G_{rms}$ (root mean square acceleration), doubling the available vibration force previously available. For HASS and HAST (highly accelerated stress screening and highly accelerated life test, respectively) work, the vibration systems are installed in specially designed environmental chambers capable of temperature change rates of 70°C a minute.

"We don't control the frequency band [of the system] – that is pre-determined by the design of the vibrator – but 90% of our energy is stored in the 5-400Hz range, and the unit can work in all three axis simultaneously," explains Peter Hanse, vice president at Hanse Environmental, who also confirms work has started the unit's replacement. "The next generation of the vibration system is in its prototype phase," he confirms. "It is a combination unit that uses both electric and pneumatic shakers, which will allow us to shape the frequency responses.

"At the moment it is pre-determined by the table design, but with this new system,

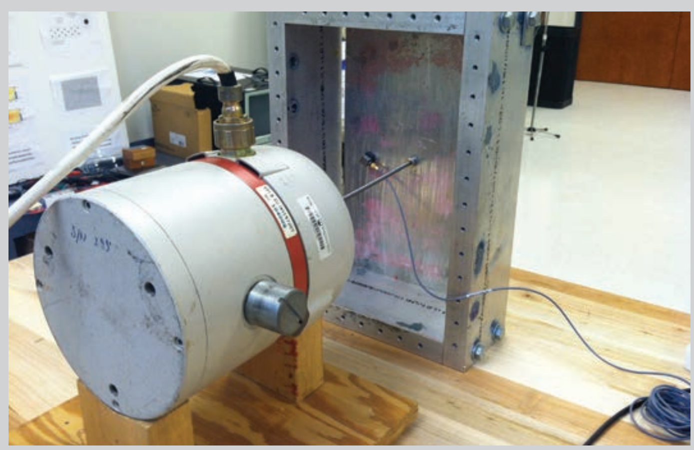
Virginia's vibration test investment

Virginia Polytechnic Institute and State University has recently opened a new laboratory dedicated to vibration and acoustics development for aerospace applications.

The laboratory, sponsored by Brüel & Kjær, is part of Virginia Tech's new National Institute of Aerospace (NIA) Research and Innovation Laboratories in Hampton, Virginia. The facility contains instrumentation and equipment for measuring and analysing vibration and sound, and will support education in acoustics and vibration. It will also enable advanced research into analysing, understanding and developing innovative solutions for noise and vibration problems that occur in aircraft, rotorcraft, and spacecraft.

One of the main areas of development work undertaken by the facility will be active noise control, to help reduce aircraft exterior noise. "One of NASA's important goals is the development of environmentally friendly aircraft and noise is a key aspect of this program," says Christopher R. Fuller, professor of engineering at Virginia Tech. "The work in this new lab will support NASA and the commercial aviation industry in developing quieter engines, and less airframe and interior noise in aircraft and rotorcraft." Fuller, an expert in acoustics and noise and vibration control, has previously worked on controlling interior noise and vibration in aerospace applications, launch vehicle payload noise, and other related concerns in the automotive and marine industries. "I am very pleased that Brüel & Kjær has agreed to sponsor our laboratory," he says. "The sponsorship and interaction with Brüel & Kjær will undoubtedly lead to a significant increase in the quality and reputation of the work and education performed in our laboratory."

Multifunctional and advanced acoustic materials that reduce vibration and harvest energy will also be studied at the new Virginia Tech site, given the



importance that vibration control has when designing efficient aircraft and space structures.

Future directions in acoustics and vibration research to be considered in the laboratory include the investigation of meta-acoustic materials, which combine advances in nano-and material technologies to create lightweight, sound-absorbing materials with increased performance. The combination of microbiology and materials may lead to genetically grown materials which have improved vibration and noise reduction qualities.

"Brüel & Kjær is pleased to be helping with this partnership to ensure that NIA students can benefit from B&K's core sound and vibration knowledge and our multiple and dedicated solutions for core markets such as aerospace," says Bill Wright, Brüel & Kjær application engineer for the mid-atlantic region.

French connections

One of the most recent destinations for LMS's NVH test technology is the French technical center, CETIM. The organization has acquired multiple LMS SCADAS mobile testing systems for NVH, which, it says, will be used in numerous tasks ranging from in-vehicle measurements and vibration diagnosis to failure, to vibro-acoustic and modal analysis.

"In our opinion, SCADAS is the most flexible system that we can find for our test applications," explains Patrick Vincent, from the noise and vibration engineering department at CETIM. "We use only SCADAS systems and, because many of our customers are LMS users as well, using the same testing systems simplifies communication immensely."

A key asset for CETIM is the flexibility offered by LMS's equipment. On average, a test setup requires 40 channels, but certain customers require more channels than others. To solve this, CETIM can chain separate LMS systems together to reach the additional channel capacity and handle simultaneous test runs.

"Since we have very limited time to test our customers' prototypes, we need to work as fast and efficiently as possible. We recently linked three LMS SCADAS mobile systems into a 120-channel configuration. This way we could do on-site parallel data acquisition and collect as much data as possible for later processing at the CETIM facilities," states Vincent.

"A group of the RAF's most experienced qualified flying instructors was involved in the T2 project from the outset"

operators can adjust the frequency response, making the machine more versatile and able to run more types of testing beyond HALT/HASS." Hanse says the new system, set to be launched within the next 12 months, will allow additional parameters to be adjusted for the best test results and the lowest frequency response into a lower or higher band, enabling failures to be realized in the quickest possible time.

Typically square, vibration table shape has also been investigated by Hanse Environmental, in a bid to achieve better test results. "We have developed new round tables that provide a more even response between the x, y, and z axis," he confirms. "Most people like the square because of the ease of mounting the products, but round is better because there are no sharp points on the table for the vibrations to come into contact with. A lot of the nodes you experience on corners you don't get on the round tables because you get a slightly different response from the main area of the table."

Hanse Environmental's 4ft standalone VC-16

Data acquisition

Also helping to achieve better results and a more efficient test program is an effective data acquisition system (DAS), and this is where DTS can help. Historically involved in crash testing and safety work, more recently the company's attention has turned to other markets, including aerospace.

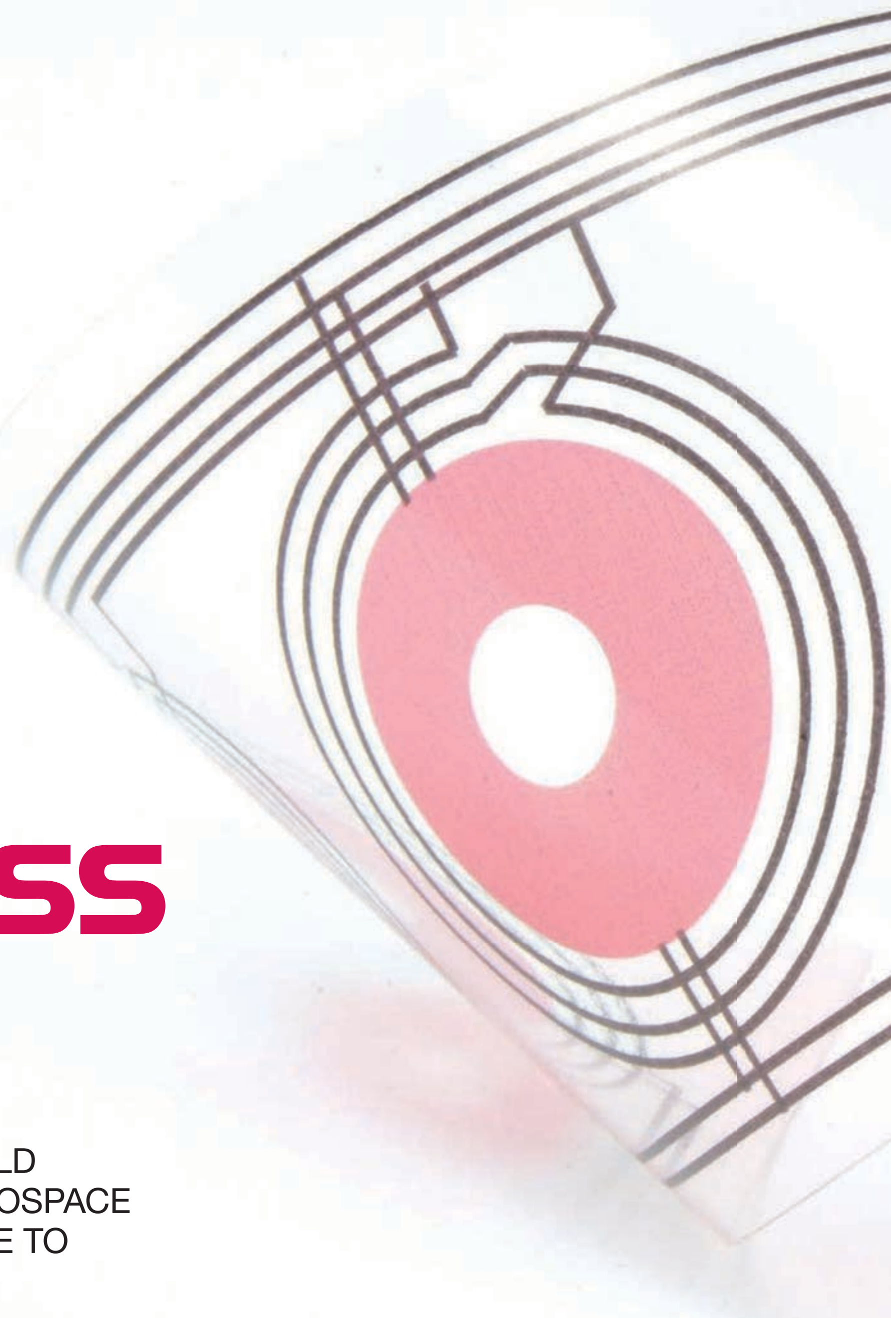
Mike Beckage, vice president and one of the owners of DTS, reveals that the company's compact DAS, SLICE made a big difference. "When we introduced our SLICE products, we took the company into a different direction, because we were offering products that were the smallest on the market, had the highest sampling rates, and huge memories that can receive data over long periods of time," he reveals. "Last year we introduced the IEPE SLICE DAS recording capability, a three-channel module that supports external IEPE piezo-electric sensors and is specifically targeted at the aerospace market." With this product, says Beckage, DTS has been working with Boeing and NASA to develop systems that engineers can use for noise evaluation and squawk and pop testing in airframes.

"Boeing was using a system based on an old tape recording system, which collects data from multiple points," recalls Beckage. "We were able to package that system in something the size of a shoe-box, which has all of the battery power, data recorder, and connections in it. If test engineers need to put it on a plane quickly and carry out some evaluations, they are now able to do that quickly and efficiently."

Beckage says the fact that DTS is relatively new to these systems, and also competing against established companies with a lot of experience of new testing technologies, should not be a problem. "We will be adding digital interfaces that can integrate GPS data, and improve the ability to do time-synchronized data acquisition over the location of the aircraft – that is one of the main areas we are looking at now."

Beckage assures that having become established in the market, it intends to stay. "We are already working on a new version of SLICE – SLICEPRO – and prototype units will be delivered in July," he says. "This new version will see the sampling rates increase from 100,000 to one million samples per second, and the data bandwidth will be up to 200kHz, making it ideal for a number of advanced applications." ∎

John Challen is a UK-based journalist who specializes in engineering and technology in the aerospace, automotive, and transport industries



Weight-loss program

PLASTIC AND PRINTED TECHNOLOGIES COULD POTENTIALLY MAKE A GREAT IMPACT IN AEROSPACE ELECTRICAL AND ELECTRONIC SYSTEMS DUE TO THEIR WEIGHT-SAVING PROPERTIES

BY STEVEN BOWNS

Few commentators can have failed to notice the great leap in military capability that has been delivered by unmanned aerial vehicles (UAVs) over the past 15 years. UAVs have jumped from effectively large model aircraft curiosities such as the British Army's Phoenix in the 1990s, to a critical element of military capability today.

