THE OFFICIAL MAGAZINE OF **AEROSPACE TESTING, DESIGN & MANUFACTURING EXPO EUROPE**

# AEROSPACE TESTING INTERNATIONAL

MARCH 2010

## Trials of the A400M

Since its maiden flight, the controversy around this aircraft has only heightened

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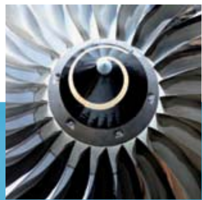


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WHAT MOVES YOUR WORLD

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The latest Winter Olympics, just concluded in Canada, captured the imagination of people across the world more than ever before. I stayed up way too late, engrossed in bizarre sports like curling, speed skating, and snowboarding.

Despite being a 'colder' country, the UK has never been a huge participant in the Winter Olympics; the mountains are not big enough, the climate is too wet. However, the country rejoiced when Great Britain won its first individual gold medal in nearly 30 years in the downhill skeleton. Amy Williams cruised to victory in a record time. However, Canada and the USA put in complaints about the aerodynamic design of the helmet. They were all rejected, but as a result I looked into the application of aerospace science and testing to the design of winter sports equipment and was staggered by the enormity of it. I have a little experience with this, which I will come back to.

Just with regard to the skeleton, a sport in which you soar head-first down an ice runway at more than 70mph, aircraft know-how was brought in. Timothy Wei, the head of aerospace engineering at Rensselaer Institute in New York was drafted in to help the US team, and actually built a mock sled track in his laboratory, where competitors lay stationary on their sleds while a wind tunnel fan blew air past them at more than 60mph. "Even in the short time since developing the system, we have learned a whole lot more about how the athlete's suit, helmet, body movements, and positioning affect aerodynamics," Wei explained.

Across the pond, the aerospace engineering department at Delft University of Technology in Holland was used to assist the Dutch bobsleigh team by analyzing the aerodynamic flow around a bobsleigh by doing both scale model wind tunnel tests and performing CFD calculations.

The first gold medal of the 2010 Olympics went to Switzerland's Simon Ammann, who won the ski jumping competition with a jump of 108m. Luca Oggiano, an aerospace engineer focusing on sports at the Norwegian University of Science and Technology in Trondheim, explained that aerospace testing has critically assisted the ski jumpers with the four major factors to succeed: a stable position at take-off, high speed at the take-off point, the position of the skis, and the shape of the body. A number of the downhill teams spent a lot of time flying over an imaginary course, but were actually stationary inside high-speed wind tunnels testing helmets, clothing, and general aerodynamics.

Testing at the National Research Council's Institute for Aerodynamic Research in Canada alone involved 11 winter sports: bobsleigh, skeleton, luge, alpine skiing, ski cross, para-alpine skiing, nordic skiing/biathlon, para-nordic skiing, freestyle aerial skiing, snowboard/snowboard cross, and speed skating.

Even the latest Olympic flame was developed through aerospace rocket science with a new fuel and combustion system.

As I said, I have some experience of this. Nearly two decades ago, on a freezing Alpine morning, I vividly remember standing at 6:30am, with my 'skeleton' facing the awesome Cresta Run. I had arrived in St Moritz the afternoon before, and with my teammates, immediately did the right thing and headed straight to the big nightspot, Badrutt's King's Club. Having never even set eyes on the Cresta Run and the wrong side of several (incalculably expensive) tequilas, I boasted to the man next to me for some time that I was here as one of the brave 'Cresta Runners'.

"You British are crazy!" he applauded. "Yes," I smugly agreed, "we are totally mad, AND crazy." I later found out he was Jan Badrutt, one of the wealthiest people in Europe, the owner of St Moritz, and the world-record holder on the Cresta Run, and skeleton. He could have told me.

Although that was only five hours before, now, standing next to the 'start line' high on a mountain side, in the cold half-light, receiving a very brief briefing on how to semi-control a metal tray at Mach 6, things became a terrifying reality, particularly as my brain and body felt like a landfill site. In front of me was a half-tube of ice nearly a mile long, in which the 'runner' reached speeds of over 70mph head-first, two inches above the ice. The Cresta 'tube' is very shallow, unlike its bobsleigh counterparts, making it look less dynamic, but much, much more easy to take a very unplanned exit. I eventually took my position behind a nervous German. His turn came; he climbed on and after the countdown, shot off. Sadly, 20 seconds later, he shot off the course earlier than planned. Having over-compensated at a tight corner, he hit the ice wall – hard – pushing both his radius and ulna straight out through his elbow, shrinking his arm by nearly a foot in a millisecond. They had to wash the run down with water, but it was still pink when I hurtled past 20 minutes later, somewhat vexed by my predecessor.

The one minute it took to reach the end resulted in the shortest hangover in history, and the biggest adrenaline buzz ever received.

Two weeks later, I was the proud owner of a bronze interservices medal. Perhaps I might have got silver if I had applied aerodynamics. The Navy and RAF teams wore Lycra go-faster suits. I wore plus fours, a scarf, and a thick jumper.

As one aerospace engineer commented, unlike the Summer Olympics, the Winter games are all about aerospace testing. The extent of applications that the scientists extend themselves into other fields is incredible, over and above the day job.

**Christopher Hounsfield, Editor**


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# A400M talks go to wire

## ITS MAIDEN FLIGHT WAS IN DECEMBER 2009, BUT SINCE THEN THE CONTROVERSY SURROUNDING THE A400M DEVELOPMENT PROGRAM HAS ONLY ESCALATED

BY TIM RIPLEY

After a delay of almost two years, the European Airbus A400M airlifter took to the skies on December 11, 2009. This milestone for the troubled program was a relief for European aerospace industry executives, but it did not secure the uncertain future of the A400M.

The European customer governments, including the UK, France, Germany, and Spain, met twice in January 2010 to try to work out a way to align their diminishing defense procurement budgets with the needs of the Airbus Military parent, EADS, to restructure the shifting financial foundations of the program. The outcome of these discussions is still unclear, although it appears that they did agree to keep the flagship European military aircraft program going.

Amid much fanfare, aircraft F-WWMT (c/n 001) took off from Seville's San Pablo Airfield in southern Spain at 10:16 for a 3-hour 46-minute test flight, with chief test pilot Ed Strongman at the controls. At the airport, workers at the A400M assembly facility were joined by international journalists and company executives to watch the event. The flight progressed without incident, and 11 days later, the aircraft took off again on its second test flight. A company spokesman said the tests validated a large portion of the aircraft's flight envelope.

This, however, is only the first stage of a three-year flight test effort that the company now hopes will enable the delivery of the first aircraft, c/n 007, to the launch customer, the French Air Force, in December 2012. Development testing will now be done on five, rather than six, aircraft. The work is to be split between Seville and the main Airbus site in Toulouse in southwest France. Aircraft c/n 001, 003, and 006 are to be used for the Spanish-based work, and aircraft c/n 02 and 04 will operate from Toulouse. Aircraft c/n 001 is intended to bear a heavy burden of the 3,700 hour-long test program, flying some 1,200 hours of aircraft handling, load, and flutter testing missions.

This will be joined in March this year by aircraft c/n 002 to undertake performance,


AIRBUS MILITARY
A400M
F-WWMT
A400M

# Deal hammered out

The joint nations behind the A400M are finalizing a deal on the future of the joint military project after an announcement in Paris in February 2010.

According to French defense minster Herve Morin, an agreement was being hammered out "step-by-step". A statement released by the seven national defense ministers said that "significant progress has been achieved during negotiations" with EADS. The talks on the A400M were held on the sidelines of a meeting of EU defense ministers in Spain.

Morin said EADS had responded to the customers' final offer by asking for guarantees that the 180 total order book won't be reduced, and that technical specifications will not be further amended.

The UK has already indicated it may reduce its order from 25 to 22 aircraft. Germany wants to install a terrain-following system that would mean the hulking plane could fly low-level missions.

EADS also asked for clarification of the €1.5 billion in loan guarantees the customers are offering, besides a €2 billion that they will provide to cover cost overruns, said Morin.


certification, and defensive aids testing. In May 2010, aircraft c/n 003 will take to the air to test autopilot, fuel, hydraulics, and navigation systems. Aircraft c/n 004 is expected to fly in January 2011, and it will be involved in cargo operations and air-to-air refuelling trials. The next aircraft to roll off the Seville line, c/n 006, is scheduled to fly in July 2011 and it will undertake system maturity, engine endurance, and route proving trials.

In the UK, the Joint Air Delivery Test and Evaluation Unit (JADTEU) at RAF Brize Norton has been carrying out trials of a A400M cargo-hold mock-up with Ridgeback and Panther mine-protected vehicles that are in use in Afghanistan.

"The Ridgeback weighs 20,000kg and the Panther (loaded to the rear) weighs 6,300kg," said an EADS spokesman. "Given a contractual payload of 32 tons, this would leave 5,700kg for additional freight, mail, passengers, and baggage. There is room and payload left on the aircraft for either two cargo pallets on the ramp, or 48 passengers and two pallets of baggage on the ramp, or a Land Rover loaded to the ramp."

> "The A400M contract, as it is today, puts the whole of EADS in jeopardy. I will not go down that road."

In late 2009, Airbus Military executives briefed their customers on its proposed revised timelines for the A400M test and delivery schedule. EADS asked the seven customer governments for an injection of additional cash to fund the development and production program, over and above the current fixed price contract, by January 31, 2010. It has reportedly asked the governments to provide an extra €5.3 billion (US$7.6 billion) including additional money immediately for flight testing and ramping-up production facilities. This is in addition to increasing the price of production aircraft 25% above the current estimated €100 million per unit. The company also proposed a revised delivery schedule to spread out the production run for the 180 aircraft being built for European air forces.

Tom Enders, Airbus president and CEO, ramped-up the pressure on the governments, saying at a press briefing in the A400M factory in Seville that "the A400M contract, as it is today, puts the whole of EADS in jeopardy. I will not go down that road."

Unsurprisingly, this news did not go down well with the customer governments, which all face pressure on their defense procurement budgets because of the global financial crisis and the need to fund the war in Afghanistan. The customer procurement ministers met in the UK in mid-January, and later in the month in Berlin, to discuss the proposals from EADS.

The Spanish and French governments were reportedly the most keen to move ahead with the new Airbus plan because of the high numbers of jobs that are at risk in both countries if the project should fold. In the rival camp were the British and German governments, who had, in the past, blamed the company for the delays, and waved the fixed-price contract at EADS executives. Both London and Berlin had, at points in the past, tried to extract penalty payments from EADS for late delivery of the first aircraft. This would mean temporary airlift capability could be purchased to cover for the loss of capacity. They reportedly threatened to


A400M with the new Panther & Ridgeback armored vehicles

> **"All nations remain committed to the program – but not at any price"**

cap their spending on the A400M, effectively threatening to cut their orders for aircraft, if EADS tried to raise the price.

Airbus struck back, and in January blamed the European governments for forcing Airbus to spread the manufacturing around the Continent and take an engine built by a consortium of European manufacturers, rather than the one the company wanted – and engine built by Pratt & Whitney in the USA. Louis Gallois, chairman of EADS, called the A400M engine consortium, made up of Rolls-Royce, Safran of France, and Germany's MTU, "the most baroque organization I have ever seen".

After the first ministerial meeting, the UK Ministry of Defence said that the difficulties facing the A400M project were 'complex', but that "good progress has been made on all fronts, with the only outstanding issue surrounding any additional funding" and that "all nations remain committed to the program – but not at any price". It said that the next step was to invite EADS/Airbus Military to a meeting "in the next few days to try to achieve an acceptable settlement".

The fact that the governments all agreed to stick with the program indicates that a compromise could be on the table. Lord Mandelson, Secretary of State for Business, Innovation and Skills, and Lord President of the Council, is understood to have intervened with the UK Ministry of Defence, pressing the case for keeping Airbus wing design and assembly work on a range of Airbus civilian airliners in the UK, which could be under threat if London pulled out of the A400M. This has led to a softening of the UK approach and may result in London signing up to a major delay in A400M delivery schedule to spread out its estimated €650 million additional payments over most of the coming decade. The French and Spanish governments seem likely to stump up more money in the near term, leaving Germany to reduce its order.

While EADS is locked in a dogfight with its European customer governments, the company stepped up its rhetoric about export prospects in the USA. EADS North America chief executive Sean O'Keefe predicted that within five years, the USAF would be lining up to buy A400Ms because of emerging gaps in its airlift capabilities. These are the prospect of the ending of Boeing C-17 Globemaster production, coupled with the small size of the Lockheed Martin C-130J Hercules, and the pending retirement of the aging Lockheed C-5 Galaxy airlifters. There is no other military transport aircraft in development or production in the USA, and Airbus argues that this is likely to force the Pentagon to turn to the A400M to fulfill several airlift or special mission requirements toward the end of the decade. ∎

# UK buys more US helicopters

A package of equipment enhancements for British troops fighting in Afghanistan, including the purchase of 22 Boeing CH-47 Chinook heavy-lift helicopters, worth almost £1.2 billion (US$1.79 billion) was announced by UK Defence Secretary Bob Ainsworth on December 5, 2009.

UK Prime Minister Gordon Brown won plenty of headlines for boosting the British war effort in Afghanistan, but industry executives were left worrying about its effect on the long term future of the British helicopter industry. To pay for this equipment, Ainsworth revealed a package of cuts to the UK armed forces. The center piece of Ainsworth's spending package was a re-organization of UK helicopter procurement plans, dubbed Vision 2020 or the Future Rotary Wing Strategy. The UK is to enter into negotiations with Boeing to buy the additional Chinooks, and a spokesman said that the variant and specification of the helicopters would be determined during the discussions with the company.

Ainsworth said the first 10 helicopters would be built in the USA, starting in 2012, for delivery the following year. The narrow time scale makes it unlikely there would be major UK industrial participation in project which is expected to take up the bulk of the extra equipment package's budget.

Plans to buy some 50 medium-support helicopters worth up to £3 billion (US$4.5 billion) from the middle of the decade have been dropped, and the entire UK Westland Sea King helicopter fleet is to be withdrawn from service in 2016. The RAF's current fleet of Merlin HC.3/3A helicopters are to be modified for maritime operations on amphibious warfare ships and transferred to the Royal Navy to equip the commando helicopter force.

In June 2006, the UK Ministry of Defence and AgustaWestland signed a strategic partnering agreement to sustain so-called 'sovereign capability' to build and upgrade helicopters in the UK. The effective cancellation of the cornerstone of that agreement, the future medium support-helicopter program, leaves the UK helicopter industry in a state of limbo. The fate of the company's Yeovil plant is now uncertain, and with it the ambition of the UK to retain its 'sovereign' ability to upgrade and modify helicopters.

# Europe's UAS road map?

European experts have outlined a possible road map for the integration of unmanned aerial systems (UAS) into non-segregated civilian airspace. The €4.3 million (US$5.8 million) Operation Unmanned Air Vehicle Integration (INOUI) project, has been funded by the EU as an adjunct to the single European skies (SESAR) project, after it became clear that the definition phase of the multinational effort to reform air traffic management across Europe up to 2020 and beyond was not addressing UAS operations.

The issue is seen as vital in enabling the widespread use of UAS for civilian purposes in proximity to other manned aircraft. Key technological advances needed to ensure safe UAS operations include: secure data links to ensure radio links to control air vehicles are not interrupted, dynamic flight path replanning for rapid response to sudden flight-path conflicts, and better situational awareness for pilots in remote control facilities.

Although many of these technologies have been developed for manned aircraft, the unique characteristics of UAS means they need to be adapted for use by unmanned aircraft. The study said data links, based on satellite communication systems, should be mandatory because they would ensure operations beyond-the-line-of-sight of any ground control facility, and prevent communications links being broken.

The Flarm active and cooperative traffic and collision warning system could also be adapted for use on unmanned aircraft. This would give ground station pilots better warning of unplanned approaches by other aircraft. Dynamic replanning systems being developed for manned aircraft by the European Union's Sofia research project would mean rapid replanning of flights in response to sudden events is possible. This would automatically direct any unmanned aircraft to land, if unauthorized attempts were made to take control.

Although existing inertial, satellite and radio navigation devices were sufficiently robust for use by unmanned aircraft, the study said their automation needs to be enhanced. The future navigation and

Production of the Wildcat variant of the Lynx light helicopters is to wind up by mid decade, and long-term Merlin orders look like running out in the same time frame. The December announcement offered the prospect of some UK Ministry of Defence work to modify the RAF's Merlin HC3s for amphibious operations and convert a handful of Merlins to carry airborne early-warning radars but this is unlikely to secure Yeovil's future. Without the underpinning of long-term production contracts, the company's ability to keep its research and development teams in existence at Yeovil is open to question. Options for the site include diversification into civil work and/or some participation in the Chinook project.

In July 2008 Boeing and AgustaWestland signed an agreement for the joint manufacture of the CH-47F helicopter in Italy for the Italian Army. The contract to acquire 16 Chinooks is a deal worth €900 million (US$1.43 billion). The deal includes a license for AgustaWestand to produce, market and sell the Chinook CH-47F as prime contractor to the UK, Greece, Turkey, Morocco, Libya, and Egypt. This could open the way for AgustaWestland to participate in the new UK production order, if the tight time lines can be aligned with UK government requirements.

However, the design authority for UK Chinooks still resides in Boeing USA, and in the past, the company and the UK Ministry of Defence have had a strained relationship over upgrades to the helicopters. So the degree to which Boeing will be willing to permit AgustaWestland to upgrade and modify the Chinook in the UK is unclear.

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communications architecture and systems used by UAS in Europe need to be fully compatible with those being put in place under the SESAR project. European Air Safety Agency (EASA) certification regulations for unmanned systems should be in place by 2012, with implementation complete by 2015. This will enable technology for the unmanned sector to be rolled out in parallel with the effort to field SESAR.

The study says a major effort should be mounted to overcome public ignorance, raise public awareness about the safety of UAVs, and overcome possible opposition. Funding from the EU for development and deployment for several of the important technologies required is considered essential.

Germany, France, and Spain funded the project, which was undertaken by the Frankfurt-based DSF Deutsche Flugsicherung, the French ONERA aerospace agency, Rheinmetall defence electronics, Boeing Research and Technology Europe, and Spain's ISADEFE research institute. The participants ran several forums or workshops over the past 24 months to identify issues and possible solutions. However, this is one of many reports that have looked at how UAS can be brought into civilian air space in Europe, but it is still far from clear that the aviation authorities will choose this option.

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# US aerospace industrial-base crisis

The director of US think tank the Mitchell Institute for Airpower Studies has warned that the ability of the USA's aerospace industry to continue to develop revolutionary products is threatened by the lack of investment in military aerospace programs.

In her study, The Vanishing Arsenal of Airpower, defense academic Rebecca L. Grant, who is also a senior fellow of the Arlington-based Lexington Institute, says that the number of 'new start' military aerospace programs in the US is at an all-time low. The Pentagon is concentrating its resources on projects that meet near-term operational needs in Iraq and Afghanistan, and the long-term viability of the US military aerospace industry is in doubt, with the human expertise in designing, project managing, and flight testing new military aircraft declining.

Grant, regarded as one of the USA's foremost air, space, and cyber power analysts, says that in two years, the US could have only one active production line for fighter aircraft (for the Lockheed Martin F-35 Joint Strike Fighter), a single active production line for airlifters (for the Lockheed Martin C-130J Hercules), and only a single company producing advanced engines for fighters (Pratt & Whitney). The termination of Lockheed Martin F-22 Raptor stealth fighter by the current US defense secretary Robert Gates and his ongoing attempts to stop production of the Boeing C-17 Globemaster, and the alternate F-35 engine will all accelerate these trends, alleges Grant.