This capability leap has been achieved partially by a large investment in R&D but also by a multitude of innovations from outside defense. Examples range from ducted fan technology to new electronics technologies.

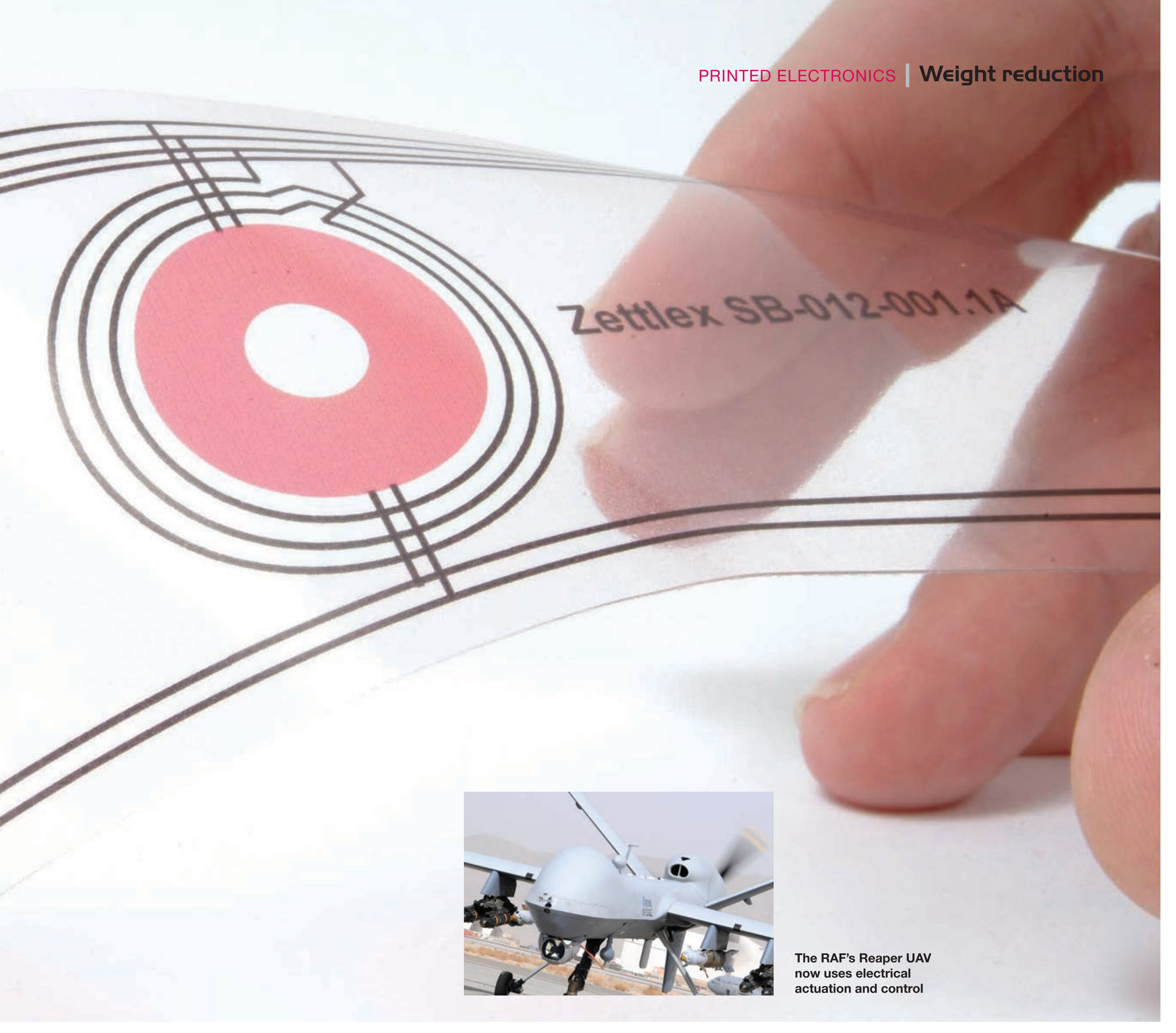
Removal of the human pilot has also removed many of the flight safety process constraints, allowing UAV engineers to take greater risks – with greater performance returns as a result. The drive for ever-higher levels of endurance, speed, stability and payload in UAVs and the ability to exceed the 7g limit of human endurance has focused attention on mass and driven the adoption of many weight reduction technologies. This in turn has resulted in a widening of the technology gap between military and civil aerospace.

In contrast, over the same period, the increasingly complex and burdensome regulatory standards for civil aircraft require that any new technology has a significant and proven track record before it can be adopted. In other words, it must not be new. Accordingly, the civil aerospace sector has been considered by many component and system manufacturers to be slow moving, where quality control and conformance to standards are paramount, with cost and innovation secondary.

Test and evaluation

There are other more subtle barriers at work, for example, within the area of testing and evaluation regimes. Although the requirement is typically cascaded down from a high level, any program will often specify a particular test or method system needed in detail. It might specify a 'cable and wiring harness', for example, which could have the effect of inadvertently excluding a plastic electronic solution. There is certainly scope for more progressive testing and evaluating regimes to be developed in order to encourage the adoption of these weight-saving technologies.

Despite this trend, the increases in oil prices over the past few years have seen the civil aerospace sector focus again on weight reduction. The cost of aviation fuel has doubled since 2006 and increased almost four-fold since 2001. Fuel is typically an airline's single largest operating cost and the increased cost of fuel has bitten hard into most operators' margins. Fuel efficiency is directly linked to aircraft weight. Roughly, a 1% reduction in aircraft weight equates to a 1% increase in fuel efficiency. This might not seem significant until one considers that for an operator such as the combined BA & Iberia, its 2011 fuel costs will exceed €1 billion. Reducing the



The RAF's Reaper UAV now uses electrical actuation and control

weight of its aircraft fleet by 10% would add €100 million per year to its bottom line.

Airline operators are facing fierce commercial pressure and this is being transmitted to the aircraft manufacturers and designers. There is now a degree of immediacy in demands for weight and cost reduction, which coincides with a raft of proven weight-reduction technology in the military UAV sector. Due to the long lead times and regulatory constraints of the airframe itself, this pressure is likely to be transmitted onto the component and system manufacturers. It remains to be seen whether they are able to rise to the challenge of transferring and delivering this military UAV technology across to the civil aerospace sector.

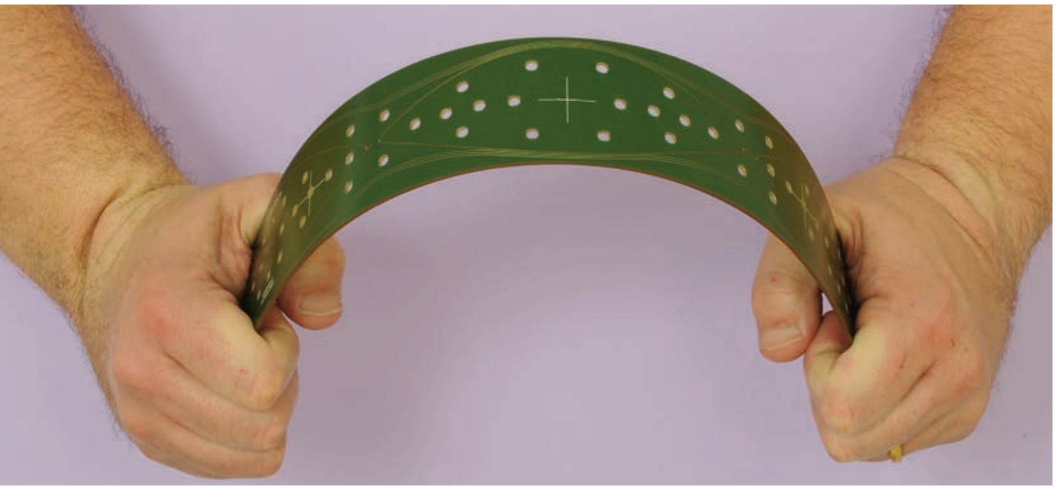
Reducing weight in other systems

Many of the more obvious candidates for weight reduction, such as airframe and landing gear, have been trimmed to such an extent that there is nothing more to work with. Attention is now turning toward less obvious areas – not least of which is actuation and control systems, which can account for up 15% of an aircraft's weight. In a move to meet these new demands, there has been a marked trend away from hydraulically powered actuation and control to electrical power.

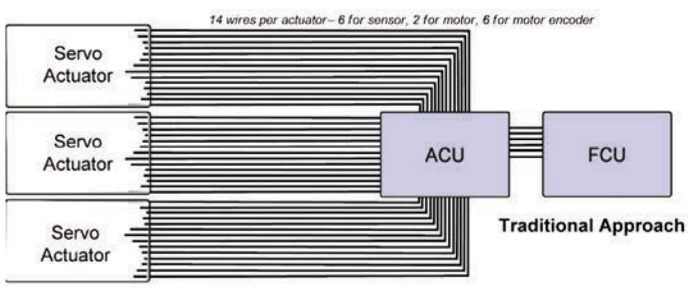
The use of electromechanical systems as a lightweight alternative to hydraulics was identified as far back as 1979 by NASA. More recently, the UK government funded an £11 million (US$17 million) study called ELGEAR (Electric Landing Gear Extension and Retraction) for UK industry to develop electrical actuation technology. The transition to electrical actuation and control is still underway for the civil aerospace sector but UAVs in the military sector are already using electrical actuation and control combined with plastic and printed electronics to minimize weight and costs.

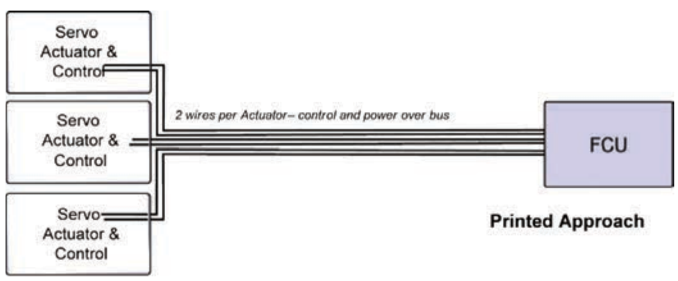
Printed electronics technology typically uses conductive, semi-conductive or insulating inks printed onto thin, flexible substrates such as Kapton, polyester or polyimide. The term 'plastic' electronics is also used because many of the substrates are plastic or organic. The technology is most usually associated with high-volume applications such as RFID tags, photovoltaic cells and printed circuits for consumer electronics. Until recently, it has not been generally considered for aerospace applications, but now that the advantages can be seen so clearly, the technology's range of potential aerospace applications has expanded dramatically.

Printed and plastic electronics technology's most obvious application is as a replacement for cabling. More interestingly, it is also a candidate for high-functionality elements such as motor encoders, servo feedback devices, and motor control circuits. The technology's extreme lightness and flexibility offers some unusual features and benefits to UAV designers who are able to avoid the cost, weight, and mechanical-electrical constraints of traditional cable harnesses, electronic enclosures, and connectors. In some instances the flexible electrical laminates may be



ABOVE: Another example of printed plastic sensor technology from UK company Zettlex





The diagram shows the difference between the original 14-wire approach and the latest 2-wire printed approach

position and speed sensors are used in fixed- and rotary-wing military aircraft, as well as a raft of other applications in the industrial, medical, oil, and gas sectors.