Grant, who worked in the early 1990s in the operations group of the Chief of Staff of the Air Force, compares the situation in the 1950s at the height of the Cold War-defence ramp up to the situation over the past decade. In the 1950s, there were more than 50 first flights of new experimental or operational fixed-wing aircraft. This led to an explosion of development in the US aerospace industry. For the next 40 years, maintaining technological supremacy over the Soviet Union remained an overriding US government policy. This led the Pentagon to maintain rival centers of expertise to drive technological advances. Grant highlighted the competition between Lockheed and Northrop to develop rival stealth aircraft designs, with the former developing the 'facetted' F-117 and the latter designing the 'curved' B-2 heavy bomber.

In contrast, over the past decade, first flights of new aircraft were reduced to only nine events. These included the

# Superjet undergoes cold-soak trials


The third Sukhoi Superjet 100 flight prototype SN95004 has arrived at Yakutsk airport in Russia. The aircraft flew there to undergo cold-soak trials, which are required to examine the ability of the aircraft and its systems to resist temperature shock. This testing validates the standard flight preparation of the aircraft after short (up to two hours) and long (no less than 12 hours) parking.
The test session confirms systems performance, including the warm-up time prior to departure.

first flights of two prototypes of the F-35, the electronic warfare variant of the F/A-18, three unmanned aerial vehicles, and the upgraded version of the 45-year old C-5 Galaxy.

Looking to the coming decade, Grant writes, “the prospects are…simply very bleak for new aircraft production. There may be a new aerial tanker, a light strike aircraft, and a stealthy unmanned air vehicle, and the US Navy plans to seek a replacement for the F/A-18, but that could easily slip into the 2020s. This is the first time anyone can remember… that there are no new programs going forward.” This is likely to lead to hemorrhaging of talent from the US aerospace industry as companies and workers look to find other work.

“We can’t turn this around quickly,” said Grant’s report, which recommends that the US government work to preserve a ‘nucleus of manufacturers’ that can keep combat aircraft know-how advancing, even when there is no perceived imminent threat to the USA. She recommends that the US armed services and Pentagon become the custodians of a ‘core industrial policy’, using as an example the US Navy’s commitment to preserve the US shipbuilding industry.

Responding to criticism that spending on advanced weapons diverted money and resources from the ongoing wars in Iraq and Afghanistan, Grant says, “War is a mighty driver of innovation, yet it is not the only litmus test of sound aeronautical development. It takes a longer view of technology and military requirement to set a successful research and development program.”

She uses the example of the jet engine, which transformed air combat in the 1940s and 1950s, citing the unwillingness of the US government, in World War II, to support the development of the new power plant. “The US had secret prototype jet aircraft, yet no American-made variant flew in combat in the war. Basically, the jet engine was still so complex and raw that there was doubt about investing in it, given the wartime needs of immediate production.”

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The interior temperature in both the cockpit and the passenger cabin is also a part of the trials. Overall, the main checks will refer to engine launch procedures, and fuel system and environmental system functionality. The current set of tests are required to employ SSJ100 SN95004. The test aircraft represents full certification configuration with full crew cockpit interior and passenger service equipment, such as the interior, a kitchen and a lavatory. The launch and systems operations will be monitored by a tailored onboard control system.

Yakutsk has average February temperatures falling to -35°C and nearby is the ‘Pole of Cold’ where minus 71.2°C was recorded – the lowest ever temperature in an inhabited place, so it is little wonder that Yakutsk airport is a well-known location for Russian cold-soak trials.

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Since the inaugural show in 2003, the expo has been a must-attend event for top professionals across the civil and military aerospace sector

# Back home in Hamburg

FROM MAY 18-20, 2010, THE AEROSPACE TESTING SHOW WILL BE GOING BACK TO ITS ORIGINS IN HAMBURG, GERMANY AND BUILDING SOME NEW ADDITIONS

BY CHRISTOPHER HOUNSFIELD

After four years, the Aerospace Testing show will return to Hamburg and join hands with its old partner, Aircraft Interiors Expo.

The organizers have announced a first-time addition: a French Pavilion. This will be put together by UBIFRANCE (the French Agency for International Business Development). The French national pavilion will showcase the best of French aerospace testing technology, and some of the companies involved include: d2T, Fontanie, Clemessy, BCSA, Global Vision, and AAVD.

The Young Aerospace Engineer Awards (YAEY), launched at Aerospace Testing 2009, are back for a second year due to popular demand. The YAEY awards, in partnership with the European Conference for Aerospace Sciences (EUCASS), aim to recognize excellence and identify promising talent in engineers about to enter the workplace:

In particular, the Technology and Innovation Award recognizes the best project in aeronautic and space testing, design, and manufacturing. The Scientific Award recognizes the most innovative project in the field of aerospace research, covering a broad domain including: system integration, including multidisciplinary optimization and fluid-structure interaction; flight dynamics, such as guidance, navigation and control; propulsion physics; and flight physics.

Last year's winners were Dimitrios Sikoutris from the University of Patras and Dorian Colas of École Centrale de Paris. Both students were invited to present their winning projects and received €1,300 each in prize money. The project submission deadline for this year's show is April 9, 2010.

The Career Development Day will be held on the final day of the show, May 20, and will feature seminars on exploring the latest opportunities within the aerospace test engineering industry. Visitors will learn how to take their career forward through workshops and presentations delivered by aerospace recruiting companies.

"I am excited that the expo has returned to Hamburg after a four-year break away," says exhibition director Jonathan Heastie. "It will provide the thousands of engineers in the north of Germany, especially those from Airbus, Lufthansa Technik, and the DLR with the chance to exchange ideas with each other and evaluate the latest testing solutions from over 100 leading suppliers in one place and at one time.

"We also have more than 60 free educational seminars that engineers can attend during their visit to the expo. Speakers from EADS, Airbus, BAE Systems, and many other leading organizations will provide technical presentations and case studies in theatres around the exhibition floor. "On the third day of the show, we will present further workshops from Airbus as part of our career forum which will help our visitors to develop their engineering career.

"Lastly, as an added bonus, all visitors can also attend the co-located Aircraft Interiors Expo next door, at no cost. There are over 500 additional exhibitors, including a number of cabin testing and certification houses, plus an exciting innovation zone showcasing leading-edge design and 3D virtualization software from Autodesk."

## Technical seminars

More than 60 expert technical presentations from across the aerospace design, testing, and manufacturing and engineering industries will be presented at the expo. Some of the highlights include a forum on real-time testing of complex avionics systems. Other forums will focus on metrology and materials, and composites testing. Ultrasonic testing machines with robot mechanics, and the studies into a new approach to CFRPM component testing will be a topic from GE Inspection Technnologies.

The flight test seminar is a regular and popular feature of Aerospace Testing expo, and is once again being coordinated in cooperation with the SFTE. Actual concepts and implementations to improve the efficiency of ground-test facilities at the EADS Military Air Systems Test Centre is also being presented by EADS Military Air Systems

## European Telemetry Conference

The organizers have announced that the European Telemetry Conference will run alongside Aerospace Testing 2010. The ETC 2010 workshops will start on May 17, the day before Aerospace Testing opens. ETC 2010 will highlight the most recent innovations in methods, systems, and instrumentation from industry, research, and laboratories all around the world.

The European Telemetry Conference will showcase original technical papers and ideas in test, telemetry, telecontrol, instrumentation, and recording technologies for industrial, automotive, scientific, aerospace, space, naval, and military applications. ∎

*More info on www.aerospacetesting.com Find out more about the YAEY Awards www.aerospacetesting.com/yaeyhome*

EMALS – The Electromagnetic Aircraft Launch System – will launch carrier aircraft for the first time from its test site this year. Frank Colucci looks at the US Navy's catapult system and the program meant to send EMALS to sea by 2015

# Force field

> For the Super Hornet or Hawkeye pilot flying from the US Navy's next-generation carrier deck, the Electromagnetic Aircraft Launch System (EMALS) will be no different than today's steam catapult. The launch bar will still engage a deck shuttle, and the shuttle will accelerate the aircraft from standing start to flying speed in less than 310ft and three seconds. However, below the flight deck, the new computer-controlled system of linear induction motors and power supplies promises design and operating advantages for new carriers and their aircraft.

A full-length EMALS test track was officially dedicated at naval air engineering station (NAES) Lakehurst, New Jersey in November 2009 following years of component, subsystem, and half-stroke system tests at Lakehurst and elsewhere. "Now we're trying to fully qualify the system and wring out performance," explains Naval Air Systems Command (NAVAIR) aircraft launch and recovery program manager Capt Randy Mahr.

NAVAIR certifies EMALS and the associated advanced arresting gear for the fleet with the support of lead technical authorities from the Naval Sea Systems Command (NAVSEA). The US Navy's next nuclear-powered aircraft carrier – CVN-78, the USS Gerald R. Ford – is designed around the electromagnetic systems and scheduled for delivery in 2015. EMALS is now beginning the third phase of its system functional demonstration. By the time the new carrier conducts sea trials, the launch system will have undergone more than five years of testing at Lakehurst. "Our goal at the end up at Lakehurst is a Launch Bulletin to tell the Navy how to start launching aircraft," says Mahr. "In aircraft terms, we're developing the equivalent of a flight clearance."

The Lakehurst site, which was commissioned in early 2010, has a full-scale EMALS energy storage group – one-third of the Ford complement of motor generators and rectifiers. The production-representative powertrain drives just one of the four catapults planned for the ship. A trough below the New Jersey flight deck holds four stacked linear induction motors and the traveling armature that carries the launch shuttle. A windowed, in-ground station beside the catapult accommodates a launch control officer.

A separate underground building contains the inverters and controllers of the power conversion system. Another building above ground houses the inverters and transformer/rectifier of the prime power interface subsystem, the rectifiers of the power conversion subsystem, the motor/generators of the energy storage subsystem, and closed-loop controls. General Atomics Electromagnetic Systems is the EMALS prime contractor and integrator. Company director of advanced launch and recovery equipment Sue Wojtowicz says, "Now it's just making sure everything talks and works as required."

**Right: A C-2A Greyhound prepares to launch from catapult 3 aboard the aircraft carrier USS Carl Vinson. Steam catapults put high launch stresses on carrier aircraft. EMALS promises lower peak-to-mean force ratios. (US Navy)**

As part of its commissioning, the full-stroke EMALS at Lakehurst ran no-load tests to show the control system could position the shuttle repeatedly. The catapult launched dead-load sleds this February and real F/A-18, E-2, and C-2 aircraft this summer. By the time EMALS is cleared for sea duty, the shore-based system will have launched around 3,600 dead loads from 10,000 to 100,000 lb.

An F-18 fighter instrumented to measure structural loads will be launched at 150 to 160kt depending on 'wind-over-deck' available at Lakehurst. E-2C airborne warning and control

"Our goal at the end is a Launch Bulletin to tell the Navy how to start launching aircraft"

The full-length EMALS at Lakehurst NAEC has four stacked linear induction motors in a reinforced concrete trough (General Atomics Electromagnetic Systems)

and C-2 carrier onboard delivery aircraft will follow at 110 to 130kt. All three aircraft types will cycle through a test plan including degraded mode simulations with one of the four linear motors inoperative. "Obviously we'd want to do those with dead-loads and not a manned aircraft the first time," notes Capt Mahr.

EMALS is also designed to accommodate future aircraft both lighter and heavier than those in today's carrier air wing. The F-18, E-2, and C-2 all launch at weights around 60,000 lb. "Right now, I'm launching everything the Navy's got," says Mahr. "But we're allowing for the fact that over the life of the Ford class, the Navy may choose something different."

### Cat shots

The underlying principle of the Electromagnetic Aircraft Launch System is used in commuter trains, industrial robots, and elsewhere. Wojtowicz explains, "You're applying a traveling wave to the linear motors, and it induces current in the armature. It's the interaction of the magnetic field that causes the shuttle to move. We use the same system to launch, retract, and brake. You just reverse polarity." However, the 100,000hp linear motor of EMALS turns 1.35MW continuous input power into a 60MW, two second pulse to shoot the aircraft from the deck. Alternating current reverses in the last 20ft of the stroke to stop the shuttle without a water brake and return the shuttle to start position. The EMALS energy storage subsystem recharges a precision-balanced high-speed rotating electrical core between launches.

Without massive steam pistons and their associated plumbing, the largely solid-state EMALS has few moving parts to fail and eliminates tons of topside weight associated with steam-powered catapults. Carrier designers will exploit the lower center of gravity and reduced interior volume dedicated to launch gear. Navy planners meanwhile expect better EMALS reliability and other CVN-78 enhancements to increase combat sortie rates by 25% compared with today's Nimitz-class ships. Operationally, steam catapults require hours to warm up and a long series of no-load launches before aircraft can fly. EMALS should be ready to fly aircraft with one or two no-load calibration launches. The closed-loop control system monitors aircraft speed in real time and adjusts thrust throughout the stroke. "Because I can control end speed better, I need less wind over deck," observes Mahr. For carrier captains, a 5kt reduction in wind-over-deck requirements means another 2.5 miles maneuvering room in constrained operating areas.

EMALS should also reduce structural wear-and-tear on carrier aircraft. In contrast to the brutal jerk of steam catapults, linear electric motors will accelerate manned and unmanned aircraft to launch speed with lower peak-to-mean force ratios. "We term it a softer launch," says Mahr. "We will deliver less fatigue load to the aircraft during the launch cycle." As a result, new carrier aircraft may be designed lighter and more efficient. "One of the payoffs we see potentially is when you get into the very lightweight aircraft," says Mahr. Unmanned Air Vehicles expected aboard the Ford may need less than the 10,000 lb minimum force generated by steam catapults. "When you get to lighter aircraft, you don't have to put as much structure in to be compatible with the catapult."

### Test strokes

The US Navy first showed an interest in electromagnetic carrier catapults in the 1940s, but packaging efficient EMALS technology for a ship took nearly 50 years. Several companies started risk reduction efforts in the early 1990s. General Atomics demonstrated its pulsed power conditioning concepts in magnetic fusion research sponsored by the US Department of Energy and received a four-year contract from the Navy in 2000 to apply the technology to EMALS. The same contract paid for energy storage system design and analysis by the University of Texas at Austin Center for Electromechanics.

In component and subsystem testing at various sites, General Atomics demonstrated power-to-weight densities two or three times the then-state-of-the-art in the energy storage, power conditioning, and motor subsystems. The Power Conditioning System, for example, achieved 16kW/kg, better than the 10kW/kg required by the Navy. General Atomics ultimately integrated power electronics from L3 Communications Applied Technologies Pulse Sciences, energy storage systems from Kato Engineering, and controls and system health monitoring technology from Forster Miller.

The General Atomics manufacturing center in Tupelo, Mississippi ran high cycle tests on the EMALS power subsystem. "We've run approximately 30,000 launch cycles on that," observes Mahr. "We're going to run that one for another year." Initial testing uncovered motor generator vibration issues subsequently corrected by a bearing redesign. The motor generator of the energy storage subsystem completed factory acceptance testing at Tupelo in March 2008.

> **"Several companies started risk reduction efforts in the early 1990s"**

Highly accelerated life testing and high cycle testing at Tupelo led to the system functional demonstration at Lakehurst to validate the EMALS design predictions. Lakehurst hosts a joint government-industry test team including NAEC craftsmen to fabricate and install equipment. According to Mahr, "The test team is more than just engineers and testers; it's all manner of competencies." Development testing with a half-stroke EMALS at Lakehurst included 400 launches with 10,000, 30,000, 60,000, and 100,000 lb dead loads traveling to 150kt. "The only difference from what we have now is we didn't have the full catapult," says Mahr.

EMALS launch strokes are tracked by radar and cameras to record speed and side-to-side motion of the armature. The EMALS team also instrumented the 'footstools' at the bottom of the motor trough with strain gauges to measure loads ultimately imparted to the ship structure. Lasers are used to measure deflection in the EMALS structure itself. "We're looking to verify the analysis that was done," says Wojtowicz. "We're applying current to the linear induction motor but not allowing movement of the shuttle. We're measuring induced force so we know we're accurate with our predictions."

EMALS also has to accommodate the hog and sag of the ship. The linear motors, for example, are separated by just one inch, as Mahr observes: "Lakehurst doesn't move very much, but the ship does move. We'll be doing gap analysis testing to see if the ship moves and the launch goes smoothly." National Technical Systems Inc is meanwhile under contract for electromagnetic compatibility and environmental testing at Lakehurst and the company's own laboratories.

Northrop Grumman Shipbuilding began laying the keel of the USS Ford in late 2009 at Newport News, Virginia. Production EMALS components will be tested following installation aboard the new carrier. Integrated system testing will be conducted while the new carrier is still under construction, including a series of no-load and dead-load launches while the Ford is at the shipbuilder to confirm the catapults are fully operational. At sea, no-load testing will be run prior to initial aircraft launch. After scheduled delivery in September 2015, the Ford will be certified to release the full flight deck, including EMALS and the electromagnetic aircraft arresting system for unrestricted operation. Navy plans call for the land-based EMALS to stay operational for the life of the system as an engineering and training tool. ∎

**A flight deck director guides an F/A-18F Super Hornet onto the steam catapult aboard the USS Nimitz in the Gulf of Oman**

**"EMALS launch strokes are tracked by radar and cameras to record speed and side-to-side motion"**

# Dream come true?


BOEING'S 787 DREAMLINER FINALLY TOOK TO THE SKIES IN DECEMBER 2009. JOHN CHALLEN FINDS OUT HOW THE TROUBLED PROJECT GOT TO THAT POINT, AND WHAT THE FUTURE HOLDS

BY JOHN CHALLEN

Initially planned to enter service in May 2008, the 787 Dreamliner made its maiden test flight 19 months later when chief pilot Mike Carriker and engineering pilot Randy Neville took a development 787-8 – ZA001 – down runway 34L at Boeing's Everett, Washington facility. Getting to this point in the program on December 15, 2009 has not been straightforward. Announced to the world in 2003 as a replacement for the defunct Sonic Cruiser – itself a replacement for the 767 – the 787 Dreamliner (originally designated 7E7) had its introduction delayed numerous times, for a variety of reasons. These issues included difficulties for certain members of the 787's extensive project partner list in procuring parts, with striking machinists and component quality, and with key personnel leaving the test program.

As well as time, the delays have cost Boeing plenty of dollars. The first three production Dreamliners have been deemed unsellable and worthy of mere preproduction evaluation work, forcing the company to write off as much as US$2.5 billion. With sales of its most fuel efficient, most composite-heavy aircraft topping 850 – the first airplanes are due for delivery to All Nippon Airways in late 2010 – Boeing realizes that the remainder of the 787 Dreamliner test program must be without hiccups. As you would expect, there are thousands of engineers from Boeing, and thousands more from the project partners working on the 787. In the works from December 2002, the company expects the Dreamliner project to keep those engineers busy for decades to come.

Boeing is limiting the amount of information released about the project, but confirms that two test aircraft in service will soon be joined by four more airplanes. All six 787s will be conducting test operations at a variety of locations, including the project's headquarters – Boeing Field in Seattle, Washington. The city will also be home to full-scale airplanes used for static tests and fatigue evaluations. Flight testing will be assigned to a total of 34 pilots, who will spend a total of 3,100 hours in the air.

"In addition to actual flying hours, we have thousands of hours testing the integrated systems in a simulated cabin and thousands more


BOEING
DREAMLINER

> **"Of the 20% fuel savings expected with the 787 over the 767, 8% comes from the engines"**

hours in individual bench tests," says Lori Gunter, spokeswoman for the 787 program, confirming that 3,700 hours of test work will be completed on the ground. "This work will be complemented by hundreds of hours of systems testing on real airplanes on the ground."