Although at first sight such devices might seem flimsy and delicate, it should be remembered that the printed forms are rarely used in their 'naked' state. More usually they are fitted by bonding or encapsulation to the host mechanical structures such as the aileron, wing spar, gearbox, seat, etc. They will often be completely embedded in resin, for example. The printed feedback devices do not need a precision alignment of the moving and stationary parts of the sensors, so further mechanical elements such as guides, bushes, bearings, and seals can also be eradicated, producing further weight savings.

Plus points of print

The advantages of such printed technologies do not just end with weight reduction at the actuator itself. Their weight advantage is increased still further due to the eradication of cabling between actuator and centralized control units – typically a flight control unit (FCU) or actuator control unit (ACU). Traditionally, these centralized units receive signals from the servo feedback device and motor encoder and, in turn, transmit the required power to the motor. Such signal and power lines might typically require 14 individual wires per actuator. Compare this to the printed approach, where the intelligence is distributed to each of the actuators.

The modest amount of software for actuation is embedded into the printed sensor's control circuit. There is no need to transmit power and signals for computation to the centralized unit as the necessary computation is carried out at the actuator itself. Only command signals and power are transmitted from the ACU or FCU to the actuator. Because the command signals can

simply embodied as layers within composite structures. This is already being used in some Formula 1 racing cars.

Printed electronic application

One area where printed electronics is already proving its worth is in sensors and motor control systems for servo actuation and feedback. Such systems are common in flight surface controls, intake ducts, brakes, throttles, and undercarriage controls, as well as business- and first-class seating.

Traditionally, these systems use an electric motor, motor encoder, gearbox, and a transformer-based servo feedback device such as a linearly variable differential transformer (LVDT). Although such transformer-based feedback devices offer precision and reliability, they are often as bulky and heavy as the motor. A 300mm stroke LVDT might be a 25mm-diameter cylinder that is 500mm long and weighs 1kg, whereas its printed alternative is 3mm high, 330mm long and weighs 25g.

The advantages of the printed approach are even more obvious when one considers that many aircraft systems require duplex or triplex redundancy. Whereas a duplex or triplex LVDT roughly doubles or triples the original weight and volume, a printed device simply uses more layers of printed tracks to form an isolated second or third electrical system. In a simplex system, the weight reduction is typically >95% whereas in a duplex or triplex system the weight reduction is >99%. On an individual device the net effect is modest; however, when one considers that more than 50 such devices may be used in an aircraft the total effect begins to be very significant.

> **"Many of the obvious candidates for weight reduction, such as airframe and landing gear, have been trimmed to such an extent that there is nothing more to work with"**

There is a technology cluster in Cambridge, UK (which started with the Cavendish Laboratories in the 1990s and includes Cambridge Display Technologies (CDT) and Plastic Logic), that developed some of these technologies at the turn of the millennium.

They are now being commercialized successfully into printed devices that are in production by companies such as Zettlex in Cambridge, which produces rotary, linear, and 2D sensors as part of printed actuator control systems. Their be provided over the power lines, only a two-wire bus is required.

The use of printed electronics technology is already well underway in the military sector – they are flying today on UAVs in their electrical actuation and control systems. In time, the technology will be adopted by the civil sector because its weight and other advantages are so marked over the traditional techniques. The driving force will be increased fuel efficiency as a result of weight reduction. The greater the inflation of fuel price, the greater the pressure for adoption of printed technologies. It is likely that this technology transfer challenge will be laid at the door of component and system manufacturers. ∎

Steven Bowns is a director and consultant with Technology Futures Ltd, based in Cambridge, UK

Defence with a race pedigree

BUILDING ON RACE CAR TECHNOLOGY, BRITISH COMPANY LOLA HAS EVOLVED AND MOVED INTO THE AEROSPACE TEST INDUSTRY

BY DAVID OLIVER

It is exactly 50 years since the first Lola Formula 1 racing car appeared on the Grand Prix grids in the hands of former motorcycle World Champion, John Surtees. Designed by Eric Broadley, who trained as an architect and built his first sportscar in 1956, Lola racing cars would become one of the most successful British marques in motorsport, winning a Grand Prix, the Indianapolis 500, and countless international sportscar races.

Building on its formidable heritage as a racing car manufacturer, in addition to Lola's impeccable racing record, the company has broadened its new technology and testing capabilities into other sectors – including defense.

Conventional warfare has changed, and a combination of international resolutions and public opinion makes boots on the ground less and less likely. Reaction time is key, opportune targets disappear as quickly as they first present themselves, and military forces must be fast and flexible – and so must their suppliers.

Lola's commercial director, Paul Jackson, is quite sure that the company's racing experience gives Lola a competitive advantage within the defense industry: "The race track is a demanding

> **"The 54 air vehicles will be equipped with a synthetic aperture radar/ground moving target indicator"**

environment; cutting-edge technology, meticulous specifications, and tight timeframes. We are used to the pressure and know-how to deliver on time, every time."

The technical center forms a separate part of the Lola factory and incorporates a commercially available 50% scale rolling road windtunnel, seven-post vehicle dynamic test rig, and a model shop.

Tooling and production of parts for aerospace has long been a Lola specialty. Typical parts include cowlings, wing components, fuel cells, floatation systems, and door components, as well as various in-cabin structures. Lola has recently been working on various classified contracts for the US Department of Defense (DoD) and the UK Ministry of Defence (MoD) as private sector clients. These include the design and manufacture of advanced unmanned aerial vehicles and systems, and sophisticated aerial targets.

UAV tools

Lola Group was commissioned for the design and manufacture of the tooling of the prestigious WK450 Watchkeeper unmanned aerial vehicles for the MoD. Its composites department is responsible for producing the tooling of the entire airframe using the design supplied by Silver Arrow/Elbit, the manufacturer of the Hermes 450 UAV, on which Watchkeeper is based.

U-TacS is a joint venture between Thales and Elbit Systems, leading industrial and defense companies based in UK and Israel respectively. In August 2005, Thales UK was awarded an £800 million (US$1.2 billion) contract for the development, manufacture, and initial support phases of the Watchkeeper tactical unmanned air vehicle system that will provide the UK armed forces with intelligence, surveillance, target acquisition, and reconnaissance capability, which will be deployed to Afghanistan from the end of this year.

The 54 air vehicles will be equipped with a synthetic aperture radar/ground moving target indicator, and either datalink relay or electro-optical/infrared sensor to deliver high-quality image intelligence day and night and in all weather conditions. Lola used its total composite design and manufacturing capability, including design optimization analysis, CAD/CNC programming using CATIA 5 pre-preg kit cutting, and trim/finish/assembly.

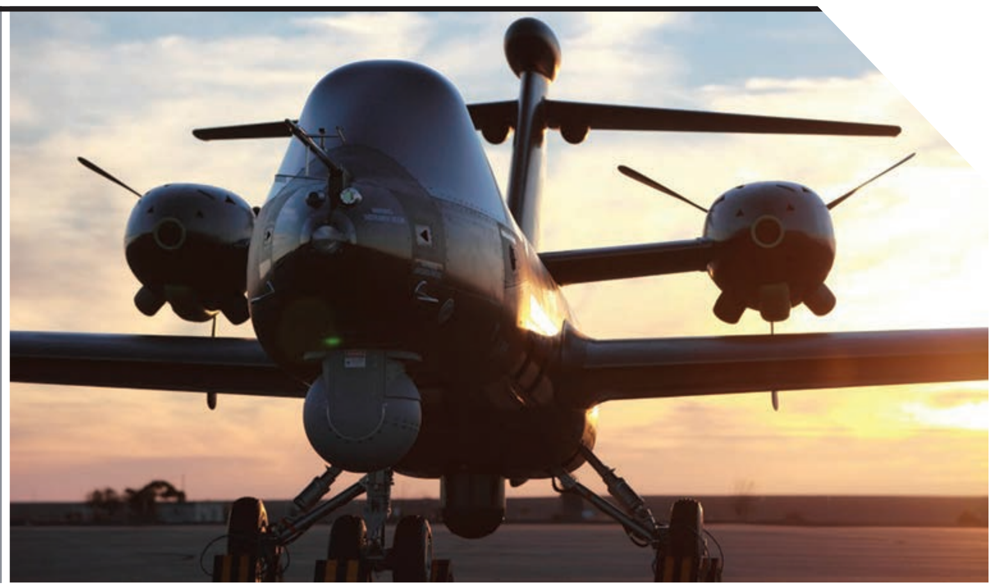
At the same time, Lola was contracted to provide composite components for BAE Systems' Mantis medium-altitude, long endurance unmanned aerial system technology demonstrator. The assembly of the twin turboprop-powered aircraft and ground control infrastructure took place at Lola, and was delivered to BAE Systems in 2009. Gary Bootle, head of ASFC operations for BAE Systems Warton, said of the project, "Lola has undertaken some excellent work around the production of the fuselage components,

LEFT: Watchkeeper will equip the UK forces with intelligence, surveillance, target acquisition, and reconnaissance capability (Thales)

RIGHT: The Mantis medium-altitude, long endurance, UAS technology demonstrator (BAE Systems)

BELOW RIGHT: The advanced composite airframes of the Watchkeeper UAV produced by Lola

BELOW LEFT: The Meggitt Banshee aerial target has a one-piece composite wing by Lola (David Oliver)



"Meggitt also provides Voodoo target services to the Danish, Norwegian, and Portuguese navies"

specifically the monocoque, which houses a 5m-long fuel cell. With the project seeing design work one day and manufacturing the next, Lola's exceptional ability to respond rapidly to changes in design requirements has been put to good use."

Building on its success with Thales and U-TacS, becoming a partner of choice to a Tier 1 manufacturer underscored Lola's ability to deliver proactive support, engineering ingenuity, and speed of build.

Aerial target

The UAV's projects were not the first aerospace projects that Lola has been involved in. The Meggitt Defence Systems' Banshee is a low-cost recoverable aerial target constructed with glass-fiber reinforced plastics developed by Lola. More than 5,000 have been produced since the mid-1980s. The Voodoo is a high-performance, propeller-driven aerial target, capable of sustained airspeeds of over 300Kts, at all operational altitudes between 16ft and 20,000ft. With an endurance in excess of two hours, and an ability to carry a range of proven mission specific augmentation devices up to distances of more than 100km, Voodoo provides a realistic and affordable alternative to more expensive jet powered targets.

A team of engineers at Lola Composites worked closely with members of Meggitt's design team to turn the Voodoo into productionized air vehicles. Lola looked at the main aspects of the design with the aim of downscaling the part-count of the aircraft and reducing its weight to enable an identical build for the future and also to use commercial-off-the-shelf parts. The fuselage is two-piece carbon composite and the main part has a removable top portion with a V-tail attached. The parachute bay is integrated and the only add-ons are the wings, which are assembled together for complete span. It is powered by a three-cylinder engine, which powers the UAV up to 300kts.

Meggitt's customers asked for a target that is capable of speeds in excess of 300-330kts, able to carry all of the necessary payloads, be catapult launched, and be more cost-effective and versatile than booster launched jet targets. The Voodoo is in service in Spain and Taiwan, and since 2010 with the UK armed forces. Meggitt also provides Voodoo target services to the Danish, Norwegian, and Portuguese navies, as well as the US Air Force at Tyndall AFB in Florida.