### Tried and tested

According to Boeing, the nine-month test program for the 787 will follow a similar path endured by other recently introduced aircraft. The 777 (Boeing's previous major aircraft) testing took 11 months, using nine aircraft that covered 7,000 flight test hours, but much of this work was designed to demonstrate the capabilities of one of the airplane's features, the extended-range twin-engine operational performance standards (ETOPS).

"For structures, we test in a building block fashion – first testing material samples, then small sample pieces, then full-scale pieces of structure, then integrated assemblies, and finally full-scale airplanes," explains Gunter. "Similarly for systems, we test each individual system in the laboratories, then we test integrated systems, up to fully integrated systems, on-ground airplane testing and now flight testing.

"Of the 20% fuel savings expected with the 787 over the 767, 8% comes from the engines," explains Gunter. The engines used will be the GEnx from General Electric and Rolls-Royce's Trent 1000. Boeing says that costs and time will be saved by changing engine types, due to the addition of a standard interface. However, observers have argued that changeover times could exceed two weeks, calling into question the actual amount of money saved. At launch, 787s will be powered by the Rolls-Royce unit, which was certified for use in August 2007.

Clearly there is a lot more testing to go before delivery to the Japanese, but Gunter says the team has renewed confidence in the program: "The first flight was very successful. We have a total flight test program of more than 3,000 hours and have completed more than 100 hours, so there is still a lot of data to collect."

## Number three

**A third airplane has joined the Boeing 787 Dreamliner flight test program. ZA004, the fourth flight test airplane to be built, took off at 11:43 local time from Paine Field in Everett, Washington. The program plan called for ZA004 to fly before ZA003 because the data ZA004 is collecting is needed more quickly for the certification and development of the 787-9.**

**Captains Heather Ross and Craig Bomben completed a three hour two minute flight at 14:45, landing at Boeing Field in Seattle. Flight test personnel were also on board to monitor aircraft performance.**

**"Airplane Number 4 operated flawlessly," Ross said after landing. "We've got a lot of work ahead of us, but I can't imagine a better start to the flight test program for this airplane."**

**Ross will serve as chief pilot for ZA004. This airplane will be used to accomplish testing of: aerodynamics, high-speed performance, propulsion performance, flight loads, community noise and extended operations (ETOPS), and other test conditions.**

**During its first flight, the airplane reached an altitude of 30,000ft (9,144m) and an airspeed of 255kts, or about 293mph (472km/h). As the testing of the 787 fleet progresses, the airplane will fly at its expected in-service maximum altitude of 40,000ft (12,192m) and speed of Mach 0.85.**

**"We are continuing to make good progress on the flight test program," says Scott Fancher, vice president and general manager of the 787 program, Boeing Commercial Airplanes. "The team is staying focused and disciplined in keeping the priority on safety and execution of the plan."**



**Boeing's second 787 flight test airplane has moved from Boeing Field to Victorville, California along with 200 flight test personnel**

### Model behavior

Boeing has so far concentrated purely on the 210-seat base model 787, the 787-8, but Gunter reveals that: "Further variations will be produced, undergoing their own testing for those areas that are different from the baseline model."

The next 787 to break cover will be the 787-9, which is planned to enter service in 2013. The 787-9 will feature a stretched fuselage, giving up to 290 passengers space in three classes. Alterations over the base model will include a higher fuel capacity, increased range (8,500 miles), higher maximum take-off weight, and increased structural strengthening. At the beginning of the 787 program, the 787-9 had the same fuel capacity as the other versions, but design developments have enabled the addition of a forward tank and a slightly higher range than the base model. Orders have been led by Air New Zealand, Qantas, Etihad Airways, and Singapore Airlines.

The 787-3 currently has no orders, after delays prompted Japan Airlines and All Nippon Airways to cancel or change their orders to 787-8s. Specifically designed for the Japanese market, if it reaches production reality, this 290-seat short-range version will have a range of 2,500 to 3,050 miles. Alterations over the base model include a reinforced fuselage and blended winglets replacing raked wingtips to reduces wingspan. Although not confirmed, Boeing says that a longer version of the 787 will be produced; the official line is, "It's not a matter of if, but when we are going to do it." Providing competition for Airbus's A350-900, the 787-10 would seat 310 and additional cargo, sacrificing some range offered in the 787-8. ∎


**A commercially available electric model rotorcraft shown after its battery-power system has been replaced with power generated by a United Technologies Corporations PEM fuel cell stack**

# Fuel cell revolution

UNITED TECHNOLOGIES CENTER'S RESEARCH PIONEERS HAVE JUST PROPELLED THE FIRST FUEL CELL-POWERED ROTORCRAFT INTO FLIGHT

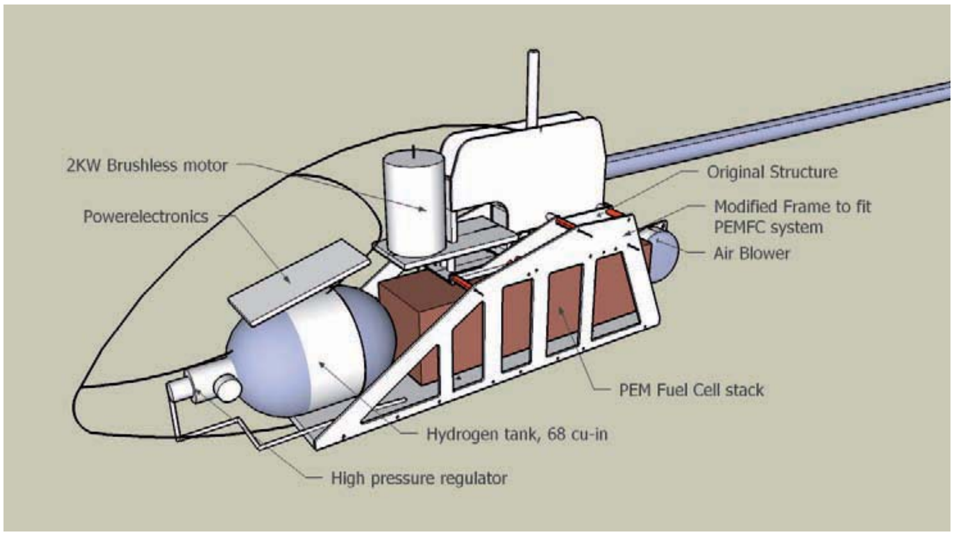
BY DR DAVID PAREKH

Not until the last decade were the first fuel cell-powered aircraft flown and reported. The majority of these were small fixed-wing remotely piloted unmanned aircraft.

In the past two years, fuel cell-powered manned flight has been demonstrated through the integration of fuel cells in powered gliders. Fuel cells have the inherent advantage of higher energy density than batteries, but they have much lower power density. This effort is motivated by the need to close that gap.

Whether for stationary or mobile applications, increasing power density provides benefits of weight and volume reductions. A rotorcraft was selected as the demonstration platform as it exemplifies the need for high power density. This work is the first example of fuel cell-powered rotorcraft flight within UTRC's (United Technologies Research Center) knowledge.

On October 11, 2009, UTRC hydrogen/air proton exchange membrane fuel cell (PEMFC)-powered helicopter took to the skies. The flight tests were conducted on UTRC grounds in East Hartford, Connecticut, USA. Prior to this, on October 23, 2008, a proof-of-concept flight was demonstrated with a helicopter powered by compressed $H_2/O_2$ Gen1 stack. In both cases, the fuel cell system is able to self-start, with no additional power assist, and provided all the power needed for the helicopter flight. In the recent demonstration, 4,200psi compressed $H_2$ and blower supplied air were used to provide a 20-minute flight. Although the fuel cell stack can provide a peak power of 1.75kW, an average of 1.2kW was drawn from the fuel cell with occasional surges up to 1.4kW. The additional power made the rotorcraft easy to maneuver.




The successful flight demonstration of a fuel cell-powered rotorcraft marks another milestone in the continuing development of fuel cell technology. Future work will focus on improving the energy density of the system at the 1kW scale by enhancing the power density of the fuel cell stack to over 1 kW/kg. This effort is one of a broad portfolio of research programs in energy conversion, energy efficiency, and systems integration aimed at supporting UTC's commitment to sustainability across its broad range of aerospace, building, and industrial products.

Above: A schematic of the rotorcraft showing the layout of the fuel cell system components. Left: cell-powered rotorcraft in flight. The red battery seen in the picture enables communication with the remote controller

## Fuel cell technology

Fuel cells are devices that directly convert chemical energy into electrical energy from hydrogen and oxygen, and produce water. A PEMFC contains a proton-conducting membrane sandwiched between two electrodes (anode and cathode). Unlike combustion systems, where hydrogen and oxygen react homogeneously, in a fuel cell they react separately. At the anode, hydrogen is electrochemically oxidized to generate electrons and protons. Protons are then transported to the cathode through the membrane to react with oxygen to form water, and electrons flow through an external circuit providing electrical power for applications. Therefore, air and hydrogen are separately fed to each electrode through bipolar plates containing machined channels. PEMFC operates at lower temperature (65-80°C) and is inherently more efficient than combustion engines. By virtue of their design, fuel cells have no moving parts, resulting in low noise and enhanced reliability compared to internal combustion engine (ICE)-based generators. Additionally, PEMFC have a low thermal signature and produce no emissions.

A fuel cell powerplant includes an assembly of fuel cells called a stack and the balance of plant, which enables stack operation. The balance of plant includes a hydrogen management system to provide regulated hydrogen to the fuel cell stack, air management system to provide air at designed humidity and flow to the stack, thermal management system to regulate the temperature of the stack, and power management system to regulate fuel cell electrical power to meet the power quality requirements of the primary load and balance of plant. Depending on the end application requirements for weight, efficiency, and life, the balance of plant can be simplified. UAV applications are more weight sensitive and less demanding in life requirements than ground transportation applications. Hence, high power-density fuel cell powerplants with significant system simplification are desirable for UAV applications.

For mini-UAV propulsion power, in the 1kW range, batteries, ICE, and PEMFC offer special advantages within their limitations. Batteries are excellent for short missions, but fuel cells and ICE are good alternatives for long endurance missions. The applied energy density of a power system factors in the weight of the complete powerplant including fuel storage, efficiency of fuel conversion, and the energy content of the fuel. PEM fuel cell systems can exceed the energy density of typical ICE systems at this scale when the hydrogen storage tank can exceed 8 wt% of $H_2$. Achieving higher than 10 wt% $H_2$ storage is feasible with liquid hydrogen, but not yet demonstrated at this scale with compressed hydrogen. Regarding power density, although >1,400W/kg PEMFC stack is claimed in the 100kW scale fuel cell stacks, only about 250W/kg is commercially available at the 1kW scale..

## High-power fuel cell design

The performance of PEMFC is strongly dictated by its water management strategy. In addition to being a by-product of the fuel cell reaction, water is critical to its operation. Effective removal of product water from the fuel cell is important to prevent poor supply of hydrogen and oxygen to the electrodes due to 'flooding' within the cell. However, insufficient water increases the resistance to proton transport through the membrane, resulting in

The high power density PEM fuel cell stack developed at Untied Technologies Research Center using proprietary technology

lower performance. Traditional architectures for PEM fuel cell systems manage water through specific cell designs and operational methods that requires high reactant pressure drops in the cathode and anode, and a high degree of temperature and humidity control. These designs generally render the fuel cell system more complex, more expensive, and less efficient.

UTC's proprietary PEM stack technology effectively overcomes the water-management challenge by replacing the commonly used solid bipolar plates with porous bipolar plates. In this special cell design, a pressure differential across the porous plates is the primary driving force to remove excess product water from the cell. Additionally, the UTC porous plate PEM fuel cells requires no external pre-humidification of the reactants because the hydrogen and oxygen are internally humidified by the water in the porous plates. As a result, the system weight is reduced and the balance of plant is further simplified, enabling unprecedented power densities, even at the 1kW scale.

Researchers at UTRC designed and built a greatly simplified PEMFC powerplant based on this water management technology. The power density of the fuel cell stack exceeded 675W/kg and that of the powerplant exceeded 500W/kg, which is the best-known power density in its class. The fuel cell stack operates at ambient pressure with air supplied from a high-speed centrifugal blower. The stack requires no external radiator as the heat rejected by the stack during operation is mainly removed by evaporation of liquid water. This unique thermal management system reduces the amount of coolant flow by an order-of-magnitude relative to traditional PEM fuel cell systems.

Additionally, the fuel cell stack is designed to meet the power quality needs of the rotorcraft, greatly simplifying the power management system. These changes not only reduce the powerplant weight, but also provide high system efficiency of >52% with only 3% losses from balance of plant.

> **"The successful flight demonstration of a fuel cell-powered rotorcraft marks another milestone in the continuing development of fuel cell technology"**

Another key feature of UTRC stack design for UAV applications is the use of a proprietary stack-assembly technology that enables individual cells in the stack to be easily removed or exchanged; and if more power is needed, individual cells can be added without compromising stack performance. The simplicity incorporated into this stack design enables stack assembly and the modification process to be performed without the need for special tools or expertise.

## Platform selection and integration

Significant advances in the performance of electric rotorcraft has been reported over the past few years, where electric helicopters in small scales often outperform their internal combustion engine-driven counterparts. These rotorcrafts are becoming popular for aerial photography, as well as numerous surveillance applications. The overall power to take-off weight (TOW) required varies from 0.12-0.2 kW/kg-TOW for helicopters up to several hundred kilograms. The 1-2kW (5-15kg) range was a desirable size for the demonstration rotorcraft as it could be developed and flown at UTRC's facilities. The Maxi Joker made by Minicopter was selected as a demonstration platform as it was found to be the most efficient helicopter on the market in this size range.

The airframe required only minor modifications to integrate the fuel cell system. The fuel cell is mounted in the center of the aircraft, and the blower can be seen protruding behind the stack. The high-pressure hydrogen tank is mounted on a shelf in the front to make it easy to fill or replace. The brushless motor and its power electronics are located above the tank. The fuel tank used is a US Department of Transportation approved high-pressure filament-wound carbon fiber tank designed for 4,500psi. The tank is connected to the cell via pressure regulators and a remote-controlled valve. Refilling of the tank can be done in less than a minute compared to the hour required for recharging lithium polymer batteries. The controls are provided with a 2.4GHz radio control system; inflight data is transmitted via a 900MHz link to a ground station.

The power system weight to the projected flight duration is a good way to compare alternate propulsion power technologies for aerospace applications. For short duration flight, when one sizes the power system for short duration flights, batteries weigh less than the PEMFC system, which is burdened with fuel cell stack and tank-empty weight. However, the applied energy density of $H_2$-PEMFC is three to seven times higher than batteries, enabling significantly longer mission endurance from the fuel cell-based propulsion system, when the payload requirements are reduced.

The successful flight demonstrations of a fuel cell-powered rotorcraft marks another milestone in the continuing development of fuel cell technology. Future work at UTRC will focus on improving the energy density of the system by enhancing the power density of the fuel cell stack to greater than 1 kW/kg. ∎

*Dr David Parekh is vice president, research, and director, UTRC. Other contributors include: Dr Mallika Gummalla, principal engineer/scientist; Dr Rachid Zaffou, staff engineer and scientist and Dr Ulf Jonsson*

# Air-breaking UAS

THE PREDATOR-SERIES UNMANNED AIRCRAFT SYSTEM IS THE MOST SUCCESSFUL AND CAPABLE CRAFT OF ITS TYPE. IT HAS EVOLVED THROUGH MANY VARIATIONS, TAKING IT TO THE PREDATOR C TODAY

BY SCOTT NYBERG

Since 1993, General Atomics Aeronautical Systems (GA-ASI)'s Predator series unmanned aircraft systems (UAS) have supported US and coalition forces worldwide, amassing over 900,000 cumulative flight hours. Predator series aircraft are currently averaging more than 28,000 flight hours per month, a number that continues to increase.

Providing essential situational awareness for the war fighter, the MQ-1 Predator is used in a variety of combat missions, to include intelligence, surveillance, and reconnaissance; targeting; forward air control; laser designation; precision strike, and bomb damage assessment. First flown in 1994, Predator has accumulated almost 700,000 flight hours, with over 85% of its time spent in combat operations. It is the first weapon-equipped UAS and features precision air-to-ground weapons delivery capability with Hellfire missiles. The reliable UAS has the highest operational rate in the USAF. Predator is also operational with the US Navy and the Italian Air Force. Selected by *Air and Space Magazine* as one of the top 10 aircraft that changed the world, Predator's success was the catalyst for GA-ASIs and subsequent development of the sophisticated Predator B and next-generation Predator C UAS.

## Predator B, the overview

Commonly referred to as MQ-9 Reaper by its USAF and UK Royal Air Force customers, the turboprop-powered Predator B was developed with GA-ASI funding and provides greater capabilities than Predator.

**The vertically-oriented V-tail of the Predator C deflects radar and shields the 4,800 lb thrust Pratt & Whitney PW545B engine exhaust's infrared signature**

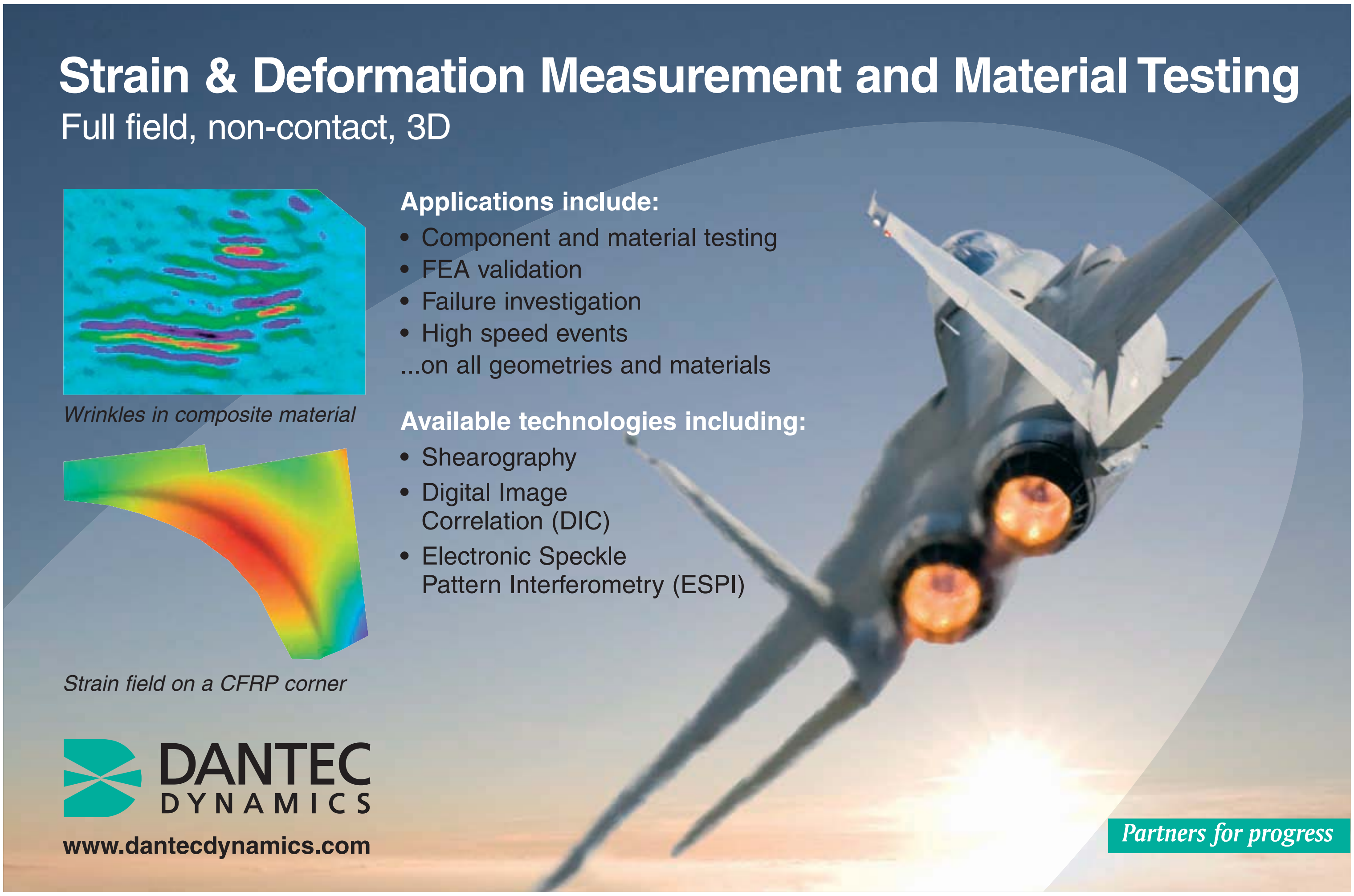
First flown in 2001, Predator B is an improvement in performance and reliability of the battle-proven Predator UAS. Featuring operational flexibility, the multimission Predator B has an endurance of over 30 hours, speeds greater than 240 KTAS (knots trues airspeed), can operate up to 50,000ft, and has a 3,850 lb (1,746kg) payload capacity that includes 3,000 lb (1,364kg) of external stores. It is twice as fast as Predator, carries 500% more payload, and has nine times the horsepower. Predator B provides a long-endurance, persistent surveillance/strike capability for the warfighter.