The US connection with Lola has continued with Northrop Grumman's development of the Long Endurance Multi-Intelligence Vehicle (LEMV), a state-of-the-art hybrid military airship for the US Army that will provide intelligence, surveillance, and reconnaissance support for ground troops. Lola was involved in the UK-built HAV-3 hybrid airship, which first flew in 2008 to serve as a subscale development vehicle for the 300ft-long LEMV. In addition to its defense projects, 2012 will see more new motor racing teams compete with Lola LMP products at the world-famous Le Mans 24 Hours, as well as the new 2012 FIA World Endurance Championship. ∎

David Oliver is a freelance aviation writer, author, and an IHS Jane's consultant editor

RIGHT: Lola has been involved in the design of Northrop Grumman's Long Endurance Multi-Intelligence Vehicle (Northrop Grumman)

BELOW: Lola designed the production version of the Meggitt Voodoo high-speed aerial target (David Oliver)

Keep the fire burning

THE ONE AND ONLY FLYING AVRO VULCAN SPENDS HER LIFE PERFORMING AT AIR SHOWS THAT ARE FAR REMOVED FROM THE FAST, HIGH-ALTITUDE RUNS FOR WHICH SHE WAS DESIGNED. *AEROSPACE TESTING* EXAMINES THE PROJECT THAT RETURNED HER TO THE SKIES AND THE TEST REGIME THAT KEEPS HER THERE

Photo: Jamie Hunter

“Surprisingly, civilian life can be harder than military service”

BY RICHARD GOTCH

It was 20 years ago this year that the UK’s Ministry of Defence placed an advertisement for the sale of one of the country’s most popular aircraft. At its center was a simple black and white drawing of Avro Vulcan XH558 – the last of her type still flying.

She had led a charmed life. When Vulcans were withdrawn in 1984 she had recently received an expensive ‘major service’, allowing her to fly on for another eight years with the RAF’s Vulcan Display Flight. But by 1992, another major service was due, as well as a costly modification to the rear spar – substantial expenses that the RAF was not able to justify in a financial climate where they were expected to show ‘peace dividend’ savings from the end of the Cold War. So the advertisement was placed, and in March 1993 she was delivered to her new private owners, C Walton Ltd, at the company’s Bruntingthorpe Aerodrome in Leicestershire, UK.

In a separate and remarkably visionary transaction, the company also acquired the RAF’s entire stock of Vulcan spares – around 16,000 line items weighing more than 600 metric tons – hoping that one day, it would be possible to return XH558 to the skies.

Most complex project

The return-to-flight project began in 1997 when David Walton met Dr Robert Pleming, an experienced technical manager looking for a new challenge. It was immediately apparent that the project would be uniquely complex. In addition to the technical challenges, the team would require the cooperation of well over 100 companies that had manufactured thousands of systems and components for the aircraft. They would also have to persuade the UK’s Civil Aviation Authority to issue a permit to fly: something that had never been achieved for an ex-military aircraft of this power, weight, and complexity.

Testing was central to the renovation project, which began with a detailed inspection, removing almost everything that could be removed. Every aspect of the aircraft’s structure was inspected visually and various non-destructive techniques were employed to reveal any hidden problems. More than 450 x-ray images were taken and numerous minor faults were found and repaired.

Even mundane components received rigorous inspection and renewal. Many miles of pipes and hoses that passed through inaccessible places were taken out, cleaned, visually examined, leak tested then refitted or replaced. The Vulcan has many critical systems powered by electricity so all critical wiring was replaced. Other wiring was checked inch-by-inch for embrittlement, chafing, and other damage to ensure there would be no in-air surprises.

“The energy put into this by everyone was remarkable,” says Robert Pleming, who was leading the project as chief executive of the charity Vulcan to the Sky Trust, which had been created to buy the aircraft for the nation.

Many systems were sent back to their original manufacturers for expert refurbishment using original drawings and specifications. Often this provided a worthwhile apprentice training program and introduced a new generation to the precision and regulated working practices of aerospace engineering – a contribution to the future of engineering that the charity is keen to continue developing.

Early in 2007, the team was ready to start bringing XH558 back to life. Electrical power was applied, starting with 24V DC, followed by 200V 400Hz three-phase AC. One by one, the various systems were put through RAF-documented test procedures to ensure correct setup and operation.

"Everything we do is based on proven RAF procedures and test regimes that were carefully developed and enhanced throughout the aircraft type's 28-year service life," explains Pleming. "The test phase went reassuringly smoothly, but it would be wrong to imply that there were no problems – after all, that is what testing is all about. A couple of the faults were spectacular, both arising from component failures in the 3000psi hydraulics. But all of them were fixed and we eventually achieved sign-off for each of the critical systems."

Finally, after 26 months of hard work by staff and contractors totalling more than 100,000 man-hours, Avro Vulcan XH558 was ready to fly. On Thursday, October 18, 2007, there were clear blue skies above an expectant audience. "She roared down the runway, lifted her nose wheel and soared into the air," says Pleming. After a 30-minute flight, the crew brought the world's only airworthy Vulcan back to the airfield for a perfect landing.

Maintenance and test

Today, XH558 is well into her fifth display season. This year will be particularly special as it combines the 60th anniversary of the prototype Vulcan's maiden flight with the Diamond Jubilee of Her Majesty Queen Elizabeth II (although the aircraft's part in this had to be canceled, see *Broken Arrow*) and the 30th anniversary of the only time that a Vulcan was used in anger: the remarkable 8,000-mile Black Buck raid on the runway at Port Stanley during the Falklands Conflict. The captain on that famous flight, Martin Withers DFC, is now chief pilot with Vulcan to the Sky Trust.

Flying your name

The biggest challenge for Vulcan to the Sky Trust is not technical, it's financial. Maintaining and operating XH558 costs around £2 million (US$3 million) a year, which comes from a mix of commercial activities, corporate sponsorship, and public support. To learn more about the Avro Vulcan and how to support the last flying example, visit www.vulcantothesky.org, where you can also find out where to see her flying and register for email newsletters.

XH558 has successfully completed her pre-season test flight following the most extensive service since her return to the skies. "Some of the systems that were renewed during the restoration had reached the end of their five-year installed service life," explains technical director Andrew Edmondson. "Safety-critical items such as the ejection seats must be sent back to their suppliers for specialist testing and maintenance every year, and some extremely costly items such as the brake parachutes must be replaced."

Surprisingly, civilian life can be harder than military service. During Cold War peace-keeping duties, the Vulcan's typical mission profile created few worries for those monitoring her fatigue life. "She was designed to cruise at constant speed and high altitude, traveling continents on the way to her target," says Edmondson. "Today, her Permit to Fly is for Visual Flight Rules, which means she must fly much lower, where the air is less stable. Even more demanding is the change in her mission profile, which is now typically only a few hundred miles and involves delivering an air display, with regular transient accelerations in all axes."

Working closely with the engineering team, the flight crew has learned to deliver a visually and aurally dramatic display while minimizing stresses on the engine and airframe, but the need for rigorous testing remains paramount. "We are very proud that thorough testing and maintenance has delivered safety and reliability that outstrips many modern military jets," says Edmondson.

Non-destructive

The most sophisticated element of the test program is the extensive non-destructive testing (NDT), which includes x-ray, dye penetrant, eddy current, and ultrasonic techniques. X-rays are taken at night when the hangar is empty to minimize unnecessary risks to personnel as each exposure involves a dose equivalent to 50 chest x-rays. The position on the airframe of each film, the strength and duration of each exposure, are all specified by the RAF procedures adopted by the charity.

Preparation for NDT is also defined in procedures. XH558 spends much of the week prior to the NDT program with daylight under her wheels – not flying, but carefully suspended on jacks so that her wings deflect the appropriate amount to reproduce the effect of flight stresses and reveal any potential problems. Even lowering the aircraft from her jacks onto the undercarriage is a sophisticated process, carried out slowly to avoid any over-stressing of the structure.

New test technology is employed where appropriate. Borescopes are used to check for corrosion or loose rivets inside sealed areas, such as the internals of the Olympus engines, and digital recordings are made to enable repeated study of critical areas, as well as to provide an auditable record of the procedure.

"The procedures to which we work must comply with the current, extremely rigorous standards set by the CAA, as well as meeting the requirements of the highly professional design authorities, whose support is vital in allowing us to fly a complex ex-military aircraft," concludes Pleming. "We are now starting to think about how we can combine these skills with the excitement of a living, breather delta-winged aircraft to enthuse young people with a passion for engineering and to provide training throughout their careers." ∎

Richard Gotch is spokesperson for Vulcan to the Sky Trust based in the UK

Broken arrow

Two of the engines of the Vulcan, which failed to take off in a test run at the end of May, are beyond repair. The aircraft experienced engine problems and smoke was seen pouring out of the XH558 bomber with debris covering the runway. A statement from Vulcan says that the last flying Vulcan's Jubilee programmed flights will have to be called off: "The technical team has investigated the engine damage on XH558 to determine its cause and to start assessing the timescale and cost of rectification.

"We have already established both engines, on the port side are sadly beyond repair, both having suffered blade damage and the effect of excessive heat. The primary cause of the damage has been determined to be ingestion of silica gel desiccant bags. The most likely event was that material was ingested by one engine, which surged and suffered LP compressor blade failure. Debris was then sucked into number two, which then also failed."

Servicing of jet pipe on Vulcan XH558

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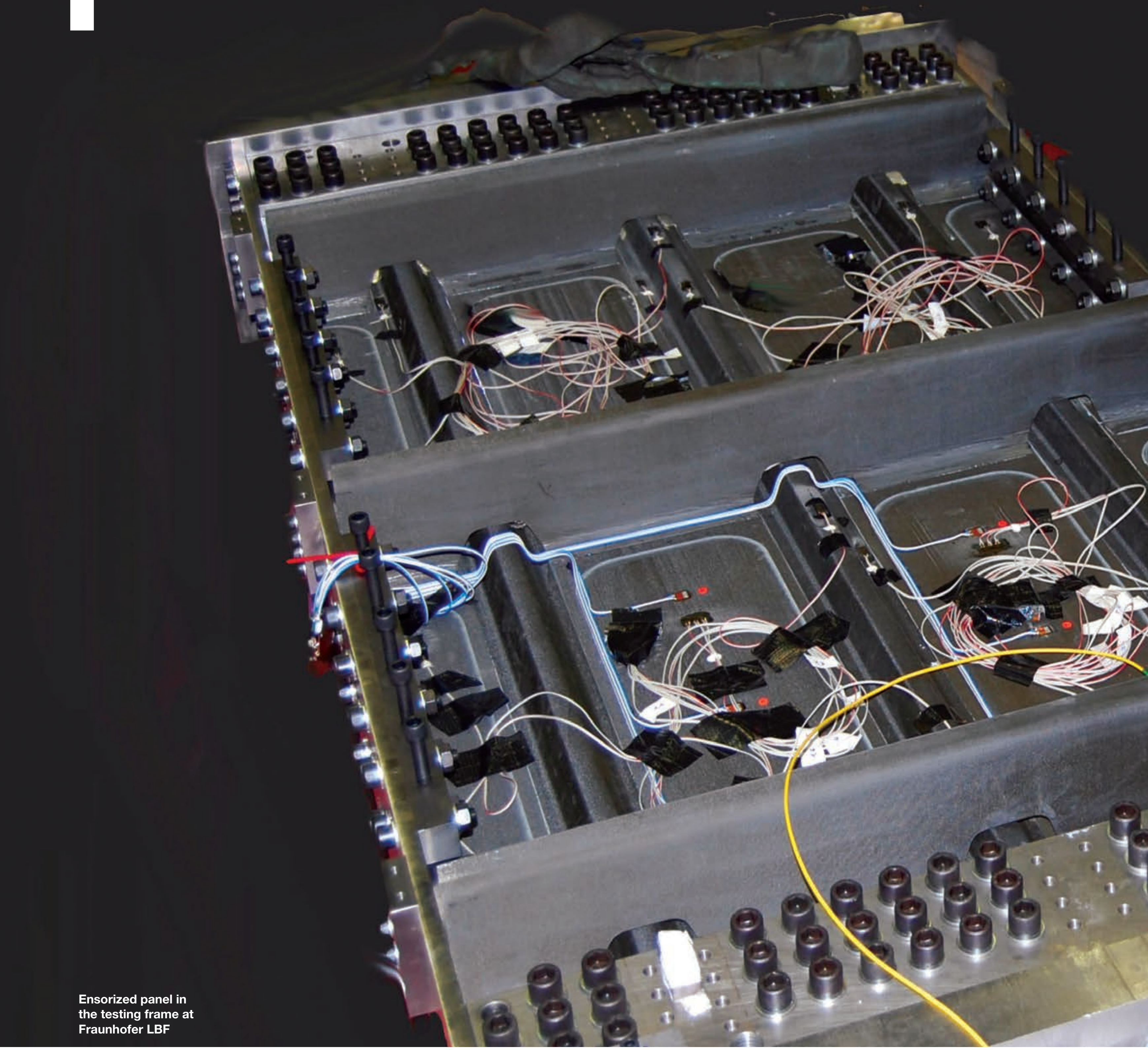


Ensorized panel in the testing frame at Fraunhofer LBF

A TWO-STEP EXPERIMENTAL ROAD MAP FOR THE GREEN REGIONAL AIRCRAFT INTEGRATED TECHNOLOGY DEMONSTRATOR HAS BEEN DEVELOPED BY THE FRAUNHOFER INSTITUTE AND ALENIA

BY VALERIO CARLI & MARTIN LEHMANN

Three years into development, the Clean Sky project is now entering the four-year implementation and demonstration program phase. Clean Sky, the most important European project for greener aeronautics to date, has a well-defined objective: to demonstrate the applicability of the most promising environmentally friendly technologies to future aeronautic products.

ITD (Integrated Technology Demonstrator) is the key phrase for all Clean Sky partners (and also the stem name of each technological platform of the project). The final objective of each technological stream is one or more full-scale demonstrators on the ground and – for several applications – also in flight.

Europe wants to play an important role in the strategies set to preserve the environment: Clean Sky is the concrete answer to the request for more environmentally friendly technologies for aeronautics. ACARE (Advisory Council for Aeronautical Research in Europe) has established targets for 2020, including: 50% reduction in fuel consumption and CO_2 emissions per passenger/km; 80% reduction in NOx emissions; 50% reduction in perceived noise; and substantial progress in reducing the environmental impact of the manufacture, maintenance, and disposal of aircraft and related products (best lifecycle impact). These long-term objectives require a synergetic approach to the problem by all involved partners. A greener life chain is under consideration, from pre-conceptual design to manufacturing, dismantling, ground operations, and mission-related issues.

Among the ITDs, which represent, along with the Technology Evaluator, the backbone of the Clean Sky project, the platform that is Green Regional Aircraft (GRA) contributes to the targets by enhancing regional aircraft and related technologies. Alenia Aermacchi and EADS-Casa lead this platform, and 29 European members contribute their expertise. The platform is structured into five domains: low weight configuration (LWC); low noise configuration (LNC); all electric aircraft (AEA); mission and trajectory management (MTM); and new configuration (NC).

LWC and LNC are more independent domains, as far as complex systems like the aeronautic ones can be, while AEA, MTM, and NC are integration-orientated domains and therefore interact more with other ITDs with similar and complementary targets.

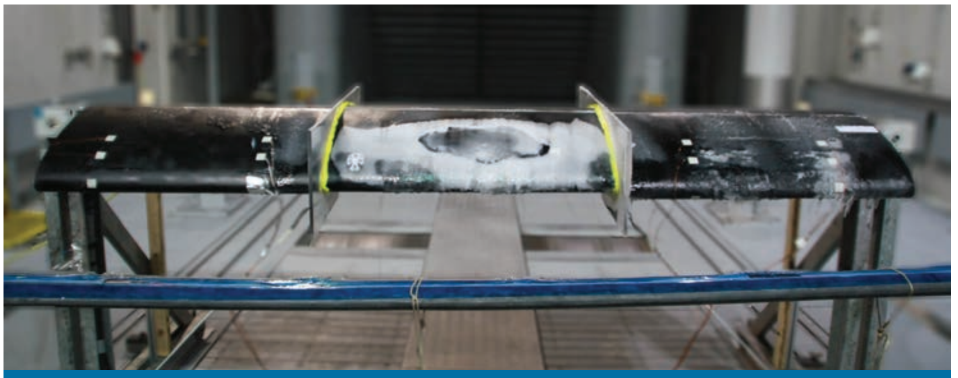
GRA contributes at a regional aircraft level to the global environmental objectives set by ACARE: a reduction in burned fuel and consequently fewer emissions as a result of weight and drag reduction, enhanced aerodynamics, and optimized energy management; noise emission reduction by means of enhanced high-lift devices and landing gear; and enhanced flight patterns for optimal fuel use. All the above is investigated by the partners of the ITD. For each domain, development and validation phases have been planned. During the project the TRL (technology readiness level) will be improved from 3 to 5-6, depending on the impact validation of the different technologies.

Aircraft ratios

For regional aircraft the ratio between OEW (operating empty weight) and MTOW (maximum take-off weight) is higher than with long-range aircraft; OEW counts significantly on fuel consumption and therefore on emissions during all phases of the mission.

The Fraunhofer-Gesellschaft, along with the other partners involved in the domains, supports Alenia Aermacchi with its competencies and expertise and by managing some key work packages. Fraunhofer is involved in LWC and LNC domains and is responsible for several technologies. The LWC domain mostly focuses on the possible technologies for weight reduction and multifunctionality. These include sensorized structures for structural health monitoring (SHM), multifunctional composites for improved performances, and new manufacturing techniques for composite as well as for metallic materials.

The LNC domain focuses on the technologies for enhancement of high-lift devices, load control and alleviation, low-noise main, and nose landing gears. For both LWC and LNC domains, as well as a



Left: Leading edge with embedded nanoparticles for ice protection. Left and right sides: active leading edges. In the middle: passive leading edge for comparison

Below: Sensorized panel at Fraunhofer LBF; under testing: local buckling of the skin

Ice-protection system

Some technologies are being investigated for their impact on more than only one technical domain. In the frame of the GRA platform Fraunhofer has been working on an advanced ice-protection system.

A more efficient aerodynamic configuration is also needed for low drag systems that concern ice-protection of parts more prone to this problem such as the leading edge. This technology affects structural integration and energy management of the aircraft. Fraunhofer's concept is based on a system for electrical heating with nanomaterial for composite leading edges. The nanomaterial is protected from erosion as it is fully embedded in the composite lay-up.

As no metal is used inside the composite material many disadvantages of conventional metallic heating systems are avoided. The system has been enhanced over the years and the latest generation was recently tested in a climate wind tunnel. The tests have proved that the system works properly under different icing conditions. During critical temperatures ranging from -7°C to -18°C operating modes like de-icing and anti-icing were tested on two heated leading edges equipped with the novel system. A leading edge without ice-protection has been also tested under the same condition for reference.

continuous technology enhancement, a two-step validation road map has been defined and scheduled. Final objectives of these domains are on-ground and inflight demonstrators for full-scale validation of the technologies.

For LWC a fuselage barrel and a wing box as ground demonstrators will be manufactured considering specific requirements for the advanced regional aircraft. In-flight tests will be performed by means of an on purpose modified aircraft, which will enable the experimental validation of selected technologies. For LNC most of the validation of the novel solutions regarding improved aerodynamics of the wings and landing gears with low noise emission will be tested in the wind tunnel by means of mock-ups, manufactured with the new solutions.

Experimental results

The first down-selection was performed last year. For the LWC domain, experimental results have been obtained from coupons and small panels that have been tested as first bench for technologies improvement. The objective of this first phase was to verify the manufacturability of the new technologies and methodologies and to assess the mechanical properties of the samples.

Typical aeronautic tests – such as tension, compression, open-hole tension and compression, and shear – have been performed. For sensor technologies combined with SHM methodologies, BVID (barely visible impact damage) and VID (visible impact damage) scenarios have been investigated. All materials have also been tested under fire and lightning conditions. Selection criteria have been set for this phase of the project in view of the future steps of the project and of the main target. These are: specific mechanical properties improvement over the conventional material; manufacturability for the second down-selection; and weight, depending on the specific application

For the technologies of the LNC domain the different concepts developed have mainly been assessed by numerical simulations. Different criteria have been set for the technologies, such as aerodynamic performances, mechanical complexity, and noise emission reduction.

Second down-selection

The concepts and technologies that have passed the first down-selection have been further developed for the second down-selection phase. This will take place later this year and will decide which technologies are mature enough for the final on-ground and inflight demonstrators. Fraunhofer and Alenia have been working closely for this decisive appointment.

The integration level of the different technologies and the cooperation has increased. In LWC the work is mainly based on the scalability of the technologies to larger stiffened panels for fuselage and wing. Typical dimensions for a fuselage panel are 1,600 x 900mm, and for the wing panels the typical dimensions are 900 x 600mm. The whole consortium will manufacture and test a large number of panels. The validation of the technologies will be assessed by testing the stiffened panels under different conditions: static compression, BVID and fatigue, VID and shorter fatigue cycles. NDT will be employed to assess the quality of manufacturing, damage conditions, and damage growth. The requirements for the panels considering this specific application have been the starting point. The partners have designed and manufactured the panels by taking into consideration each single technology and material properties.

In particular for SHM technologies, Fraunhofer has manufactured four stiffened panels with three stringers and three frames. Several sensors, such as acoustic sensors, optical strain sensors, and wireless antenna for damage detection and structure monitoring have been applied on the panels. Together with Alenia, Fraunhofer has embedded two different optical systems using its own ingress/egress technology. The whole technology has proved to be reliable. It has withstood the most severe fatigue test and the ultimate load defined for this structure.