The aircraft is equipped with a fault-tolerant flight control system and triple redundant avionics system architecture. Predator B is engineered to meet or exceed manned aircraft reliability standards.

Predator B is powered by the flight-certified and proven Honeywell TPE331-10 turboprop engine, integrated with Digital Electronic Engine Control (DEEC), which improves engine performance and fuel economy.

The Predator B multimission aircraft is modular and is easily configured with a variety of payloads to meet mission requirements. Predator B is capable of carrying multiple mission payloads to include: EO/IR, Lynx SAR/GMTI, multimode maritime surveillance radar, electronic support measures (ESM), laser designators, and various weapons packages.

This aircraft has been acquired by the USAF, US Navy, US Department of Homeland Security (DHS), NASA, the Royal Air Force (RAF), the Italian Air Force, and soon others.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Wrinkles in composite material
Strain field on a CFRP corner
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## The development

Development of Predator B began as a GA-ASI funded internal research and development (IRAD) effort in 1998. The goal for the program was to take Predator technology into the jet age – flying higher, faster, and carrying more payload. Both military and commercial applications for Predator B were envisioned and two versions were designed: a turboprop aircraft that could climb to 48,000ft and had 32 hours of endurance, and a turbojet aircraft that could ascend to 60,000ft and had 18 hours of endurance. The first flight of the turboprop-powered Predator B occurred in February 2001. Through agreement with the USAF, the turboprop-powered aircraft was selected over the flight-ready turbo-jet variant. Two of the turboprop prototypes were produced and delivered to the USAF for early deployment.

During January 2004, the USAF initiated Predator B's formal development program, where the aircraft entered the system design and development (SDD) phase. The 'deliverable' from the Predator B program was a complete weapon-equipped system to be used by the USAF.

In February 2006, GA-ASI acted to support the USAF's Predator B Early Fielding initiative. The Air Force wanted an increased capability, production-capable Predator B in the war fighter's hands sooner rather than later, so it approved a rapid production of an early system capability to support the Global War on Terror (GWOT).

To accommodate the requirement, an engineering team rapidly adapted its systems engineering processes to satisfy compressed development, testing, and delivery timelines. In parallel with the early fielding efforts, Predator B SDD work continued simultaneously, with a separate engineering team dedicated to fulfilling the requirements of the SDD contract. This team was responsible for creating the Predator B Block 1. This parallel path enabled GA-ASI to continually mature Predator B's system capabilities, which would later be retrofitted into already-deployed aircraft to improve their system effectiveness.

**"The team produced and delivered the first developmental Predator B to the USAF less than one month after receiving the early fielding directive"**

Predator follows a conventional launch sequence from a semi-prepared surface under direct line-of-sight control. The take-off and landing length is typically 2,000ft

Execution of the Predator B early fielding effort required close coordination between the USAF and GA-ASI on many developmental aspects of the system. System development tasks had to be re-prioritized and initial Predator B capability requirements established in concert with plans for subsequent phased upgrades. The Air Force and GA-ASI also planned to mitigate the re-allocation of development test (DT) assets. Additionally, the team accelerated technical order, development, and certification. Issues surrounding planning and support for accelerated training and logistics were also resolved.

## Early fielding success

Responding to the service's urgent request, the team produced and delivered the first developmental Predator B to the USAF less than one month after receiving the early fielding directive. The second Predator B with early fielding capability was delivered the following month in March 2006. Two additional early fielding configuration aircraft were delivered in February 2007.

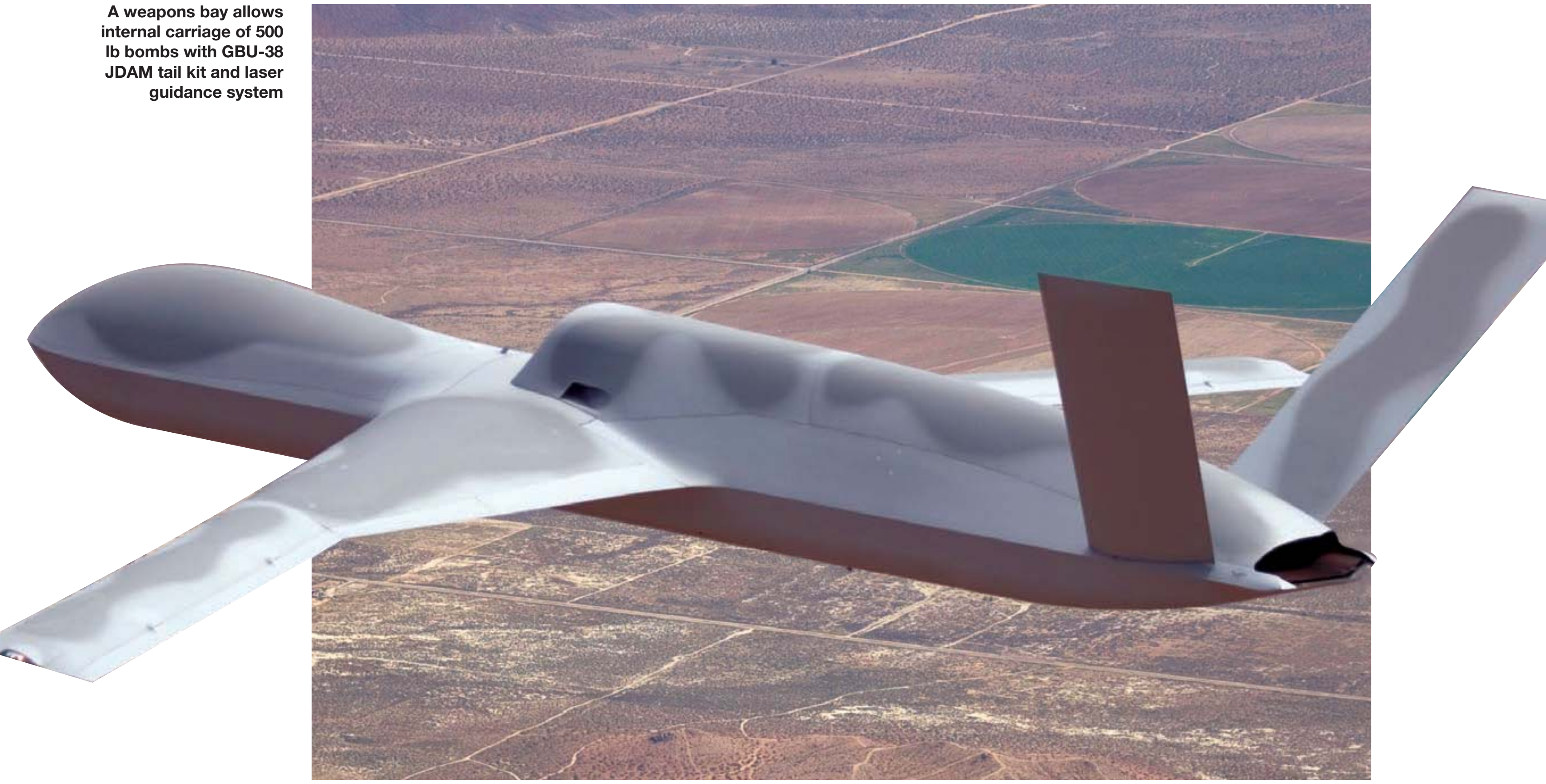
The parallel development effort, the Predator B Block 1 program, was delivered in March 2007. Following that, GA-ASI doubled its monthly aircraft production rate.

The team's engineering ingenuity, resourcefulness, and focused commitment were critical to success of the early fielding initiative. Shades of the program remain as the SDD program is still progressing concurrently with continued aircraft production and deployment. As such, the company continues to manage capability insertion as it is developed.

## The warfighter

Predator B has revolutionized the battlefield, providing operators with 24/7 all-weather/day-night persistent situational awareness, combined with an onboard precision strike capability – and all without putting a pilot at risk. Its 30-hour airborne endurance and wide-area intelligence/surveillance/ reconnaissance (ISR) coverage capabilities provide an unblinking eye in the sky, giving warfighters an unprecedented transparency across the battlefield.

Predator B's streaming video can be shared with forces on the ground, as well as with



A weapons bay allows internal carriage of 500 lb bombs with GBU-38 JDAM tail kit and laser guidance system

higher headquarters, ensuring that potential threats are visible to forces in proximity. Similarly, its Lynx Synthetic Aperture Radar provides continuous high-resolution photographic-quality images in any weather. A true force multiplier, Predator B's ISR capabilities enable it to relieve manned aircraft less well-suited to the task. It has demonstrated the ability to independently find, fix, track and, if required, conduct a time-sensitive strike against a fleeting target, or support the timely engagement by a manned aircraft.

Predator B provides warfighters with the size, weight, and power to integrate multiple payloads simultaneously, with capacity for growth through an open modular architecture. Acquisition by coalition forces further enhances training, support, and logistic synergies accrued through interoperable aircraft systems.

## Supporting civil missions

In addition to military missions, Predator B is operated by US DHS to safeguard national borders and (soon) its maritime approaches from illicit activities. The same Predator B airframe can be re-purposed quickly into a maritime surveillance configuration with the addition of a digital 360º surface search radar. The craft's maritime surveillance capability has supported mission demonstrations for US Customs and Border Protection, the US Navy, US Coast Guard, Canadian Defence Forces, and the Australian government.

DHS has employed Predator B in a variety of crisis response missions following hurricanes and floods, leveraging the aircraft's surveillance capabilities to conduct damage assessments, help locate survivors, and assist in disaster recovery efforts. NASA uses its Predator B with a sophisticated infrared sensor on its wing to map the intensity and movement of large fires, sharing the information to ensure best use of firefighting resources and streaming video to firefighters on the ground for expanded situational awareness and increased safety.

## Predator C

Similar to Predator B, Predator C Avenger was developed through funding of GA-ASI. Its unique design, reduced signature, and speed increases its survivability in higher threat environments and provides potential customers with an expanded quick-response armed reconnaissance capability. The first flight of Predator C occurred in April 2009. The aircraft is currently in flight test.

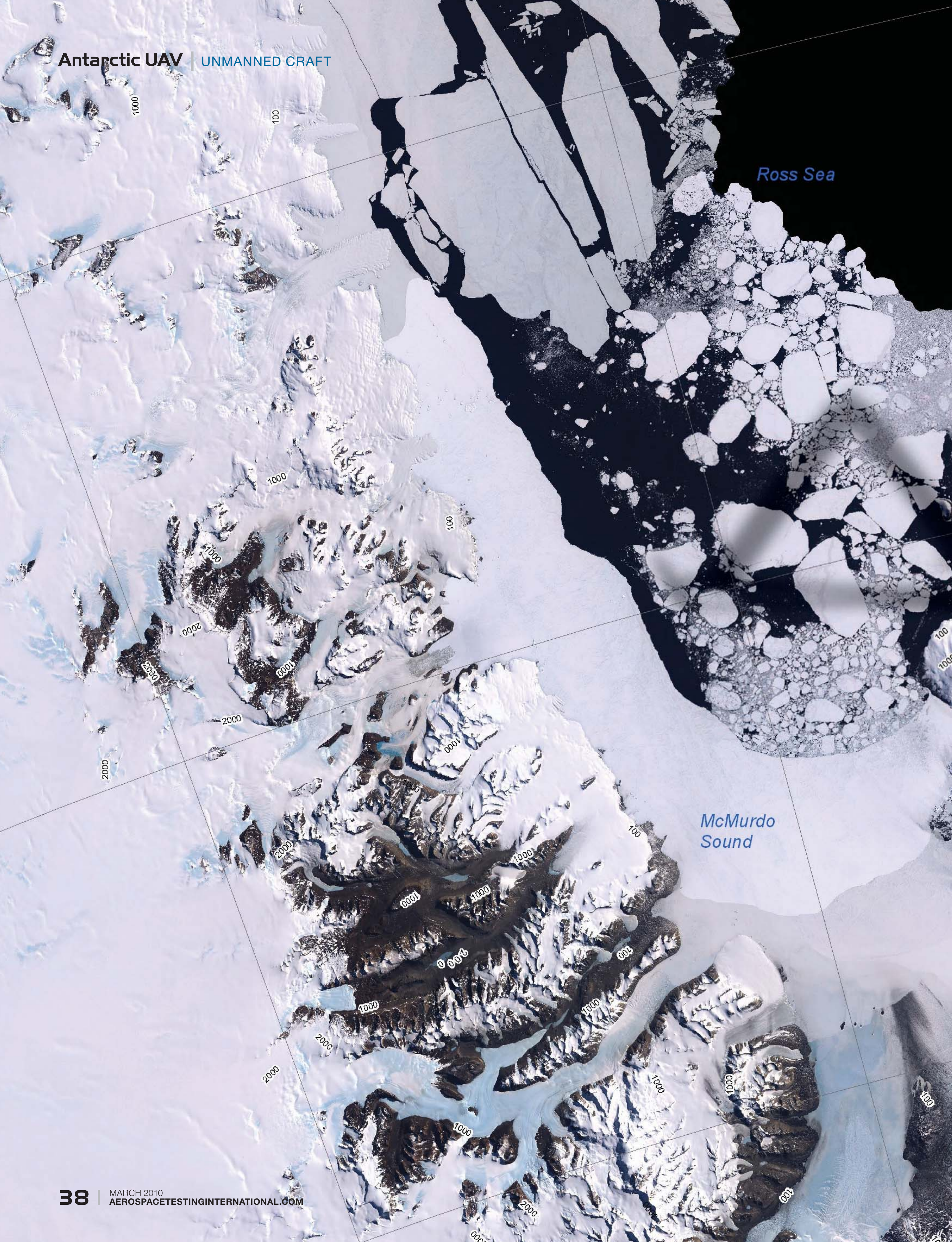
The high-speed, multimission Avenger is a long-endurance, medium- to high-altitude UAS that can perform wide-area surveillance, time-sensitive strike missions over land or sea, and a host of other challenging military missions. The aircraft has much higher operational and transit speeds than other Predator series aircraft, resulting in quick response and rapid repositioning for improved mission flexibility and survivability.

Avenger is an advanced next-generation UAS. The jet-powered Predator C is equipped with a Pratt and Whitney PW545B turbofan engine capable of producing 4,800 lb installed thrust. The engine is designed for greater fuel economy and features class-leading fuel consumption components. Avenger can operate at speeds up to 400 KTAS, a maximum altitude of over 50,000ft (1,5240m), and has 20 hours of endurance. Its payload capacity enables it to carry multiple sensors, while its weapons bay can house 3,000 lb of precision munitions.

The Avenger employs the same materials and avionics as Predator B and is likewise controlled from and fully interoperable with GA-ASI ground control stations. Avenger's low cost and advanced capabilities make it a good choice for swarm tactics where affordable quantities count in a successful outcome.

GA-ASI now expects to get the go-ahead from FAA to start tests of the Predator C Avenger at Edwards Air Force Base test range in California. According to reports chairman and CEO Neal Blue, "We anticipate receiving approval from the FAA in the immediate future to fly into the Edwards AFB range so that we may complete full envelope flight testing." ∎

*Scott Nyberg is the strategic development associate with General Atomics Aeronautical Systems Inc*


Ross Sea
McMurdo
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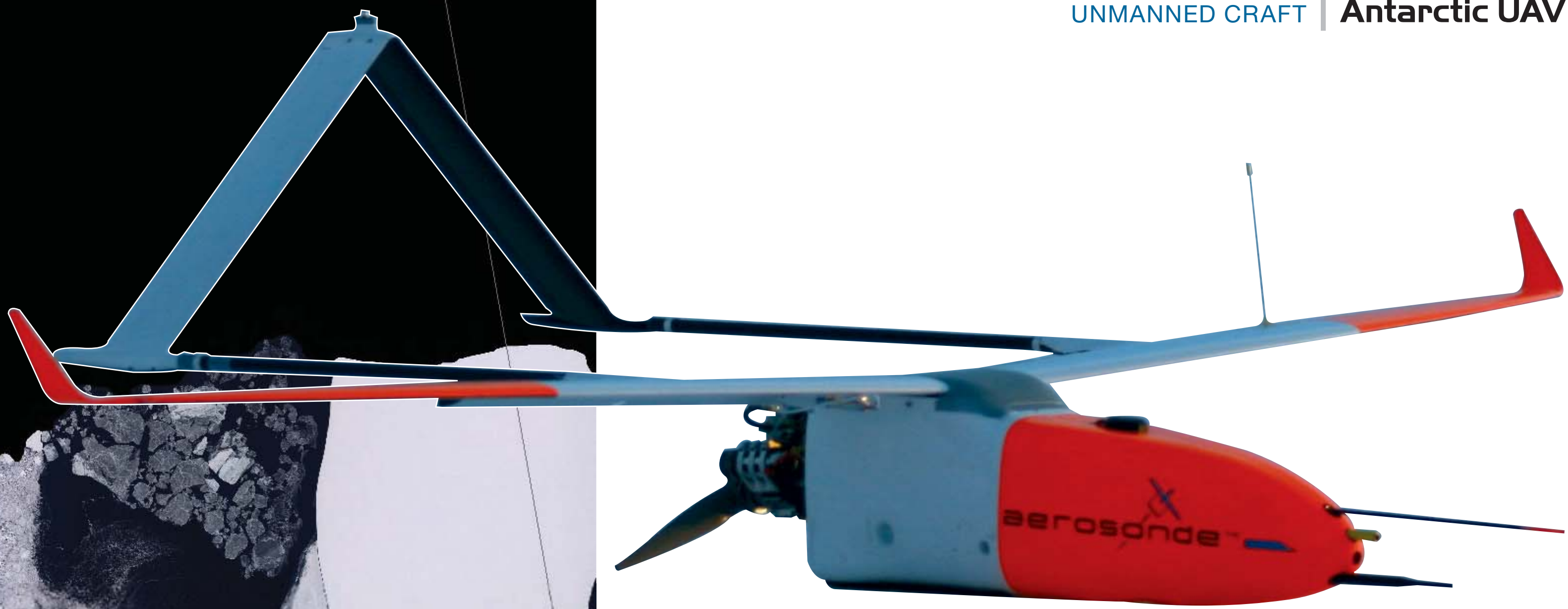
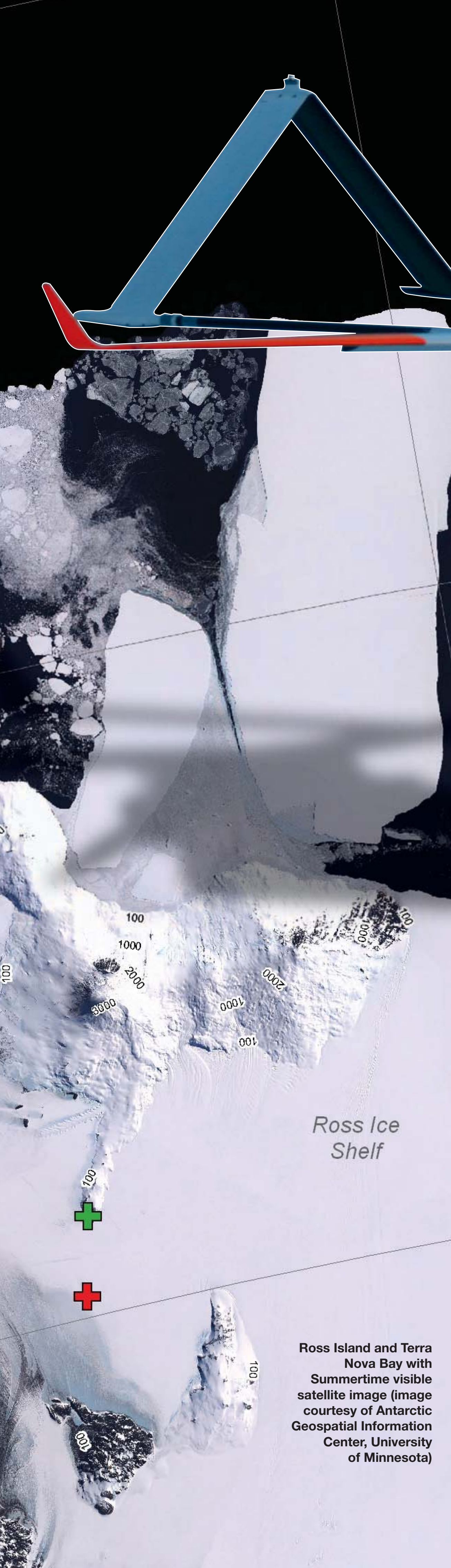



# Coming in from the cold

## IN LATE 2009, A SMALL FLEET OF UAVS DESIGNED TO WORK IN EXTREME CONDITIONS ARRIVED AT McMURDO STATION, ANTARCTICA, TO STUDY THE ATMOSPHERE AND OCEAN




Ross Island and Terra Nova Bay with Summertime visible satellite image (image courtesy of Antarctic Geospatial Information Center, University of Minnesota)

BY NICK LOGAN

The use and demand for unmanned aircraft continues to increase rapidly as their benefits become more widely understood. Their ability to gather and disseminate data is valuable to military, civil, and scientific organizations. Equally important is their flexibility, a common characterization that they can take on any mission too dull, dirty or dangerous for manned assets. This definition implies reliable mission execution under unfavorable operational conditions.

It is worthwhile examining the advantages of unmanned aircraft in challenging environments. Valuable lessons have been learned from the thousands of flight hours logged by the Aerosonde small unmanned aircraft system in some of the world's most extreme climates.

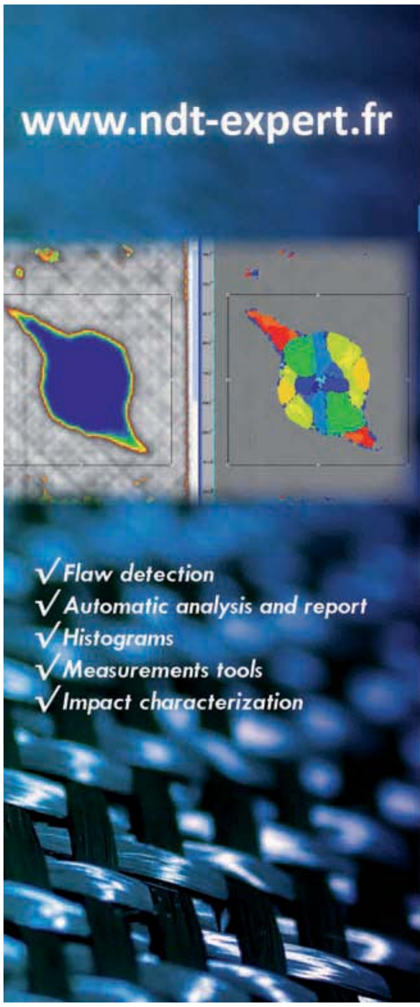
### Small and unmanned

Aerosonde aircraft fall into the small unmanned aircraft systems (SUAS) category based on size and weight. Aircraft in this size class can provide long endurance for sustained research or intelligence missions. They also are favored for the ability to accomplish a wide range of data collection tasks while aloft.

Military customers often use SUAS for intelligence, surveillance, and reconnaissance missions. Their comparatively quiet operation, light weight, and ease of deployment make them a good choice for persistent surveillance.

Civil and research organizations rarely use SUAS solely for the video capture capabilities required by military users. The ability to accommodate a variety of payloads and instrumentation means researchers can capture data including temperature, pressure, humidity, wind speed, and surface profile, in addition to still photography and video. Further, this data can be captured under far more dangerous conditions than could be achieved safely by manned aircraft.

Aerosonde aircraft were designed originally for meteorological research. From the beginning, customers took interest in the safe alternative they provided to manned aircraft. As early as 1998, an Aerosonde was the first unmanned aircraft to cross the Atlantic Ocean. Since then, Aerosonde crews have flown in a variety of challenging scenarios. Between 1999 and 2005, Aerosonde aircraft logged more than 1,000 flight hours of Arctic research, based in Barrow, Alaska. An Aerosonde aircraft, launched from Taiwan, penetrated the eye wall of Typhoon Longwang in 2005, and in 2007, it was the first unmanned aircraft to penetrate the eye of a hurricane. Under a program administered by NASA and the US National Oceanic and Atmospheric Administration, the Aerosonde aircraft flew a mission of more than 17



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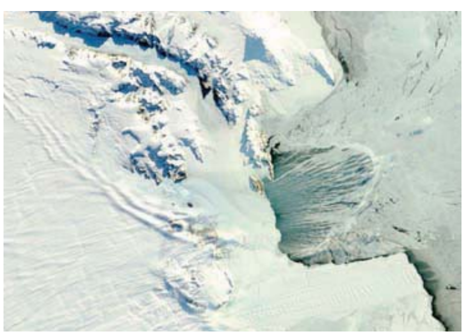

**Above: UAV prior to launch at Pegasus white ice runway. Left: Aerial pictures of Terra Nova Bay, including sea ice and open water September, 2009**

hours, 7.5 of which were spent navigating Hurricane Noel's eye and boundary layer.

In 2009, a crew logged 16 flights (more than 130 flight hours and nearly 7,000 miles) during a six-week University of Colorado exploration of the katabatic winds on the Antarctic coast.

## Product development

Unmanned aircraft may employ a variety of materials for the body, fuselage, and other sections. The Aerosonde aircraft uses composite materials including fiberglass wings and a carbon fiber fuselage. Composite construction is non-corrosive and generally able to withstand a range of moisture and temperature levels. In addition, composites perform well in the high vibration levels experienced during flight.

To minimize possible damage in extreme heat or cold, composites also can be cured during fabrication to increase temperature threshold. Yet no material is ideal; composites can erode eventually during constant exposure to hail or sand damage. Designers weigh these pros and cons to make total value assessments on aircraft materials. Similarly, manufacturers need to consider the robustness of subsystems. They must take advantage of the component manufacturer's knowledge and experience to determine each part's capabilities and limitations, and use parts that are rated for the aircraft's needs.

Onboard electronics can fail in extreme moisture, putting the aircraft at risk for damage or loss. Part ratings help and the aircraft integrator can also coat electronics with a protective layer to prevent malfunctioning. Payload manufacturers are equally diligent with their internal testing and can provide subsystems rated for a variety of conditions.

## Mission planning

Preparation for irregular mission environments frequently begins at home. Depending on budget and time constraints, aircraft can be built for specific missions. Whenever possible, making an advance trip to the location is beneficial. Accurate weather forecasting provides a basis for determining the types of conditions that will be encountered. For fixed-wing aircraft, runway availability and other launch/recovery logistics should be considered, and spares provisioning often is based more on geography than environmental conditions. If adequate spares cannot be sent to the site when required, a full store should accompany the SUAS up front.

A shelter must be available for crew health and safety in extreme weather or temperature conditions and an environmentally controlled hangar is recommended for aircraft maintenance, system checks, and storage. Payload and instrument integration may need special attention. In cases where the customer owns the aircraft, instrumentation may be tightly coupled with the aircraft by drilling additional holes in the body or through other means. With contractor-owned assets, other strategies may be explored.

Aircraft are then tested before reaching the location to verify system operation and integrity. This includes the check of parts, subsystems and overall health, as well as flight testing to verify


aircraft and payload operation. The entire aircraft or its more vulnerable parts may also be subjected to testing in an environmental chamber to simulate performance and possible failure modes under a range of temperature conditions.

**During the project, one UAV was lost due to engine failure**

> **"The aircraft or its more vulnerable parts may also be subjected to testing in an environmental chamber"**

## In-field checks and maintenance

Pre- and post-flight care does not need to be customized for environmental conditions because the same level of detail is required before and after any flight. Checks include a number of factors.

Separate inspections take place for the engine, avionics, mid-bay, assembly, runway, and payload. Several of these are checked both before and after the engine is powered up. The aircraft is also inspected from nose to tail. Vulnerable parts such as the wings are visually inspected for abrasions. Small parts such as nuts and bolts are tightened because they are subject to such intense vibration in flight. Fuel and oil levels are adjusted as needed; batteries are charged, and control sites, where data will be received from the aircraft, should be verified for connectivity.

Whenever possible, inspections should take place in a temperature-controlled hangar to mitigate the risk of operator error in harsh conditions and limit the tendency of composite materials to expand and contract in variable temperatures.

Maintenance regimes are not necessarily affected by surroundings. However, climate can dictate where crew members may need to pay special attention; sensitive areas include: the carburetor, which may become unreliable in cold weather and must be addressed with a fuel injection system or blended fuel; the fuel pump, where condensation can build in high-moisture areas and freeze in extreme cold; electronics, which are vulnerable to moisture; cameras and other payloads/instrumentation, which bear the vital burden of data collection in all weather conditions; and also wings and engines.

## The value of experience

There is no more critical preventive measure in extreme conditions than applying the most skilled, experienced people possible to each task.

An aircraft operator launches and lands the aircraft, and executes the required mission plan. The ideal operator has completed missions successfully under all types of environmental conditions, and can anticipate and take preventive action against hazards. He, or she, is unlikely to be thrown by unexpected issues mid-flight, and can quickly and calmly assess the situation and take corrective action.

This also is true of payload operators, whose job is to manage onboard instrumentation to ensure the necessary data is being captured during the mission. Under extreme environmental conditions, the ability of cameras or other sensors to capture information may be weakened, and opportunities to attempt additional flights limited. Previous experience under a variety of flight conditions can be invaluable. In addition, an experienced crew brings the knowledge to make go/no-go recommendations. Most frequently, a component in questionable shape always should be replaced and tested prior to additional flights. However, a crew member with extensive knowledge of the system can evaluate environmental conditions, the availability of additional flight time and spares, as well as the comparative life left in the component, and may decide that the best course of action is to execute the mission and make the repair later.

Experience level can make the difference between bringing the aircraft home and losing it to the elements, or ending the mission without the needed data.

With mission planning, rigorous testing, and maintenance, unmanned aircraft systems are a tremendous data collection resource, especially under extreme conditions of weather and temperature in which crew members remain safe and sheltered. ∎

*Nick Logan is a technical support manager at Aerosonde Pty Ltd, Victoria, Australia, a strategic business of AAI Corporation. He is responsible for more than 2,000 cumulative flight hours unmanned aircraft testing and operation. Web: www.aerosonde.com*

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# Off the blocks

THE RQ-4 GLOBAL HAWK UAS PROVIDES INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE FOR THE MILITARY. IT IS NOW TESTING ITS UPGRADED TURBINE ENGINE AND HAS COMPLETED ITS BLOCK 40 CONFIGURATION MAIDEN FLIGHT

BY CHRISTOPHER HOUNSFIELD

The Global Hawk first took off in 1998. Since then it has gone through a metamorphosis. The latest innovation is the AE3007H growth engine, the power plant for the RQ-4 Global Hawk high-altitude, long-endurance (HALE) unmanned aircraft system (UAS), which is currently undergoing testing in Arnold Engineering Development Center's (AEDC) T-4 test cell.

The AE3007H features upgraded turbine hardware and an improved combustor that, if validated by this project, will give the engine greater service life.

According to Andrew Jackson, Aerospace Testing Alliance's (ATA) project engineer on the test: "The new turbine and combustor are intended to provide increased hot section life, (i.e. longer intervals between overhauls), while maintaining comparable performance levels as the current hardware. The key parameters that we simulate in the test cell are altitude and Mach number.

Gary Meuer, ATA's project manager on the test, adds: "This is the first altitude test on this specific growth engine. They – the customer and sponsor – are after fuel economy; not more performance, but more efficiency and endurance."

In 2004 and 2005, AEDC engineers, including Jackson, conducted ground testing of the AE3007H engine in T-4.

The test at AEDC is taking place as unmanned aircraft systems are playing a more

> "This is the first altitude test. They are after fuel economy; not more performance, but more efficiency and endurance"


prominent role in Iraq and Afghanistan, and other countries are considering buying the Global Hawk for their own air forces.

## Block 40

It was in December 2009 that Northrop Grumman announced that the first Block 40 configuration of the RQ-4 Global Hawk had successfully completed its maiden flight. Designated AF-18, the advanced-capability aircraft flew for approximately two hours from the company's manufacturing facility in Palmdale, to Edwards Air Force Base in California.

"AF-18, the eleventh of the next-generation Global Hawk Block 20/30/40s to arrive at Edwards Air Force Base, performed beautifully," says George Guerra, Northrop Grumman

## Unique craft

One of the attributes of the Global Hawk UAS is the autonomous nature of the system. Once mission planning has been completed, the air vehicle can taxi with the aid of a small forward-looking camera. Once positioned on the runway, a simple push of an 'execute' button from the launch and recovery element sets the pre-programmed mission in motion. The air vehicle from this point onward will fly its complete mission without the need of any intervention unless commanded. During a mission, the sensor operator in the mission control element can operate any of the myriad systems loaded on board. These systems can gather information and transmit it to the mission control element in real time, or the information can be stored on board the air vehicle for download after landing. Mission re-tasking while aloft is easily achieved by entering new waypoints into the mission flight program.

vice president of HALE systems. "This flight marks the continuation of our Global Hawk flight test program, and is a testament to the team comprised of people from Northrop Grumman and the Air Force, who have worked so hard to make this happen."

The first flight also marks the end of an era, as Global Hawk production acceptance activities will transition in the near future from Edwards Air Force Base to Air Force Plant 42 in Palmdale, which according to NGC will improve efficiency and flow of company products. In addition to AF-18, a Block 30 aircraft, AF-19, was recently delivered to the US Air Force and is one of 11 major deliveries by the program within the last three months.

Steve Amburgey, Global Hawk program director for the 303d Aeronautical Systems Group at Wright-Patterson Air Force Base, Ohio, noted that the flight of this aircraft is a milestone for the Global Hawk program. "AF-18 is the first of 15 Block 40 Global Hawk aircraft scheduled for fielding to Grand Forks Air Force Base, North Dakota, in 2010," he explains. "The aircraft will carry an advanced, all-weather multi-platform radar technology insertion program (MP-RTIP) sensor, providing game-changing situational awareness for our warfighters with its unprecedented capability to detect, track and identify stationary and moving targets." Global Hawk's range, endurance and large payload capabilities are well suited to provide persistent surveillance of the enemy with MP-RTIP. Flying at altitudes up to 60,000ft for more than 32 hours per sortie at speeds approaching 340kts, the MP-RTIP-equipped Block 40 Global Hawk can persistently see through most types of weather, day or night.

As the world's first fully autonomous HALE UAS, Global Hawk is the platform of choice for a wide variety of sensors, foreign and domestic, meeting the global need for persistent ISR.

## Airworthiness certification

The USAF has also recently granted the RQ-4 Global Hawk a military Airworthiness Certification (AWC), another milestone in the life of the aircraft system and a step on the path to routine unmanned flight within the USA.

The AWC process verifies that an aircraft design has met performance requirements within the mission profile to safely fly in national airspace, and assures operators and mission managers that the production articles conform to the design. In granting the certification to RQ-4, the next generation of Block 20 and 30 Global Hawk UAS, the USAF has recognized the aircraft's ability to routinely fly safely within design parameters. The certification process evaluated more than 600 airworthiness criteria.

"This was a more rigorous and more complete evaluation than that of any other unmanned system," said George Guerra, vice president of HALE systems for Northrop Grumman. "With this historic accomplishment and more than 35,000 total flight hours, most of that time in combat support over the skies of Iraq and Afghanistan, Global Hawk continues to be a trailblazer in UAS certifications and a pathfinder supporting our men and women overseas in combat."



Left: Euro Hawk during its unveiling ceremony October 8, 2009 in Palmdale, California

Just as commercial aircraft are certified by the Federal Aviation Administration (FAA), military aircraft are evaluated against certain criteria including durability, capability to adjust to sudden changes in aerodynamic forces, and redundancies of systems and subsystems. Without this Air Force certification, the FAA cannot grant permission to fly within the United States, which is the next step in the ongoing process to accept the routine flight of unmanned aircraft in the national airspace.

"This certification resulted from a large collaborative effort between the government and the contractor, agreeing on standards and verification methods and ultimately coming together on the assessment of the system. With its Advanced Concept Technology Demonstration legacy design and early push to support Overseas Contingency Operations and U-2 retirement, this was the first

Above: Block 20 Global Hawks taken during first flight back in March 2007

> "Global Hawk was designed from the start to be a 'spiral acquisition' program introducing new technology as it matures"

comprehensive assessment of the aircraft to ensure it is ready to fly in national airspace and ready for the user to train with at Beale AFB," says Yvette Weber, chief engineer at the 303d Aeronautical Systems Group.

The certification is the latest success for the Northrop Grumman Global Hawk program. In 2006 the Block 10 version – or RQ-4A – made history when it became the first UAS to earn both a military airworthiness certification and a national certificate of authorization to operate in the national airspace. The airworthiness certification covers all Block 20 and Block 30 Global Hawks delivered to the US Air Force so far.

Global Hawk flies autonomously at altitudes of more than 60,000 feet, above inclement weather and prevailing winds, for more than 32 hours at a time. The first-generation experimental Global Hawks deployed overseas to the Persian Gulf less than two months after September 11, 2001. Since then, Block 10 Global Hawks have been flying nearly continuously, supporting combat operations in the region. The Block 20 and 30 systems, capable of carrying 50% more payload with improved sensors, are scheduled to begin operations with the US Air Force at Beale Air Force Base, California, and at several overseas locations, next year.

The Block 20 aircraft system was recently chosen to be modified with special communications relay equipment to support coalition combat forces in Afghanistan. The Block 30 Global Hawk carries sophisticated imaging and electronic signals sensors on missions that can exceed 30 hours. A similar certification will be granted in the near future for the Block 40 system, which is based on the same aircraft design of Block 20 and 30 but carries an advanced radar imaging and ground moving target tracking system used to track enemy movement, regardless of weather conditions on the ground. There are four Global Hawks currently deployed by the US Air Force and US Navy, which have flown more than 30,000 combat hours in the Middle East.