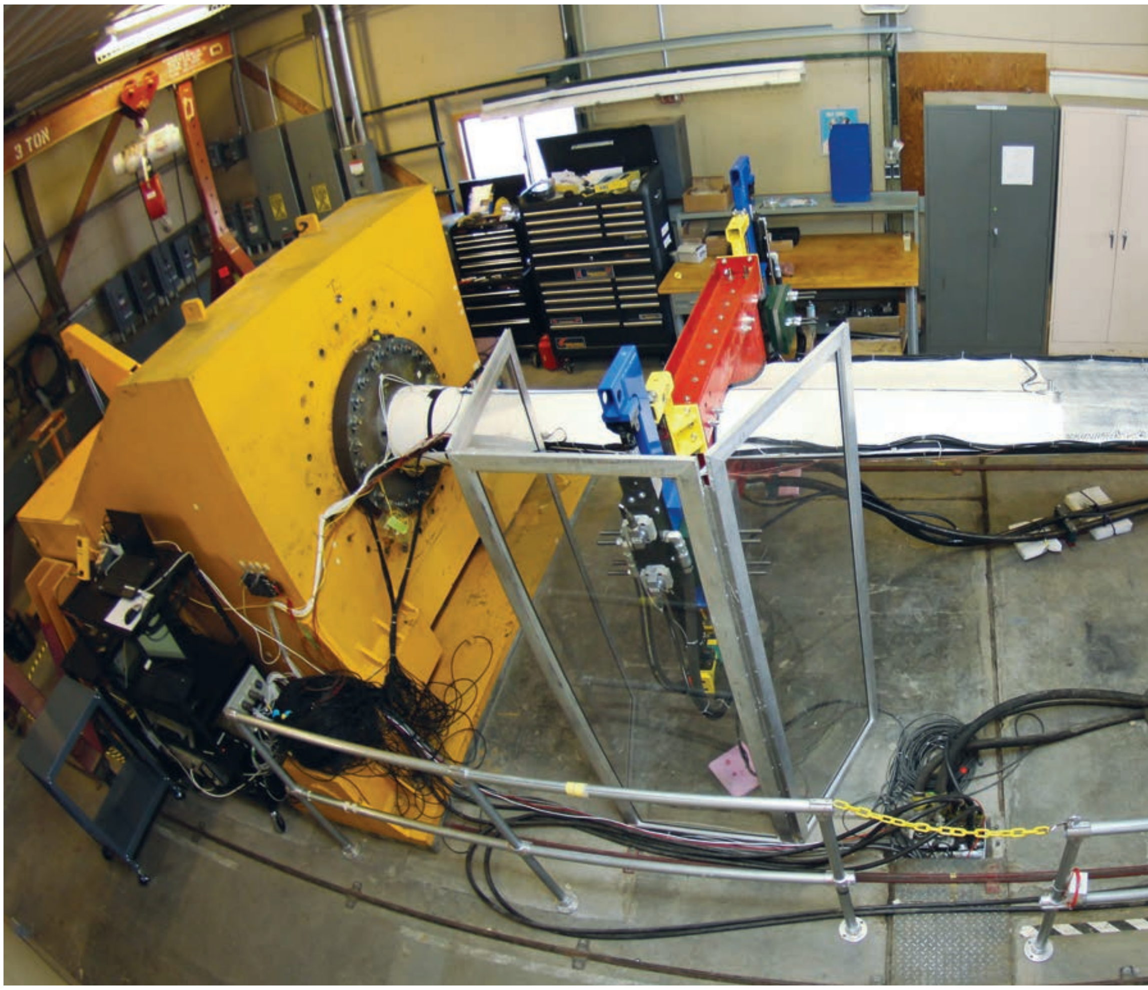
Experimental activity is an important step in the development of new technologies in Clean Sky and the basis for down-selecting the most promising ones. Cooperation and the synergetic approach of all involved partners bring the added value to the work performed by each partner. On-ground and inflight demonstration requires common efforts and perfect timing: Fraunhofer will continue to support Alenia Aermacchi and all involved partners for the high-level objectives of the GRA platform. ∎

Valerio Carli is Fraunhofer's general manager of the ITD Green Regional Aircraft, and Martin Lehmann is from the lightweight structures department at Fraunhofer Institute LBF in Darmstadt, Germany

Effects of defects

ONE COMPANY HAS DEMONSTRATED THAT FIBER OPTIC STRAIN-SENSING TECHNOLOGY CAN DETECT DEFECTS DURING MANUFACTURE AND FATIGUE CYCLING OF COMPOSITE STRUCTURES

BY DR. SANDRA M. KLUTE



Aerospace manufacturers are increasingly turning to composite materials in an effort to produce more fuel-efficient and corrosion-resistant aircraft. Huge demand for new aircraft and composites penetration of over 50% of structural weight will drive the demand up for composites in the aerospace market. Although the usage of composites varies among different types of aircraft, it is expected that future trends will incorporate greater use of composites in all aircraft.

Along with the substantial benefits of composite materials comes the challenge of ensuring the strength and integrity of resulting components both during the manufacturing process and over the lifetime of the structure. Composite airframe manufacturing methods range from manual lay-up to automated fiber placement, and from resin transfer molds to autoclave molds. However, regardless of the manufacturing method employed, accurate fiber placement is essential with uniform spacing and no wrinkles, as is complete resin introduction with no voids.

Luna Innovations Inc has already conducted tests on composite aircraft fuselage test panels showing that new sensing technology offers aerospace manufacturers and operators greater insight into residual strain left by impacts on composite structures. Now, the company, based in Roanoke, Virginia, USA, is turning its attention to the detection of defects during the manufacturing process and subsequent accumulation of damage in composite aerospace structures.

Fiber optics

In a recent US Department of Energy-funded 'Effect of Defects' program in collaboration with the University of Massachusetts Lowell, Luna demonstrated that its high-resolution, fiber-optic strain-sensing technology could monitor the internal distributed strain throughout the manufacturing process of a composite airfoil-based structure. Distributed strain measurements were taken immediately upon pulling vacuum on a carbon fiber CX-100 wind turbine blade with intentionally introduced defects designed to simulate out-of-plane waviness in the part.

With a growing demand for composite aerospace structures and an increasing number of components made across the world from a number of organizations using composite materials, the testing focused first on being able to see defects before the manufacturing process is completed, which would therefore save manufacturers and operators a great deal of time and trouble.

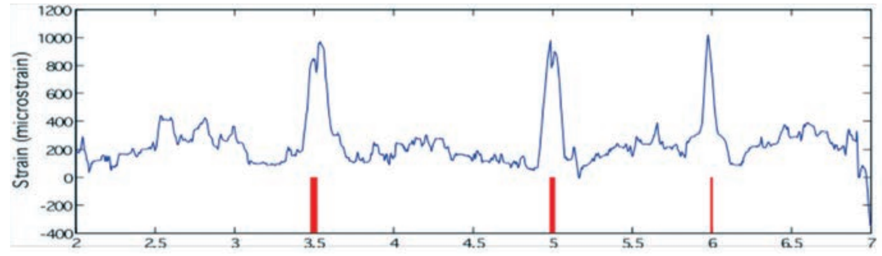
The research team embedded off-the-shelf telecommunications-grade optical fiber in several layers of the carbon fiber spar cap and used it to sense distributed strain during the vacuum-assisted resin transfer molding manufacturing process. The amplitude and phase of the light reflected from the fibers were measured using a commercial optical frequency domain reflectometer. Changes in the amplitude and phase of the back-scattered light were measured to determine the strain along the entire length of the spar cap with 5mm spatial resolution.

Distributed strain measurements throughout the depth of the spar cap provided valuable information at intermediate points in the manufacturing process to highlight defects both prior to and during infusion, the propagation of the resin throughout the

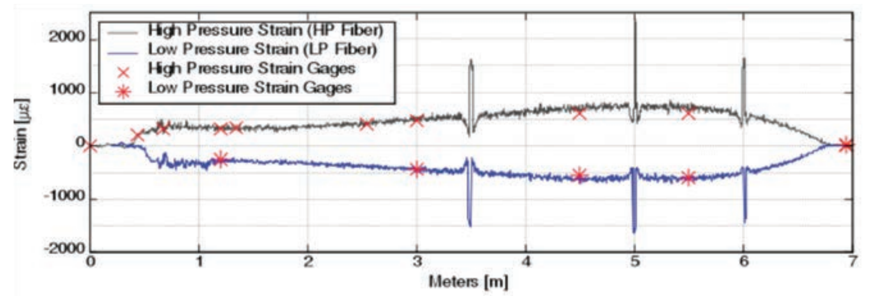
> **"The technology was also able to monitor the evolution of other defects within the blade that did not result in cracks before the test was concluded"**

BELOW: The test setup of the CX-100 blade. Fatigue cycling was accomplished using a Universal Resonant Excitation (UREX) system, whose attachments to the blade are painted red and can be seen near the root and the tip of the blade. The UREX system excites the natural frequency of the system, which applies an alternating bending moment to the blade

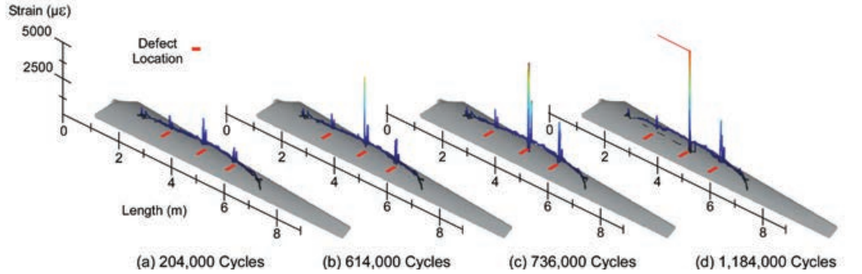
Photo courtesy of Mike Jenks



Distributed strain in optical fiber embedded in composite material along carbon fiber spar cap after vacuum. Locations and widths of defects represented by rectangles at 3.5, 5, and 6m respectively



Distributed strain measured using two of the surface-mounted fibers. The strain measurements obtained using Luna's fiber sensors are in good agreement with the measurements taken using the electronic foil gages



Distributed strain measured at four different cycle counts during the fatigue testing: (a) 204,000 cycles, (b) 614,000 cycles, (c) 736,000 cycles, and (d) 1,184,000 cycles. The data presented is for strain in the sensing fiber embedded under the defects within the carbon fiber spar cap of the blade. The growth of the defect located at 5m on the high pressure side of the blade broke the sensing fiber between data in (c) 736,000 cycles and (d) 1,184,000 cycles. The blade ultimately failed at this location at 1,968,000 cycles

infusion process, and the residual strain left in the blade after manufacture.

Trials and results

Researchers monitored the distributed strain while the blade was later cycled to failure at the National Wind Technology Center near Boulder, Colorado. There, the team further instrumented the blade by affixing three surface-mounted fibers co-located with electrical foil gages. Static tests showed good agreement between the strain gages and surface-mounted fiber data, and the internal defects were clearly evidenced by the surface instrumentation. Distributed strain was measured, under various load conditions, at intervals during the fatigue testing. The blade failed at 1,968,000 cycles due to a defect on the high-pressure side of the blade. Luna's no-load measurements identified growth in the critical defect by cycle 614,000, which correlates with the time that low-level acoustic emission was first detected from the blade.

The sensors therefore predicted a crack or delamination was forming at the critical defect by 614,000 cycles, even though it was not visible on the surface of the blade until 1,950,000 cycles. In addition to tracking the critical defect, the technology was also able to monitor the evolution of other defects within the blade that did not result in cracks before the test was concluded.

This demonstrates that monitoring distributed strain provides a cradle-to-grave method for non-destructive testing of composite structures and early defect detection in large-scale composite structural health monitoring. ∎

Dr. Sandie Klute is currently acting as technology director for the Optical Systems Group at Luna based in the USA

High speed and remote visual inspection

Modern technology has meant that inspection procedures and development testing within the aerospace industry have improved significantly. Olympus offers a wide range of non-destructive testing and remote visual inspection products for testing purposes during development, manufacture, and service; but in addition to the conventional products, the company also offers high-speed video cameras.

In the safety critical world of aircraft design and testing, it is often just a split second that can make all the difference. High-speed video ensures engineers and designers can analyze every component, every sub-assembly, in every minute detail of motion.

A complete high-speed video camera system needs to offer exceptional image quality, while maintaining portability and durability. The i-SPEED range of cameras not only utilizes Olympus' recognized expertise in precision optics, but also provides simplicity of operation. Maximizing the productivity of any test is assured and the unique controller display unit (CDU) ensures that video footage is reviewed instantly without costly delays.

The custom-designed CMOS sensor provides 720 pixel HD resolution with up to 2000fps recording speed at 1280 x 1024. The ISO rating of 1,600 (color and monochome) and 21 micron pixels maximizes performance, even in low light conditions. In the most demanding situations, the i-SPEED FS records up to one million frames per second with a 0.2 microsecond global shutter.

Applications for high-speed cameras include: wind tunnel testing; engine blade off; composite testing; dynamic drop testing; tire endurance and impact; landing gear/tire/wheel wear; and fluid dynamics. Confirmation of 'true' focus and depth of field is achieved with total confidence by the unique i-Focus feature and the onboard lithium-ion battery technology maintains camera operation at all times without the risk of data loss. Where footage captured is of a sensitive nature, it can be quickly saved to solid state compact flash memory and all video is then no longer retained in the memory once the camera is powered down.