## A look ahead

Because of Global Hawk's success domestically and abroad, it has become the top urgent operational need requested by field commanders, and not just with US forces. As such, two Global Hawk Block 20s will be modified with the Battlefield Airborne Communications Node (BACN) Joint Urgent Operation Need (JUON) system payload, and deployed by the end of this year. As Loochkartt explains: "Part of the Air Force's Objective Gateway program, BACN is an airborne gateway and communications relay system that enables warfighters to rapidly share data and information gathered by multiple users across multiple dissimilar systems present within the battlefield."

Loochkartt clarifies the international adaptations: "Our first international configuration, called Euro Hawk, for the German Ministry of Defence, will fly its maiden flight this summer (June/July 2010) followed by a ferry flight to Germany by the end of the year. Our two NASA Global Hawks will also fly their first environmental research missions this summer."

Global's metamorphosis is ongoing, as Loochkartt explains: "Global Hawk was designed from the start to be a 'spiral acquisition' program introducing new technology as it matures and, thus, always making the system better and more capable. This means that the design and engineering continues throughout the life of the program at a fairly rigorous rate. Depending on customer requirements and need, there may be additional configurations in the future." ∎

# Superiority complex

## A STRUCTURAL TEST FACILITY IN THE NORTH OF ENGLAND TOOK RECEIPT OF A SECOND F-35 AIRFRAME. IT IS NOW EMBARKING ON ONE OF THE MOST COMPLEX FATIGUE TEST PROGRAMS UNDERTAKEN BY ANY FACILITY IN THE WORLD

BY ALAN GEORGE

The second Lockheed Martin F-35 has now been delivered to the BAE Systems test facility in Yorkshire, UK for a series of detailed and intricate structural and fatigue tests. It follows a month-long sea voyage across the Atlantic from Fort Worth Texas.

The test article designated AJ-1 was shipped from the USA directly into Hull docks in the UK and then transferred to a barge to continue its journey up the Humber to the river bank bordering the Brough, East Yorkshire site.

Using a specialized mobile crane with a reach of 90m, it was lifted off the barge and into the site itself. Internal transfer from the crane location to the test hall was via a four-axel extremely maneuverable Mammoet powered trailer. The trailer was used to maneuver the test article into the test hall, at times leaving only millimeters clearance around the wing tips. This required all of the Mammoet trailers maneuverability and the skill of the operator to negotiate other test rigs and a rotation through 90º to be brought to rest in front of the test fixture. The whole logistical exercise was only made possible with the co-operation of Lockheed Martin in Texas, CEVA the logistics team, Mammoet the crane provider, and the Brough team including skills from site facilities, and structural tests.


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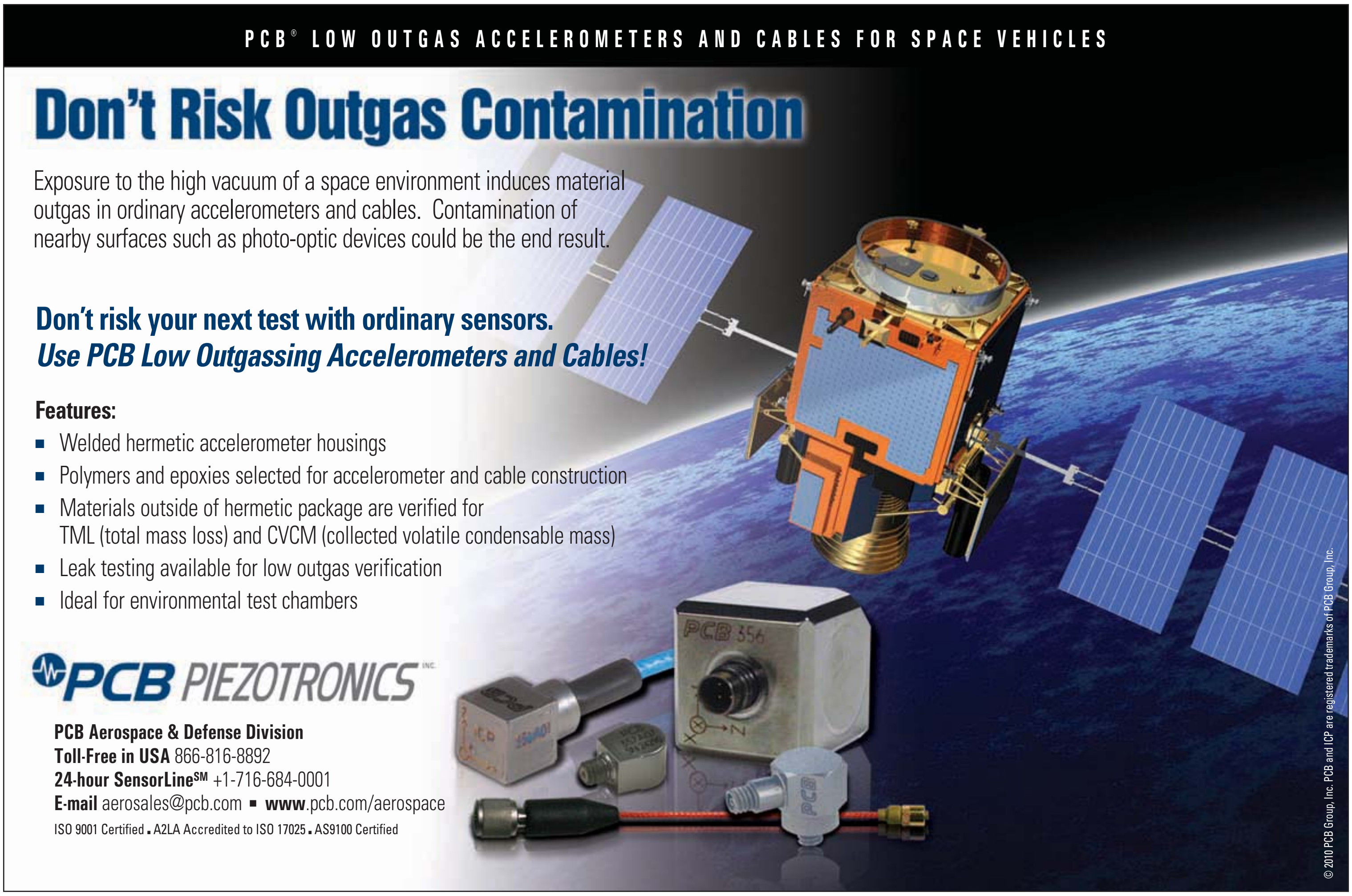
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It was an international effort to bring the F-35 airframe to Brough, showing the importance of the Structural Test Centre, which now houses some of the most advanced major airframe fatigue tests in the world.

The test article, a Conventional Take-Off and Landing (CTOL) variant of the F-35 Lightning II, is destined for the fatigue test program due to commence this year. The test will be carried out by BAE Systems as part of the work share agreement between itself and Lockheed Martin, and will be one of the most complex fatigue tests undertaken by BAE Systems and by any test facility in the world. Hydraulic actuators will apply the service loads to the airframe using state-of-the-art control system technology to ensure safety of the specimen and operators is maintained at all times.

## Service life analyses

The structural fatigue test on the F-35 CTOL airframe forms part of the structural certification in support of the service life analyses, and the demonstration of airframe fatigue compliance. This airframe designated AJ-1 is an instrumented fully production-representative version, which will be subjected to two lifetimes of cyclic spectrum fatigue loading. Minor modifications have been made to the airframe to allow for load introduction fittings and various exit locations for instrumentation wiring. Loads will be applied to the airframe using an optimized loading arrangement. The sequence is flight-by-flight, contained in repeated 1,000-hour blocks. Each flight contains randomized cycle-by-cycle loadings in correctly ordered flight segments (taxi, take-off, etc). Upon completion of all testing activities, the test article will be returned to Lockheed Martin Aeronautics in Fort Worth.

The purpose of the fatigue test is to demonstrate that the economic life of the CTOL variant is equal to or greater than the design service life when subjected to the design service loads spectrum. It will also provide strain gauge data for structural health monitoring of the airframe in service, providing a basis for establishing special in-service inspection and modification requirements. Some modifications to the airframe structure have been introduced to allow loads to be applied to the airframe through 'dummy' structures (horizontal tail, engine, etc). Strain gauges identified for the durability test article have been installed during the build sequence.

Aerodynamic and inertia loads will be applied to the test article using hydraulic actuators connected to the airframe via dummy components and loading linkages. These linkages have been designed to distribute the load accurately to achieve the required shear, bending moment and torsion distributions, without adding structural stiffness to the fatigue test article. Linkages are in general, tension/compression stable. The linkages are attached to the airframe via neoprene rubber pads bonded to aluminum backing plates and bolted fittings. To remove the mass effects of the horizontal hydraulic actuators and loading linkage, mechanical counterbalances have been provided. The masses of vertical loading systems are counteracted via tare loads from the relevant hydraulic actuator when the test is powered up.

# Vertical landing

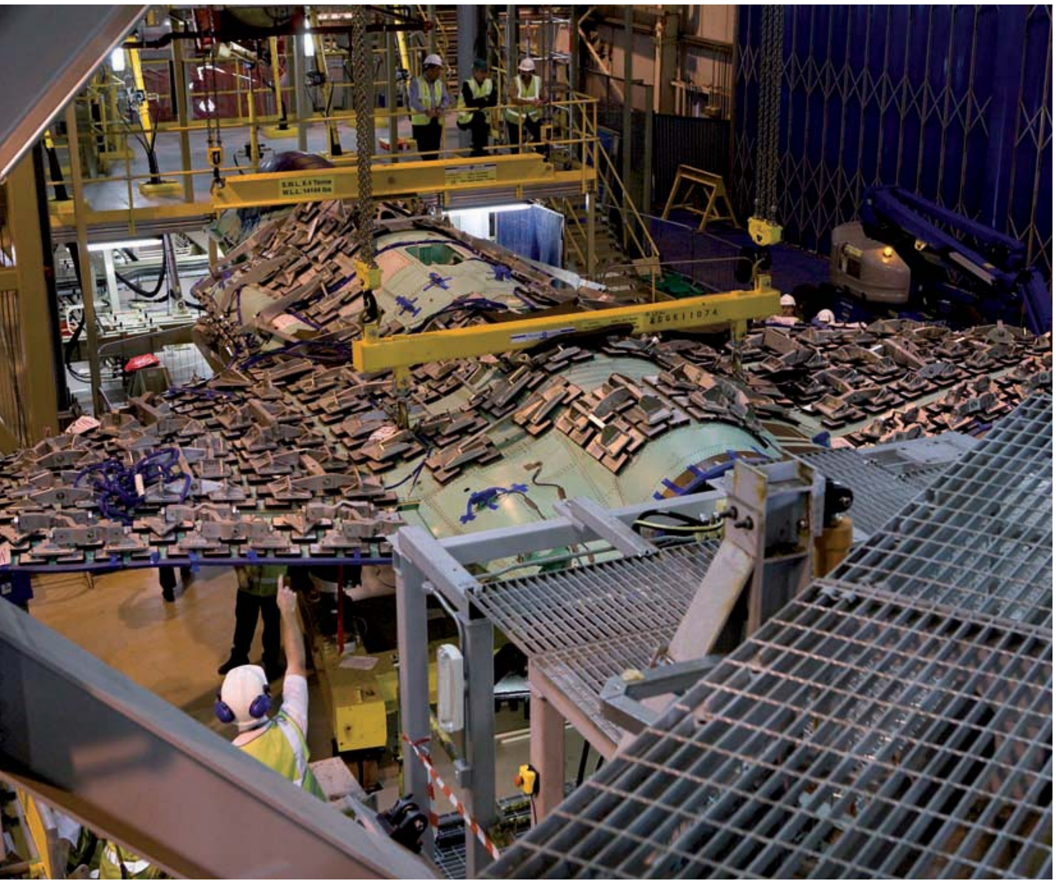
As February 2010 drew to a close and the historic snowfalls on the East Coast of the USA began giving way to fairer weather, the first F-35B short takeoff/vertical landing (STOVL) test aircraft began the final handful of flights leading to a vertical landing. Planned missions included progressively slower (down to 60kts), semi-jet-borne flights around the airfield pattern at Naval Air Station Patuxent River, Maryland, 100kt short takeoffs and 70kt slow landings. BF-1, as the first F-35B is known internally, ferried to Pax River in November from its assembly point at Lockheed Martin's Fort Worth, Texas, plant. It was joined in November by BF-2, and by BF-3 in February.

Two more STOVL F-35Bs will ferry to Pax River this year, but BF-1 is the aircraft most intensely focused on validating STOVL flight performance. As of February 19, it had completed 36 flights, six of those with the STOVL propulsion system engaged. On January 7, F-35 Lead STOVL Pilot Graham Tomlinson of BAE Systems engaged the STOVL propulsion system in flight for the first time, and on February 17 he conducted the first slow landing (130kts), with the lift-fan operating and the 3-bearing swivel nozzle deflected.

The first vertical landing appeared to be imminent as the last week in February ticked by, and crucial STOVL-mode flights were completed. The first vertical-landing flight most likely will include a short takeoff, followed by low-speed jet-borne flight to confirm performance. Tomlinson will then accelerate to about 150kts then reduce speed to the point of hovering over the airfield. From that point, about 150ft above the ground, he will command the F-35 to descend to the runway vertically. It will be the first of many vertical landings for BF-1, which will validate the F-35B's ability to operate from ships and from confined, austere land bases.

BF-2, which so far has completed 20 flights, is poised to begin envelope-expansion missions at Patuxent River, while BF-3 (six flights to date) will be used mainly to evaluate vehicle systems and expand the aircraft's structural-loads envelope. BF-3 also will focus on weapons testing, and will carry and release most of the ordnance the F-35B will use in combat. BF-4, planned for an early-spring arrival at Pax, will be the first avionics-equipped F-35 and will perform the initial on-board flight testing of the F-35's mission systems, which are essentially 100% common across the three variants. Extensive mission systems testing, including sensor fusion and SAR mapping, already has occurred on the Cooperative Avionics Test Bed, a converted 737, and on surrogate airborne laboratories and in ground-based labs. The final F-35B test aircraft, BF-5, will ferry to PAX later in the year, along with the F-35C carrier variants, CF-1, CF-2 and CF-3.

AJ-1 specimen lifted from the installation trolley ready for the transition into the test frame



The fully padded airframe AJ-1 ready to be lifted into the test fixture

# Take the strain

F-35 Lightning II Conventional Take Off and Landing AG-1 and AJ-1 full airframes are sitting comfortably inside the structural test facility in Brough, UK. BAE Systems' Structural Test Facility is a very busy place, having taken in two F-35 Lightning II airframes in 2009.

The centre of excellence at the facility houses some of the most advanced airframe fatigue tests in the world, providing evidence that airframes meet the design requirements for structural strength and durability.

The test airframes arrived after a month-long sea voyage across the Atlantic from Fort Worth, Texas to Hull docks and then a journey up the River Humber, arriving at Brough site to be safely lifted off the barge using a 90m mobile crane.

The F-35 Lightning II AG-1 airframe has commenced its latest testing having completed three of the five phases of tests it will undergo during its 15-month stay in the facility. The airframe is connected to a highly complex test rig in which 165 hydraulic actuators are replicating the loads the aircraft will see in flight, certifying the strength of the airframe and its components. The data from the testing is being captured from the 4,000 sensors that are bonded to the airframe, 53 miles of wiring spread connected to the systems and sensors, with the rig itself weighing 365 tons.

AJ-1 airframe will commence its fatigue tests early this year, being subjected to two lifetimes of cyclic testing during its stay. Loads will be applied to the airframe using an optimised arrangement of sequence through flight by flight 1,000-hour blocks. Each flight segment load will try to reproduce a taxi run, take-off and flight in sequence.

The purpose of the durability tests is to demonstrate that the economic life of the F-35 Lightning II CTOL variant is equal to or greater than the design service life when its is subjected to such rigorous load testing. The durability tests also provide data for the structural health monitoring of the airframe in service, providing a basis for establishing special in-service inspection and modification requirements.

On completion of the tests, both airframes will be shipped back to the USA.

The airframe, loading systems and control/data acquisition hardware will be located within a self-reacting test frame. The frame will provide the restraint of the test specimen and the connection of the test loading systems. This loading arrangement distributes the load across the airframe, duplicating the aerodynamic and inertia load experienced by the structure and system hardware in flight and ground-operating modes.

## Total control

Control of the hydraulically applied test loading is by a digital, closed loop, multi-channel servo control system supplied by Moog Control Systems (FCS). This is a standardized system employed across all BAE Systems' major fatigue tests. The test controller is integrated with the data acquisition system so that specific data logging actions can be carried out automatically. The design of the system accommodates the test being run 'unattended' for 24 hours, seven-days a week, in between inspection/maintenance stand-down periods, providing significant cost savings.

Loads in each of the test article supports and reaction locations will be monitored via dual bridge load cells and compared to those provided in the test spectrum. Fuselage and fuel tank pressures will be controlled and monitored by dual-pressure transducers. The control system will be linked to the hydraulic and pneumatic power supply facilities to provide the test operator with remote start and stop and status data. A comprehensive safety system is embodied as part of the controller so that in the event of any system malfunction the load is removed under full system control without risk to the specimen. The data acquisition system (DAS) utilises HBM data logging equipment. The DAS is linked with the test control system such that specific data logging actions may be undertaken manually or automatically during the test programme. This link also permits the DAS to undertake 'watch-dog' duties.

With a capacity of 2,000 channels, the DAS is configured to log strain gauges, displacements, and loads. The Control-DAS link will also be used to record the applied loads, reaction channels, fuel tank pressures and spectrum position. The system is also able to log all parameters either statically for any selected balanced load case, or dynamically during fatigue cycling. The system can log all channels at a rate high enough to capture peaks with the test running at its maximum anticipated speed.

The next stage is to ensure the test rig and fuselage support structure hardware are ready to accept the test article, and that the test article is assembled with loading linkage and wiring prepared in loomed bundles, then the test article can be lifted into the test frame. The lift into the test frame will take place over the next few weeks. Full test rig configuration and commissioning will lead into strain surveys and the start of the fatigue spectrum cycling early in 2010. ∎

*Alan George is the project manager on the F35 CTOL full scale fatigue test in the UK*

# Measure for measure

THE SCIENCE OF MEASUREMENT IN THE AEROSPACE INDUSTRY IS VITAL. HERE'S HOW TO OVERCOME THE CHALLENGES OF LARGE VOLUME METROLOGY

BY PETER BOORNE

The aerospace industry is constantly looking for ways to improve efficiency and cut costs without compromising quality, but pressure to get products to customers quickly and stringent quality controls make this difficult. However, there is a growing view in the industry that the manufacturing and testing process could benefit dramatically from improving skills in metrology, the science of measurement, and in particular large volume metrology (LVM).

LVM is the measurement of objects with typical dimensions from one meter to several tens of meters. Various processes are used to produce 3D images that can be analyzed to ensure they meet design criteria.

LVM is at the heart of aerospace manufacture, underpinning every stage of the production and testing process from design through to final inspection. It is vital for ensuring that parts can be properly and safely assembled and, in many cases, optimally designed for flight. Small differences in size and shape can make a big difference to aircraft efficiency, and because of the safety critical nature of aerospace, small errors can be costly to rectify.

Despite its importance, many of those involved are content with using a few pieces of measurement equipment without understanding the process or what they are trying to achieve. But it is an area which, with proper knowledge and understanding, has the potential to improve efficiency, reduce lead times, and ultimately save companies money.