Analysis of data alongside high-speed video often provides the complete picture, and Olympus has advanced analysis including data acquisition through the advanced Control PC software, with full camera control. Motion 'tracking', graphical representation, and report writing are key components of the software. Distance, velocity and acceleration calculations can also be acquired immediately post-test with the CDU. While developing the cameras, the cameras have maintained their established portfolio even with the introduction of the new IPLEX videoscope.

Remote visual inspection

Remote visual inspection (RVI) is a well recognized and widely used technique for first-line inspection of inaccessible areas across airframe and power plant applications.

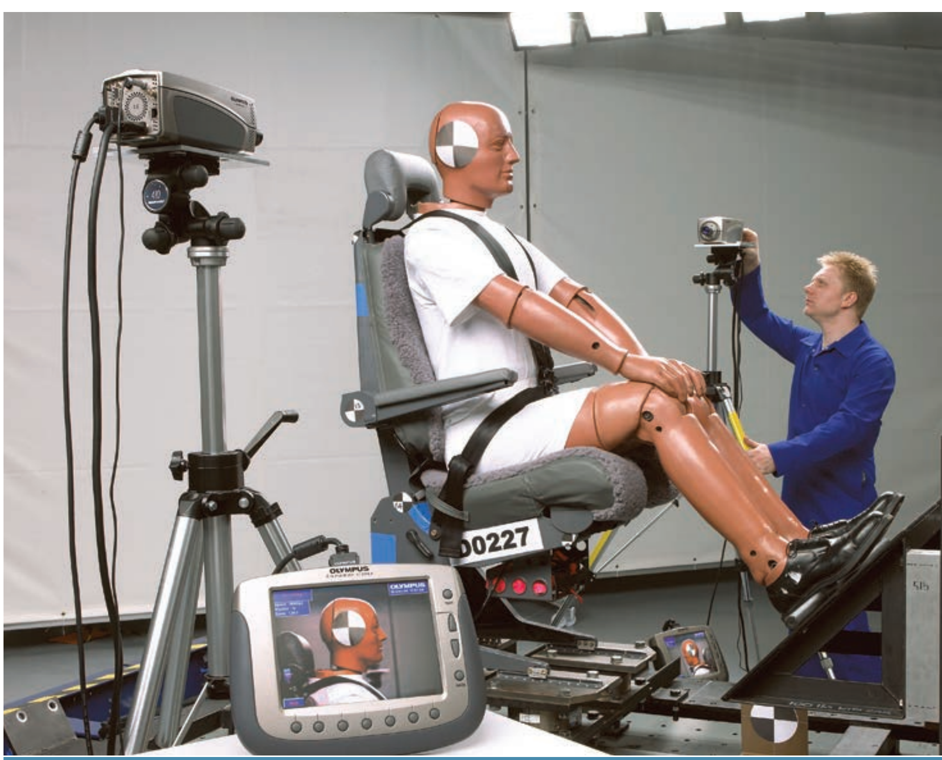
Up until very recently, RVI instrumentation has been either cumbersome or, while appearing to be 'portable', has not always provided an ergonomic device capable of being used for long periods of time without some discomfort or the need to employ a device to hold the instrument. With the introduction of the Olympus IPLEX UltraLite Videoscope, the range of comprehensive instruments has been expanded to include an ultra-portable, high-performance video endoscope with superb ergonomics, allowing true maneuverability around aircraft/power plant, as well as being truly comfortable to use by hand for long periods of time, due to weighing only 700g.

As with all Olympus Videoscope products, the IPLEX UltraLite continues to offer stunning, bright, clear images, enabling excellent defect diagnosis capabilities, and the ability to record still images and movie files directly to an onboard SD card.

Boasting IP55 environmental rating, the IPLEX UltraLite offers a truly robust system coupled with true portability. Working at height, and on or around fixed or rotary wing aircraft, can now be undertaken with great comfort and ease without compromising safety, due to the design of the IPLEX UltraLite instrument.

Working in confined spaces within the airframe itself is also now far easier, due to the incredibly compact UltraLite, which provides an exceptional performance, normally associated with much larger videoscope systems. The replaceable lithium-ion battery pack will provide 90 minutes of continuous operation and can be quickly changed and recharged for continuous operation if required.

Should it be necessary to deploy remote visual inspection equipment with an engineer to investigate temperature, vibration, or bird strike incidents, the IPLEX UltraLite can be easily transported by hand or as hold baggage, and it is perfectly suited to such use.



LEFT: A high-speed video camera being used for aircraft seat testing

RIGHT: The UltraLite Videoscope

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Sync-Clock time-tag technology

For flight test engineers, one of the biggest challenges in recent years has been the sheer number of different signals that must be recorded in order to perform comprehensive testing on today's aircraft.

A wide variety of sensors, including strain gages, accelerometers, force sensors, pressure and load sensors, thermocouples, as well as voltages and currents, require analog inputs with precise signal conditioning. In addition, there is a wealth of data coming across ARINC and/or MIL-STD-1553 databuses that needs to be acquired.

And because the power bus of the aircraft is mission critical, power analysis of the typical 400Hz single or three-phase system is often needed.

Finally, dynamic testing also requires the synchronous acquisition of video feeds from onboard cameras in NTSC and PAL formats, or the addition of higher-speed videography to analyze actuators and other fast-moving events.

Single integrated system

Recording all of these vastly different parameters can be done using multiple dedicated instruments – or by a single Dewetron system with Sync-Clock technology.

Compared with multiple instruments, using a single integrated system has some obvious advantages such as smaller size, lower power consumption, lower cost, and dealing with only one user interface.

Furthermore, during testing, even simply trying to monitor values from several instruments at the same time is nearly impossible for a single person. On the other hand, monitoring and operating a single integrated system is no trouble at all, even under challenging test conditions.

But the real power of Sync-Clock is reflected in the analysis of the data. Since everything is already recorded in sync, analysis can be performed immediately – even online during the test.

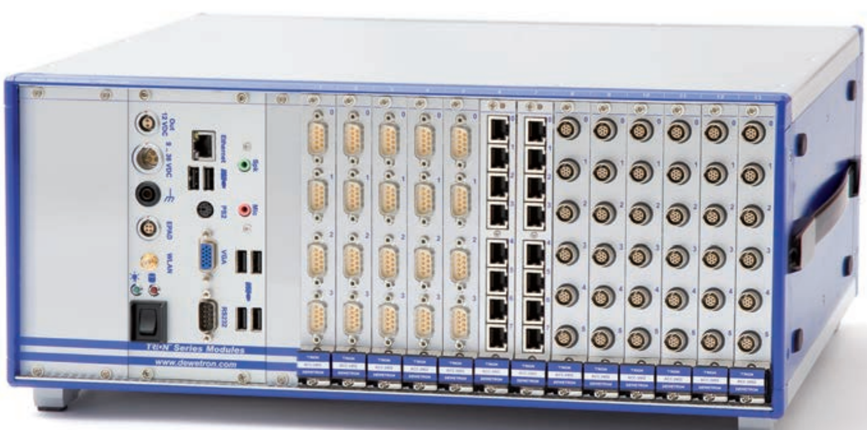
Anyone who has tried to correlate data from different devices knows that this often means spending many hours using third-party analysis software. Finally, the result of this huge effort is a dataset with manually aligned time axes that are more or less correct, but not perfect. Thus the quality of following analyses depends on the quality of manual data manipulation.

Saving time

Dewetron is a specialist in the synchronized acquisition of vastly different signal sources, and its Sync-Clock technology is used to exactly time-tag all data sources. Within the data acquisition unit, a precise 80MHz clock is generated and divided to multiple phase-synchronous slower clocks for analog inputs, bus data, or video pictures.

All are recorded in perfect sync and can be hardware synchronized to an external time reference, either the highly precise PPS signal from GPS, or one of the popular IRIG time codes. Thus the systems also can be networked, for example, one is in the air and a few more are on the ground – for applications like determining the noise emissions of an aircraft.

Today's flight test engineers are afforded a new approach to making a wide range of measurements, with less equipment, easier set-up, and better results in a shorter time. Hundreds of measurands from analog, digital, PCM, ARINC, MIL-STD-1553, the power bus, and angle-based sensors, are recorded in sync with each other and referenced to external time from the very beginning, eliminating the need to laboriously time align multiple files from different instruments later. This provides a better 'look in' to the data during the measurement, which can prevent the need for expensive re-testing, as well as better overall test results.



TOP: **DEWESoft real time screen with synchronized analog signals and video stream**

LEFT: **DEWE2-A4 all-in-one system with TRION modules**

ABOVE: **DEWE2-M13 mainframe system with 13 TRION modules**

CONTACT

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Extreme environment for piezoelectric accelerometers

Meggitt Sensing Systems, a Meggitt group division, offers more than 60 years of expertise in the design, development, and manufacture of piezoelectric accelerometers for extreme testing. Select units within the Endevco product portfolio offer reliable performance in cryogenic temperatures down to -269°C, with other models able to intermittently operate in high-temperature environments up to +760°C.

Recently announced technologies include the 2011 industry best-selling Endevco model 2220E, a hermetically sealed, miniature piezoelectric accelerometer, designed for high-temperature vibration measurements to +260°C. Units feature centrally located through bolt mounting for 360° cable orientation. The accelerometer is ideal for aircraft engine ground vibration testing; aerospace component durability testing; APU monitoring; helicopter and rotorcraft HUMS; and aerospace machinery and equipment monitoring.

The company has also recently reintroduced its Endevco model 6240M10, a hermetically sealed, high-temperature piezoelectric charge output accelerometer with a wide operational bandwidth and continuous high-reliability operation to +649°C (intermittent operation to +760°C). The unique performance attributes of this transducer allow it to be used in support of extreme high-temperature aerospace testing environments, including aircraft and ground gas turbine engine vibration monitoring; aircraft exhaust and compression systems; and related high-temperature machinery and equipment. Its 5pC/*g* sensitivity further supports low-level vibration analysis.

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Scalable fiber channel solutions

To support the growing use of fiber channel in the avionics industry, AIM's new APE-FC-2 PCIe (PCIExpress) based fiber channel interface board offers a truly flexible hard- and software solution for test, simulation, and monitoring of fiber channel applications and networks. Two physical fiber channel ports are implemented with so-called SFPs (small form pluggable) for either optical or copper-based media.

The APE-FC-2 with Fibre Channel Layer 2 support plus the optional PBA.pro software, forms the baseline for adding upper layer protocol updates such as FC-AV/ARINC818, FC-AE-RDMA, FC-AE-ASM, FC-AE-1553, and SAE5653 (also known as High Speed 1760). This approach is reflected on the commercial side, which allows AIM to offer attractive and efficient solutions for various fiber channel-based applications targeted specifically to customers' needs.

The basic Fibre Channel Layer 2 functionality offers powerful low-level test, simulation, and monitoring functions for fiber channel-based traffic. Customers can simply write their own applications or use the optional resource component for the AIM PBA.pro software.

Frame-based simulation scenarios with full control over the timing and data, as well as frame-based capturing with high resolution time stamping (which can be synchronized to other avionics interfaces such as MIL-STD-1553 and Ethernet/ARINC664P7) and full access to data, are essential features when working on these layers.

On top of the Driver Software Application Programming Interface (API), the optional resource component for AIM's PBA.pro software offers an interactive usable GUI, which can be further controlled and even automated using the PBA.pro Python Scripting support. In conclusion, this is a solid hardware and software base line for supporting the upper layer protocol options for any fiber channel applications.

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S-MIZE EM: same performance, half the size

High-speed cameras by AOS Technologies are tested and certified against MIL standards for airborne flight testing. Their performance and features exceed most testing requirements.