Stephen Kyle, an honorary senior research fellow at University College London (UCL), and a leading authority in LVM, explains that, "Different areas of testing require different skills.


Large components involved in industries such as aerospace and defense require a particular understanding of specific measurement principles, methods, and associated unique instrumentation. Its successful application is heavily dependent on its proper understanding."

This is particularly important when measuring large objects such as wings and fuselages, because the conditions of a factory floor are much less forgiving than those of a laboratory. As a result, fundamental mistakes are often made.

Having in-depth knowledge in these areas gives manufacturers several advantages, Kyle says. It allows them to choose the best instruments and techniques, develop the optimum measurement strategy for each different scenario, confirm traceability of their measure-

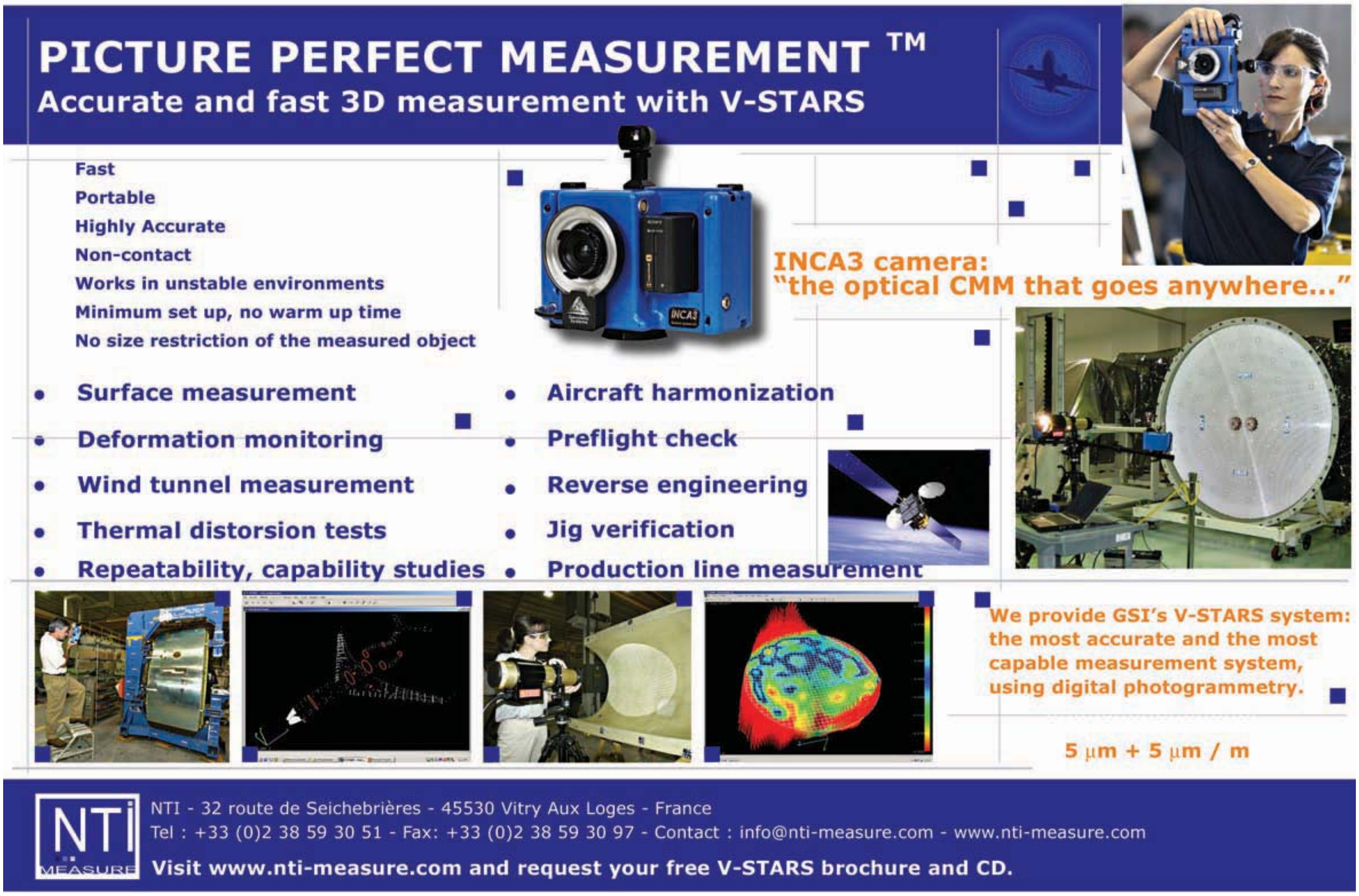
## The LVM training program

In November 2009 the National Physical Laboratory (NPL), the UK's measurement institute, addressed calls from the industry and launched the world's first independent training program in large volume metrology.

Until now, this type of training has been largely developed in-house, with no independently recognized courses available. These courses tended to focus on using specific pieces of equipment, rather than broad understanding of the processes. NPL's new modules fill this gap, providing a framework that can be rolled out internationally to meet the LVM needs of industry.

Participants in the program learn to question, understand, and plan the best way to measure, beyond simply being able to use the equipment. This allows employees to build in systems to the manufacturing process, reducing errors and waste, and improving quality control and accuracy. The ultimate aim is to help testing businesses increase productivity, reduce waste, and respond to their customers more quickly.

The program was developed with academics and manufacturers including Airbus UK, Rolls-Royce, and Boeing. It builds on the success of NPL's dimensional measurement training program, which has led to huge efficiency gains across the UK's manufacturing industry.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ments back to the primary standard, and identify where problems lie when something goes wrong. Perhaps most importantly it reassures customers that the company understands what it is doing.

## A structured approach

Keith Bevan is the training development manager at the National Physical Laboratory (NPL), the UK's national measurement institute. He explains, "People don't always approach LVM with a structured strategy. They know how to use their particular measuring equipment, but they don't always understand the implications of a poor strategy. They need to start to question, understand, and plan the best way to carry out measurements. If they don't understand the process, how can they trust the results?"

Researchers must also know whether the machine they are using is the most appropriate to the task, whether it is being used in the most effective way, and how it could be affected by outside factors.

The first step is to know the tools. "Look at what you want to achieve," says Bevan, "and then select the most appropriate tool for the task. Over larger areas, indoor GPS is proving more accurate than the traditional laser tracker. Then again, if you just want to map your shop floor to plan how to move things about, there's no need to use your most precise piece of equipment."

A welcome side effect of good measurement planning could mean the difference between a piece of equipment lasting five or 10 years.

Next, testers need to understand how to use the equipment. Take the example of laser trackers, one of the most important pieces of LVM equipment. Bevan says that, "Despite their prevalence, laser trackers are a technology where structured, guided learning is essential to using them effectively. Poor tracker location, unstable mounting, bad environment, or poorly chosen reference locations all can – and do – lead to measurement errors."

Another example is triangulation systems, such as indoor GPS, used to measure large objects such as aeroplane wings. Often such measurements are taken at a series of angles and the result trusted. But taking measurements at specific intersection angles will result in smaller spatial errors, and taking multiple measurements will average out errors, giving more reliable results.

However accurate the technology and the plan, mistakes will be made. A proper understanding of how the equipment works will help identify likely errors early on.

## The right environment

LVM also presents challenges due to the scale of the equipment and the environmental issues created by having to measure outside the laboratory. Materials expand when heated and shrink when cooled. Thermal gradients influence large objects, usually the top is hotter than the bottom, though this may also occur across a structure as a result of heat radiating from a window or steel door.

Dimensional measurements in a laboratory should ideally be made at a standard

A metrologist using T-scan – The aircraft engine housing is being surface scanned by a handheld Leica T-Scan, which is being tracked Laser Tracker + T-Cam. The tracker is locating one of the retro-reflectors (in silver cylindrical housings) in 3D and the T-Cam (zoom camera) is detecting the angular orientation of the scanner from an image of the LED targets

## Case Study: Airbus UK

Amir Kayani is a manufacturing engineer for Airbus UK and is responsible for looking at new processes and technology to reduce time and costs for Airbus's manufacturing processes. In 2009, he identified a lack of formal metrology training for objects over 10m and realized that establishing such training could aid the industry. Having seen the benefits of NPL's dimensional measurement training, he approached NPL to suggest they establish a large volume metrology course.

The course was developed throughout 2009. Airbus is now involved in the pilot studies, and hopes to put most of its staff involved in LVM through the course this year. "What we want to achieve," says Kayani, "is harmonization of our LVM processes. We want staff to better understand the science behind instrumentation and analysis, and approach each task with a strategy. This will allow them to find the most appropriate solutions and develop best practice methodologies."

This, he hopes, will enhance competence across the manufacturing staff, speed up problem solving, improve lead times, and reduce wastage. "If manufacturers know the different methods and technology, they can optimize the process to ensure better cost and delivery results."

Airbus has a policy of ensuring that if one site develops a specific competence, their other sites should be able to benefit from it. Ultimately Kayani hopes that the training will prove such a success that it will be rolled out to all Airbus's European sites to benefit the whole organization.

# Tools of the LVM

Laser tracker is an optical device that follows the movement of a target reflector on the measured object being tested to make three dimensional measurements.

Indoor GPS: an array of infrared rotating laser fan beam transmitters surrounding the measured object. Receivers sense the passing beams and calculate their position from the beam angles. iGPS is an alternative to laser tracker, suited to measurements over 10 x 10m.

Articulated arm: a fixed mechanical arm with a probing device or sensor at the end to take measurements from close range. It is suited to measuring points that are not easily accessible and interior space measurements as well as scanning and digitizing surfaces.

Laser radar: an infrared laser ranging beam is scanned across an object surface to determine the 3D coordinates of the surface points. It is a straightforward non-contact application for inspection of aircraft component manufacturing and assembly.

Photogrammetry: a sensing technology which determines geometric properties from photographic images using trigonometry. It is possibly the oldest tool in the LVM toolbox and well optimized for tasks such as measuring in unstable environments and dynamically changing situations involving vibrations, deformations and moving monitoring platforms.


Above: Leica laser tracker used by Airbus at the Toulouse manufacturing site


Below: At the Airbus delivery centre in Hamburg, Germany, the Air France A380 takes off for Paris

reference temperature of 20°C. This is not always possible when assembling an aircraft, but maintaining a constant temperature, or as close as possible, across the measured object is still important. Stephen Kyle says that there are simple procedures that can help, but they are not always followed: "By keeping doors closed, allowing the room to reach a stable temperature, and eliminating heat sources, manufacturers can vastly improve the effectiveness of their measurement run. Laser tracker beams, for example, can be greatly affected by radiation emitted from heat sources." Dust and other airborne particles can also cause problems. It is hard to completely eliminate it, but by keeping surfaces free of dust by regular cleaning, the risk of errors can be reduced. Strategies should also be adopted to avoid vibrations during measurement, such as securing parts that might move and taking multiple measurements to allow for discrepancies.

> "By keeping surfaces free of dust by regular cleaning, the risk of errors can be reduced

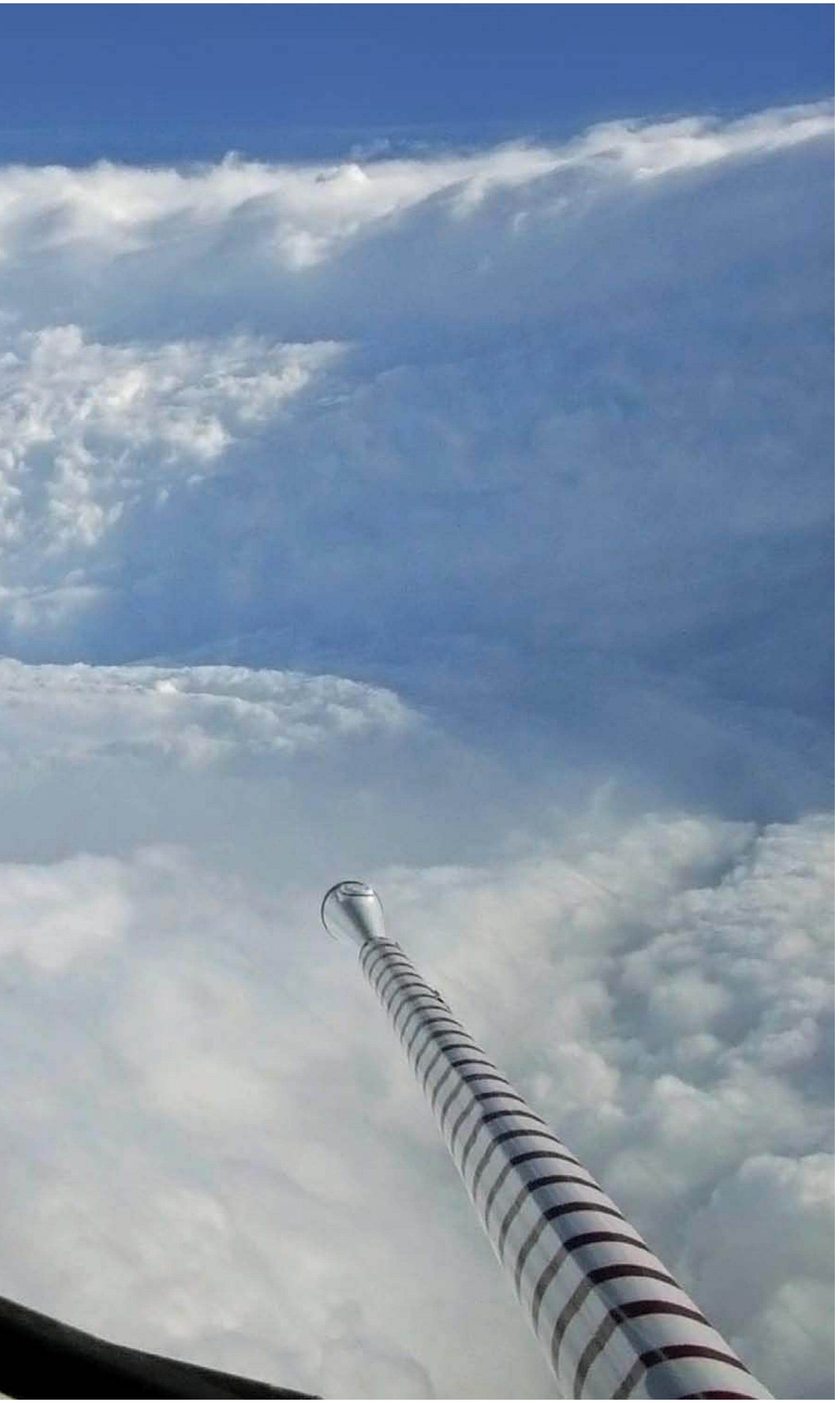
## Gaining the edge

The consequences of not getting measurements right include loss in efficiency and higher costs. In the worst case scenario, it can lead to costly mistakes such as producing parts that don't work as intended, leading to delays and wasted money while the parts are remade or adjusted. Amir Kayani of Airbus UK is one person who realized the potential of better LVM practices and sought a solution: "LVM is critical to the high quality and safety of our aircraft so naturally we take it very seriously. We have been aware for a while that better understanding of LVM among our employees could improve lead times and efficiency while continuing to meet our stringent quality requirements.

"But until now, there were no formal training programs available to address this. Over the last year we have been working with NPL and others to help develop such a program. We are currently taking part in pilots, and are looking forward to seeing big improvements in large volume metrology in 2010." ∎

# The storm chasers

SPECIALLY EQUIPPED AIRCRAFT FROM THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION FLY DIRECTLY INTO HURRICANES TO OBTAIN ESSENTIAL SCIENTIFIC DATA. TOUGHEST JOB IN AVIATION? THE TEAM EXPLAINS



**The WP-3D Orion flies through the eyewall of Hurricane Katrina, August 2006**

BY CHRISTOPHER HOUNSFIELD

Crashing through the awe-inspiring eyewall of a hurricane, buffeted by howling winds, blinding rain, hail and massively violent up- and downdrafts, the Hurricane Hunters are aircraft that fly into tropical cyclones in the North Atlantic Ocean and Northeastern Pacific Ocean for the specific purpose of directly measuring weather data in and around those storms.

The prime aircraft is the Lockheed WP-3D Orion, the latest variant of the P-3 Orion used by the Aircraft Operations Center division of the National Oceanic and Atmospheric Administration (NOAA). Only two of these craft exist, each incorporating numerous features for collecting weather information. During hurricane season, the WP-3Ds are deployed for duty.

The WP-3Ds are equipped with three weather radars – C-band radars in the nose and on the lower fuselage, and an X-band radar in the aircraft's tail. They are also equipped with dropsondes, temperature sensors, and other meteorological equipment. The aircraft are not specially strengthened for flying into hurricanes, but their decks have been reinforced to withstand the additional equipment load.

NOAA currently operates two WP-3Ds nicknamed Miss Piggy and Kermit, and it is currently in the process of acquiring a third. The other high-altitude hurricane-hunting aircraft is the Gulfstream IV-SP, nicknamed Gonzo.

The NOAA Hurricane Hunters work under the Aircraft Operations Center (AOC), located at MacDill Air Force Base in Tampa, Florida. The AOC is under the Office of Marine and Aviation Operations (OMAO). It is a small but dedicated team, and their methods of keeping their aircraft are best described by the leaders. Greg Bast is the aircraft production controller and a WP-3D flight engineer. Commander Carl Newman serves in two capacities: he is one of the five P-3 Hurricane Hunter pilots and currently serves as an aircraft commander for P-3 missions. Moreover, he is the maintenance officer, responsible for the 13 aircraft. He also spends a significant amount of time acting in a budgetary, planning, and acquisition role.

## How is the team made up?

*Bast:* Air crew consists of an aircraft commander, one or two additional pilots, one or two flight engineers, a flight director (meteorologist), a navigator, three or four electronics technicians, and two to six scientists. Exact numbers depend on the mission profile.

## What is the role of the Hurricane Hunter?

*Bast:* With the availability of satellite imagery we don't really 'hunt' hurricanes any more. We already know where they are. Our job at the National Oceanic and Atmospheric Administration Aircraft Operations Center is to provide and equip airborne platforms that can be used by scientists from the Hurricane Research Division and also the National Hurricane Center.

*Newman:* There are two distinct paradigms in hurricane hunting. The first is reconnaissance or surveillance, which serves to answer the 'where is it, how strong, what is the pressure, winds, how much water, and how are the high-level winds affecting the storm?'. The second is research, mainly performed by our P-3s. Research is currently oriented toward gathering the information for the various prediction models. The goal is to increase the accuracy and lead time of hurricane path and strength predictions. While the P-3 can serve in any role except for high-altitude surveillance, our current mission is mainly to map convection with our tail Doppler radar.

## You have various types of aircraft. Can you describe what each does, and how the types fit the role?

*Bast:* Our WP-3 aircraft are involved in atmospheric research; mostly severe weather, but they also do air chemistry missions. Our Gulfstream IV-SP is also an atmospheric research aircraft. It is involved with high-altitude research.

We have four Twin Otter (DeHavilland DHC-6-300) aircraft that are involved in mostly wildlife research, measuring populations of marine wildlife such as whales, dolphin, seal, turtles, etc. The two Twin Commanders (AC 500) and one Turbo Commander (AC 690) are involved in snow survey in the upper Midwest. They measure snow depth during the winter in areas that are highly susceptible to flooding. This data gives the hydrographers the information needed to predict flooding during the northern spring thaw and give residents of these areas plenty of warning.