AOS now presents the S-MIZE EM, an ultra-compact camera nearly half the size of previous models. The camera can be positioned in tight spaces where other cameras will not fit, and its weight has been reduced to less than 900g.

In an ultra-compact housing, the new S-MIZE EM offers a 1,280 x 1,024 pixel image resolution at up to 500fps, 900 x 700 at up to 1,000fps, and a top speed of 100,000fps.

The S-MIZE EM is shock-resistant up to 110*g*, complies with MIL 810 and MIL 461 standards, features a built-in battery for securing the recordings in the event of power loss, and has an image memory of up to 10Gb for a 30-second recording at full resolution and 250fps.

The S-MIZE EM's built-in controller allows configuration of the camera according to user demands with just minimal modifications to the airplane. Existing hand-shake routines can be duplicated by a number of programmable status lines.

The S-MIZE camera offers various features, such as a flash card interface, cable output at the back or side, and an extended battery pack for autonomous operation of up to three hours.

Further information
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www.aostechnologies.com

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Fuel component trials

In 2011, Test-Fuchs had the opportunity to develop a new fuel test rig for a major Italian OEM, to be used on the Aermacchi MB-339. The test rig was specifically designed to test the main fuel components.

The fuel system of the MB-339 consists of three main groups. The units to be tested are the main fuel pump, the air fuel ratio control, and various other valves. For this special test stand, Test-Fuchs implemented three separate test stations into the rig. The test stations are completely independent from each other and therefore it is possible to test three different components at the same time, resulting in an enormous reduction of testing time, helping the customer to significantly reduce costs. With the already well-established Test-Fuchs software, the components can be tested manually or automatically.

Each test station has an independent computer system and a separate test chamber. The chambers themselves all have a protection cover fitted with laminated safety glass and safety latches to guarantee high safety standards. The operator can easily observe and test the components on each test station using the swivelling control panels.

The fuel components test stand was developed in accordance with the explosion protection directive, ATEX. Furthermore, the test stand includes a forced ventilation system, a gas warning system for fuel vapors, and a shutdown system. One of the three test stations is equipped with a special test circuit for hot test mediums up to a maximum temperature of 40°C (104°F), featuring special additional built-in explosion risk reducing measures.

In case of leaks during maintenance activities, the test stand features removable drip trays with the capacity of the main reservoirs to avoid unnecessary spilling of liquids. Extra drip trays under all test chambers direct leaking medium (e.g. during UUT disassembly) to small reservoirs. From there, the medium is pumped back into the main reservoirs. Additionally a universal portable leak test tank can be used at all test stations.

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Next-generation NVH solutions emerge

SentinelEX, VTI Instruments Corporation's 4th generation of 'smart' dynamic signal analyzers (DSA), build upon a proud legacy established in the 1980s by continuing to deliver trusted solutions to the noise, vibration, and harshness (NVH) marketplace. After purchasing the mechanical test business unit from Agilent in 2003, VTI immediately implemented a modernization program culminating in the 3rd-generation DSA introduction, again leading the market in performance and scalability.

The EMX-4350 and EMX04250 'smart' dynamic signal analyzers incorporate the latest technological innovations and analog design methodology to deliver unmatched measurement performance. These products are the best standard for physical measurements, and are part of the largest worldwide install-base of precision data acquisition instrumentation instruments suited for a wide range of applications including NVH and general-purpose, high-speed signal analysis and acquisition.

This system offers measurement confidence and performance with excellent data rates; aggressive anti-aliasing filtering; an industry-leading spurious free dynamic range (SFDR); uncompromised IEPE excitation; FPGA-based synthetic instrument customization; corporate-wide 'cloud' data management and access; exceptional analog measurement and excitation performance; comprehensive health monitoring and run-time self-calibration; and precision distributed measurement synchronization and control.

VTI's open-architecture designs deliver unmatched hardware and software independence reducing costs, extending product lifecycles, and fostering commercial off-the-shelf availability. Advanced AXI-based FPGA synthetic instrument customization extends hardware performance by combining user-defined computational and processing capabilities, while industry standard MATLAB and Simulink design tools simplify implementation with access to hundreds of standard algorithms. Industry standard drivers extend this flexibility to software developers, offering the freedom to select the environment best suited to meet specific application needs.

Further information
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Advanced vibration control

Closed-loop control of vibration shaker systems requires controllers that deliver precise control with rapid safety checks to protect your shaker and your products. Designed with this in mind, the next generation of controllers from Brüel & Kjær spans the whole range of aerospace and space vibration test applications. Using dual, parallel 24-bit A/D and DSP technology, VC-LAN Vibration Controller Types 7541 and 7542 offer advanced performance and flexibility, with a 130dB input range and fast loop times. The VC-LAN controllers are modular and expandable, offering up to 64 input channels for control and limiting.

The high channel count enhances safety and analysis for complex, fragile structures such as satellites. Special vibration control software provides random control including sine-on-random and random-on-random; swept-sine control including tracked resonance dwell; shock vibration control including classical waveforms; transient replication; SRS synthesis and control; and time-waveform replications. Applications are specifically tailored to each type of vibration test to reduce learning time.

The controllers integrate fully with Brüel & Kjær's LAN-XI data acquisition hardware to provide simultaneous and integrated data acquisition, and to make over 1,000 channels of abort monitors possible. PC connectivity is via LAN interface, which allows wireless operation, reduces cabling, and allows the controller to be placed close to the shaker. This facilitates centralized control of multiple controllers remote from the vibration table test stations, so the entire system can be supervised and analyzed remotely.

Further information
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The Dream Chaser orbital program

The Dream Chaser Space System's (DCSS) Preliminary Design Review (PDR) has been successfully completed. The review was the third major system-level review for the DCSS as part of NASA's Commercial Crew Development Round 2 (CCDev2) Program, said Sierra Nevada Corporation (SNC).

The PDR incorporated a detailed review of all major elements of the DCSS orbital flight program, including the Dream Chaser orbital crew vehicle, the Atlas V launch vehicle, and Dream Chaser mission and ground systems. The entire design, architecture, and performance of the DCSS was reviewed and thoroughly evaluated by NASA and the DCSS partner companies, which determined that the SNC preliminary design is complete.

"The successful completion of this full-system PDR established that the Dream Chaser has a credible system design that is now approved to proceed toward integrated system testing," said John Curry, director of Dream Chaser Space System engineering, integration, test, and operations. Curry joined SNC after 25 years at NASA, where he served as a flight director for the space shuttle and space station programs, and managed integration and testing for NASA's Orion and Constellation programs.

The DCSS's successful PDR came during the same week as the Dream Chaser vehicle began its flight test program, illustrating SNC's approach of concurrent design and development. On May 29, the Dream Chaser program completed the successful first flight of the Dream Chaser full-scale vehicle. The flight met all the pre-established flight test goals and is a great step toward preparing the vehicle for an autonomous approach and landing test (ALT), scheduled in just a few months' time.

"As commercial crew program partners meet these critical milestones, we are moving in the right direction in our combined effort to advance the commercial capabilities that could eventually transport NASA astronauts," commented Ed Mango, the commercial crew program manager at NASA.

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EASTERN PROMISE

It took World War II to get the Indian aerospace industry moving – now it is gliding into full-scale development with both fixed and rotary wing aircraft

by GROUP captain Kapil Bhargava

In the 1930s, Seth Walchand Hirachand, a shipping magnate, visited the USA to explore making cars in India. His secretary told him about William Douglas Pawley, who was planning production of aircraft in China near Chunking. At the time, China was at war with Japan, and before work could begin, the intended site was bombed by the Japanese.

With shrewd planning, Seth traveled in the same aircraft seated next to Pawley. The two businessmen got down to brass tacks and soon agreed to start aircraft production in India. With the Maharaja of Mysore State joining in and financing it, Hindustan Aircraft Ltd (HAL) was registered on December 23, 1940. The Maharaja gave HAL rights to large areas of land to create an airfield and set up the factory. This was located 10km from the city of Bangalore, near a lake usable by flying boats.

Pawley moved the machinery from China to Bangalore and added to it as needed. He also organized trained manpower to begin assembly of Harlow Trainers and Curtis Hawk aircraft. He brought in 22 American technicians, selected 300 Indian engineers, and inducted 2,000 skilled local workers. The seed for an aeronautical industry had been firmly planted.

The company soon had a chief designer and a small design bureau. It designed the G-1 glider with 10 seats, including two for the pilots. The G-1 was air-towed by a Vultee Vengeance aircraft and flown for VIPs on August 12, 1941. It was the first locally designed aircraft, made of local plywood, and with indigenous know-how and labor. But eight soldiers would hardly have made a huge shock impact in any battle area and the government of India wanted a glider to carry 25 soldiers and one pilot. Concurrently, it warned Walchand Hirachand of the possible destruction of HAL by Japanese bombers, which had already dropped bombs over Calcutta. The company was sold to the government soon afterward.

For the war effort, assembly and testing of Harlow Trainers and Curtiss Hawk fighters had already commenced. The Hawks were brought to Madras by sea and unloaded at the beach. These were made just flyable by HAL personnel and ferried to Bangalore for installation of its equipment and completion of production. However by December 1942, the US Army's 10th Air Force felt that support from units in China was inadequate. After due negotiations, the US Air Force took over the factory on September 15, 1943. HAL did laudable work repairing and overhauling several aircraft types and engines of the US Air Force and the RAF. Walrus and Catalina amphibious aircraft belonging to the RAF landed in the adjacent Bellandur Lake, taxied to cement pads on shore, and

were then towed to HAL's hangars. Control of HAL was handed over to the RAF after VJ Day and there-on to the independent Indian government in 1947.

Post-independence, HAL produced Percival Prentice aircraft under license – in fact, license production became its permanent mainstay. HAL produced Vampire 52 and 55; Gnat; Jaguar; MiGs 21, 27, 29; Sukhoi 30 MKI fighters; and Hawk trainers. Avro 748 and Dornier 228 have also been made under license. Aeronca Super Chief and Aeronca Sedan were copied and produced as Pushpak trainers for civil flying clubs, and Krishak was used as air OP aircraft by the army. The Jet Provost Mk 2 was copied and adapted to become the Kiran, HJT-16 (Hindustan Jet Trainer). HAL resurrected 48 B-24 Liberator bombers left behind as scrap. These were inducted into the Air Force from 1949 onward.

HAL's first indigenous powered trainer was the HT-2, flown in August 1951. This was the world's second all-metal monoplane, following the success of Canada's DH Chipmunk. In the West, snide remarks were made that HT-2 was a copy of the Chipmunk; in fact it was substantially different from it, but did follow the concept.

Some indigenous designs followed, namely the Basant for crop spraying, the HPT-32 to replace the HT-2, the Ajeet adapted from Gnat, and the Ajeet trainer.

The first fighter aircraft designed in India, and which saw service in the Indo-Pakistani War of 1971, was the HF-24 Marut. Its design team was led by Kurt Tank, famous for the FW-190 of World War II. A long period of more than 20 years saw almost no original design work emerging into hardware. The fault lay, most likely, with a generalist bureaucratic control of HAL as a public sector undertaking. Fortunately, with nominal help from Germany, HAL designed the Advanced Light Helicopter (ALH - Dhruv). Several versions and types have now evolved and more will follow; work is also now in hand to develop a new intermediate jet trainer. Meanwhile, the light combat aircraft named Tejas, the design and development of which was taken over by the MoD's Aeronautical Development Agency, is being produced by HAL almost under licensed production. Steady but slow progress from the Indian aeronautical industry will surely follow over time. ∎

Group Captain Kapil Bhargava was a chief test pilot with the Indian Air Force (Retd), was on the board of HAL (Hindustan Aeronautics Ltd), and currently lives in Bangalore

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