*Newman:* To amplify Greg's response about the Twin Otters (DHC-6) aircraft and King Air, the reason these planes are so valuable to science is that they can carry a lot of weight and they are highly reliable while being inexpensive to operate. That's a tough combination. It's a testament to the design that Viking Aircraft is starting to produce Otters again 25 years later. There's still a strong demand for the unique qualities of the aircraft. Our new King Air 350 has the ability to operate at high altitudes and low altitudes since it's a turboprop. The G-IV was selected for high altitude and range.

## How was aircraft type chosen? What were the parameters?

*Bast:* The P-3s were acquired when the DC-6Bs we were using for hurricane research became outdated, having a similar fuselage type, but turboprop engines. The fuselage is high enough off the ground to accommodate the lower fuselage radar, which would not fit on other types of aircraft. For wildlife research, an aircraft with short field capabilities was required. Something that could fly low and slow for an extended period of time and was fairly easy and economical to maintain.

The Twin Otter fit the bill nicely. The Twin Commanders and Turbo Commander were chosen because they were fast and had a high wing. The King Air 350 is the replacement aircraft for our Cessna Citation II and can accommodate a high-resolution camera in its belly.

## Can you describe the ground team and how it is made up?

*Bast:* Our maintenance team is made up of 12 extremely experienced FAA certificated aircraft maintenance technicians, eight of whom hold an Inspection Authorization. The youngest technician on the team has 18 years' experience in both military and civil aviation. The oldest – that would be me – has 43 years' experience in both military and civil aviation. Each of the technicians is assigned to an aircraft, or set of aircraft, that they are responsible for on a regular basis. Three of the technicians assigned to the P-3 aircraft double as flight engineers and hold an FAA flight engineer certificate with a turboprop rating. Several are also certificated pilots, although we don't fly our aircraft. Although they are assigned to specific aircraft, each team member can work on any of our aircraft at any given time depending on circumstances. In my opinion, we have the finest team of aircraft technicians anywhere. We also have a group of electronic and avionics technicians, which are some of the best I've ever had the pleasure of working with.

*Newman:* We lean toward an older demographic since we need experienced hands. On the technician/engineering side, our ground team has the ability to design and modify our equipment. The P-3s are public-use aircraft so we design and modify everything ourselves with the help of designated engineering representatives. This capability is pretty unique to small science organizations like ourselves and sets us apart from other aircraft shops.

## These aircraft have probably the toughest job in the world. How does the test and maintenance regime differ?

*Bast:* All of our aircraft hold an FAA Airworthiness Certificate except for the P-3 aircraft. We adhere to CFR 14 and the aircraft/engine manufacturers' maintenance manuals religiously, with many local work cards, which have been incorporated into our program due to the one-of-a-kind equipment installed in and on the aircraft. With the P-3s we adhere to the US Navy's maintenance program with some modifications and several additional inspection criteria due to the nature of our business with those aircraft.

Above: The WP-3D Orion. Below: Commander Carl Newman at work(pictures courtesy of NOAA)

> "I recall an instance where we were struck by lightning or static discharges 17 times in one flight"

***Newman:*** Only the tough survive, and that means trial and error. If an instrument is sensitive to lightning strikes (high voltage) or wasn't designed to withstand surges, it died long ago on the P-3 aircraft. I recall an instance where we were struck by lightning or static discharges 17 times in one flight. Pretty dramatic. Regarding our P-3 maintenance, the US Navy flies P-3s as well. We use their maintenance program but don't break up any phased maintenance, meaning that what the Navy might accomplish in 12 years, we do in four to six. We look at our planes in the depot on a more frequent basis and perform more work to include wing integrity.

## What are the biggest problems you face technically, and how are they overcome?

***Bast:*** Off the top of my head, I can't think of any particularly bothersome technical problems. Most times, our problems are logistical; getting parts to remote areas when they are needed. The P-3s carry a lot of parts with them to mitigate some of that issue, but it's always the part you don't have with you that breaks 90% of the time. Our technicians are so adaptable and innovative in working problems that they aren't really problems, just speed bumps.

***Newman:*** Science and research is about a changing knowledge base. That means that we constantly have to modify our aircraft, instruments, and gear to accommodate the mission. We only have a limited time each year to modify the planes since June 1 – November 30 they have to be essentially scientifically static. We also fly winter storm reconnaissance in the January-March timeframe, further reducing our window for modification.

The end result is that we spend a great deal of time scheduling, planning, and looking ahead to ensure we're prepared for the few windows we have. We're never comfortable with our schedule and tend to be pretty critical of ourselves regarding these windows. From a longevity standpoint, our P-3s are roughly 35 years old. The irony in hurricane hunting is that the old technology works better when 'punching' through the low convection. Since there have been no large commercial turbo prop aircraft built in many years, we don't have a large cadre of candidates for replacement aircraft.

In fact, with the large radomes we require on the P-3, we don't have any viable replacements.This means we'll have to extend the life of the aircraft or give up the mission to 'something else'.

## Does the team need special training? How does this work or manifest itself?

***Bast:*** The only truly special training required is the storm qualifications for the pilots and flight engineers. Both are required to complete a training syllabus, which usually takes two, possibly three hurricane seasons to complete and consists of an hourly requirement, an eyewall penetration requirement, and skills that are peculiar to flying in the hurricane/severe weather environment. Maintenance technicians complete annual training requirements on their assigned aircraft and any other training they can fit into their schedules.

***Newman:*** The training occurs through on-the-job training. The pilots, flight engineers, navigators, and flight directors must acquire the training by flying with more experienced people. This process can take years to accomplish in some cases, and requires a dedicated effort to schedule more than a minimum crew.

## What does the future hold? How would you see things improve from an aviation point of view?

***Bast:*** Aviation technology is changing so rapidly and it is a challenge to make sure we are acquiring the right equipment at the right time and getting the proper funding to keep our aircraft fleet flying safely and for as long as possible.

UAVs present a possible alternative for us that is being explored for the multiple missions we perform. It is not unlikely in the future that we will see a mix of manned and unmanned aircraft missions. ∎

# Defects in compsites

## 100% COMPOSITE-ORIENTED ULTRASONIC DATA-ANALYSIS SOFTWARE

> The ultrasonic non-destructive inspection of large composite panels and structures requires, further to the control itself, a lengthy system of analysis of the inspections results. Detection of defects in composites by ultrasonic pulse-echo inspection is based on the analysis of both attenuation and time-of-flight C-scan cartographies. Differences in amplitude, as well as differences in time-of-flight, can be the manifestation of porosity, inclusion, or delamination defects.

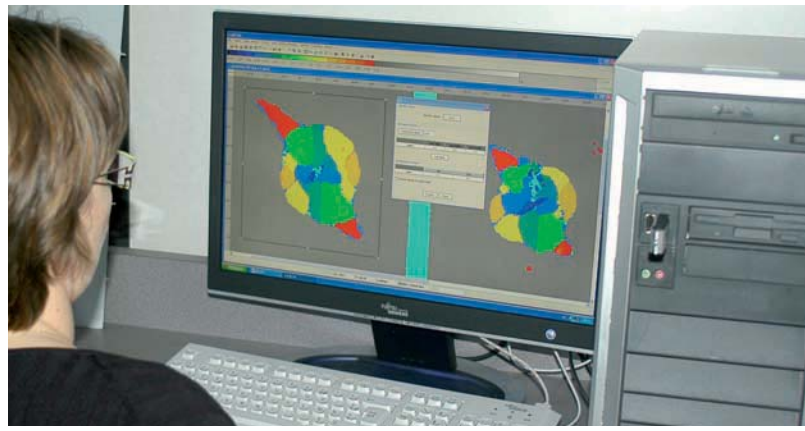
Numerous ultrasonic systems are used by the primes and subcontractors, and all the resulting data have to be compared. The analytic capabilities of the systems are not always relevant and their compatibility is often difficult. Therefore, a few years ago, the need arose to harmonize the ultrasonic data.

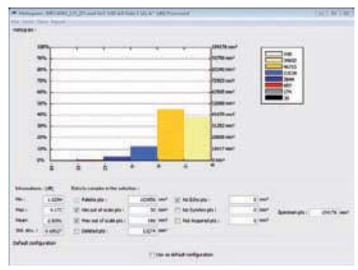
EADS Innovation Works has developed dedicated software capable of ensuring the compatibility of various data file formats (2D ultrasonic A-scans and C-scans). u-lis is a software dedicated to NDT ultrasonic data analysis and automatic diagnosis, developed to respond to cycle- and cost-reduction demands in aerospace composite production.

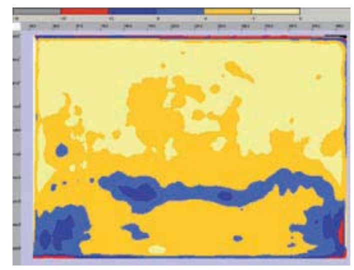
The software provides tools that help to extract more information from C-scan, as well as to give a faster diagnosis. The software is able to compute and display statistical information extracted from time-of-flight or amplitude C-scan. This tool is often used to compute the amplitude distribution in selected areas of the C-scan. Each histogram bar corresponds to one color of the palette associated to the cartography. The height of the bar is given in a percentage of the surface of the selected specimen, in mm², or in pixels. For large or complex composite parts, the manual analysis of ultrasonic C-scans is often time consuming, and errors and defects can be missed. The automatic detection of defects is a major feature for ultrasonic analysis software. The first step is to highlight the out-of-tolerance pixels. This can be done by adjusting the palette for the simplest case. For more complex parts, several tools are available to manage amplitude/thickness-dependant criteria, to filter the backwall echo, or to perform comparison with reference C-scans.

Quality requirements for composite aeronautic parts have led to the need to manage complex defect-detection criteria. Employing this analysis software, the user can define automatic defect configuration that is able to take into account one or several varying acceptance levels, which may be assigned to specific areas in the part. For each acceptance level, the user can define the maximum size of acceptable defects calculated according to the real surface or to a surrounding shape.

Results of the automatic detection will then be displayed both on the C-scan and in a table of defects that reports dimension, position, and the number of each defect. Once each defect is detected as an isolated defect, the software is able to apply proximity criteria to group defects







close to each other. Corresponding dimensions are then displayed in the table of defects. The A-scan analysis configurations for defect detection and grouping can be saved during the development steps. Then the production inspector only has to load the predefined configuration.

The analysis of C-scans coming from actual production parts often requires several post-processing actions to be performed repeatedly. This may include merging when acquisition has been via several scans, palette adjustment, edge-effect correction, C-scan calculations, or modification of the units. The software provides automatic analysis and reporting tools.

For series parts, the automatic analysis configuration is designed once during the analysis of the first C-scan. The configuration results in a batch of actions that are automatically executed on C-scans, from the loading of data to the report print-out, and report templates are fully customizable. This means the production inspector just has to launch the batch of predefined actions. The automation of C-scan analysis for series production means greater security and better reproducibility in the C-scan analysis process.

u-lis is the only UT analysis software fully compliant with Airbus requirements. NDT EXPERT has been using this software for a number of its works and is now in charge of the training of operators inside Airbus and EADS plants in Europe. Globally, the company is also in charge of deployment and training beyond the EADS group at any place where composite-material UT inspection is required. ∎

*Elisabeth Pagnoux-Lacaze, NDI engineer, is deputy head of the engineering department at NDT Expert*

# In the frame

## A USEFUL TEST AND MEASUREMENT TOOL FOR STORES SEPARATION TESTING

> There is no room for error with stores separation. Having an understanding of how a store reacts when released from an aircraft enables engineers to identify any safety issues that may put the aircraft and pilot at risk, as well as providing the data needed to help develop safer, more accurate delivery systems. One of the most valuable tools available to engineers for stores separation testing is digital high-speed video, which gives engineers the ability to conduct precise and accurate measurements of the intricacies of stores separation.

High-speed digital cameras have advanced in recent years to offer better resolution and detail, higher frame rates, and more compact form factors. Due to these three developments, manufacturers have introduced high-speed digital imaging systems that can be incorporated into new environments, such as on the hull of an aircraft or UAV for recording high-speed footage of stores separation. The technology is more precise for motion analysis.

When using a high-speed digital camera for stores separation testing, it is vital that the camera be rated for Hi-G use. Vision Research's Phantom Miro Airborne is rated to survive accelerations up to 40g, ensuring that the unit will deliver clear digital images when recording in such an extreme environment.

High amounts of vibration is also a problem when airborne with a digital high-speed camera. Having steady support is one of the fundamental needs of recording usable high-speed images, and to ensure that a high-speed digital camera is properly secured to the hull or wing of an aircraft, engineers need to consider models that incorporate options for mounting. The Phantom Miro Airborne is an example of such a camera, complete with mounting plates and standard ¼-20 holes. The Miro Airborne also offers lens mounting holes for additional lens support and flange mount Hi-G and vibration-resistant lenses.

Flexibility, especially in regard to triggering, should also be a priority. Depending on what is being analyzed, engineers may want to record high-speed video of a store moments before or after it is deployed, and use the video to analyze the performance of a release mechanism or the ignition sequence of a wing-mounted missile.

Upon power-up, the Phantom Miro's triggering system automatically sets the camera to begin recording a number of images that are stored in a circular buffer to internal memory. Engineers are then given the option of manually configuring the trigger, which programs the camera to start/stop recording a selectable number of frames before and after the set mark.

Lighting is also one of the most challenging aspects of using high-speed digital video for stores separation testing. Today's high-speed digital cameras feature improved light sensitivity and are well-equipped to perform in the uncontrollable lighting environment of airborne applications. A digital high-speed camera's imaging sensor, as well as key specifications including bit-depth and ISO rating, all contribute to its overall light sensitivity.

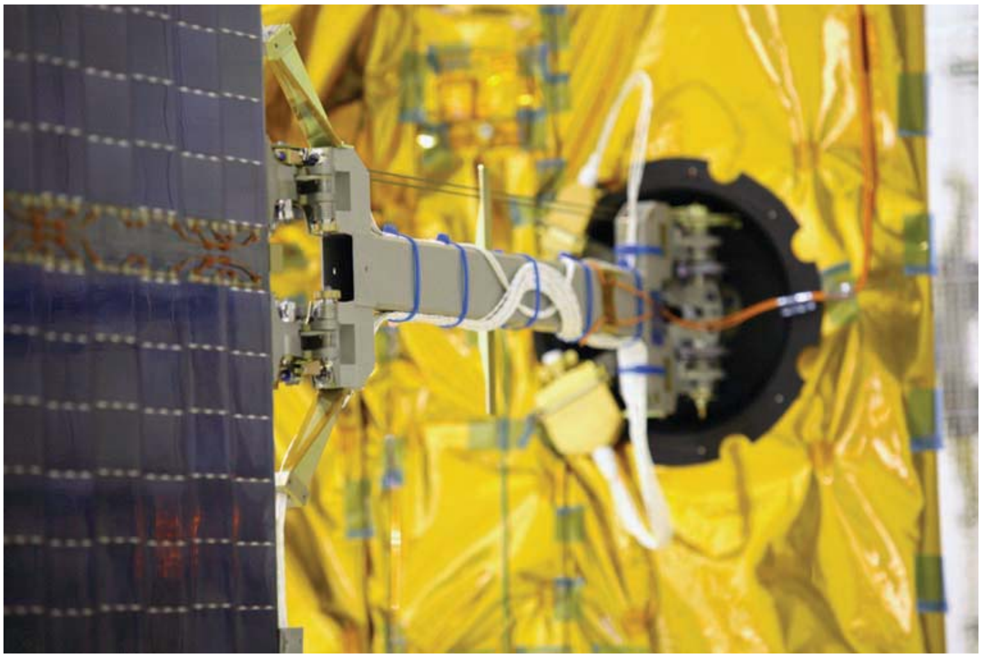
The Phantom Miro Airborne offers a custom-designed CMOS sensor with an ISO12232 rating of 4800 (monochrome), and a feature called extreme dynamic range. Exclusive to Vision Research high-speed digital imaging systems, extreme dynamic range is a valuable failsafe technique for having two exposure settings during a single frame of acquisition. This enables engineers to see detail in areas of the recorded images of the store separation that may be overly bright or blown out. ▮

*Rick Robinson is based in the USA and is Vision Research Inc's divisional VP, marketing*

# Toward a wireless world

## THALES ALENIA SPACE REPLACES THE GLOBALSTAR CONSTELLATION OF 48 TELECOMMUNICATIONS SATELLITES

BY JENNIFER SCHLEGEL



Mobile communications in remote areas beyond cellular and landline service take place around the world every day. These voice calls, as well as internet data connections, are made on mobile telephones that connect to orbiting satellites. A company specializing in this evolving telecommunications field is Globalstar, the largest provider of mobile satellite voice and data services.

The company uses a constellation of 48 low Earth orbit satellites circling the globe about every 90 minutes at an altitude of 1,414km. The satellites receive signals, then amplify and transmit them back to gateway ground stations that process voice or data calls and distribute them to telephone networks or the internet.

The original Globalstar satellites will be replaced in late 2010. The new satellites are designed with greater reliability, power, and a 15-year life expectancy. The upgraded constellation and ground network will provide more reliable service and faster data speeds to support next-generation internet protocol-based services.

### Assembly, integration, and test

Prime contractor for this project is Thales Alenia Space, Europe's largest satellite manufacturer. Thales Alenia Space is a worldwide reference in telecom, radar and optical earth observation, defense and security, navigation, and science. It has 11 industrial sites in France, Italy, Spain, and Belgium.

Thales Alenia Space has primary responsibility for the design, manufacture, test, and delivery of 48 second-generation satellites for the Globalstar constellation. The company is upgrading the Globalstar Satellite operations and control center as well as telemetry and command units and in-orbit test hardware and software located in Globalstar gateway ground stations worldwide.

The multisite capability of its three assembly, integration, and test (AIT) centers is well-suited for handling satellite constellation projects, with specialized capabilities for transporting sensitive hardware between facilities and delivering assembled satellites directly to launch sites. A critical role is testing satellites to ensure that sensitive components can withstand the acoustics and harsh vibrations of vehicle launch. Engineers focus on parts and subsystems that must remain intact, connected, and operational, and structural components deploying solar arrays and antennas as well as complex onboard electronic systems with interconnected circuit boards, semiconductor chips, and signal processors.

All three AIT Centers perform various phases of these environmental tests: sine vibration and acoustic qualification tests, acoustic flight model tested prior to satellite assembly, and delivery to the launch pad and verification testing on the antenna systems.

**Nearing the end of operational life, the entire Globalstar constellation of 48 telecommunications satellites will be replaced by Thales Alenia Space – Europe's largest satellite manufacturer**

### Standardizing on LMS

Tests are conducted using LMS SCADAS data acquisition hardware and LMS Test.Lab control and data reduction software.

With an expanded data acquisition system at Cannes, the 1,200+ channel count for all three AITs ranks Thales Alenia among the most powerful distributed LMS test system worldwide. The signal capacity, high speed, and versatility of this LMS system are key to the success of these satellite projects.

The Cannes center can accommodate subsystems, antennas and solar arrays, and satellites up to 6 tons, while the Rome facility is limited to 3 tons. In Toulouse, electronic equipment and antennas are tested. In Rome, shock loading experienced by satellites due to separation of rocket stages is duplicated on a shaker table controlled by the LMS system, which also triggers a high-speed camera recording the satellite's structural response. AITs perform tests for projects such as Globalstar and the

Galileo and EGNOS navigation satellites, as well as the Herschel, Planck, and Mars Express missions.

"Standardizing on LMS testing solutions is advantageous," said Jean-Charles Delambre, vibration and mechanical testing expert at Thales Alenia Space Cannes Dynamic Test Facility. "Our test systems are compatible with those at our largest customer, ESA (European Space Agency), since it also uses LMS extensively. We can ensure that our test procedures are done according to its standards. And we can exchange results data and technical information of the satellite projects we work on for the agency.

"Our engineers can work at any of our three sites due to the uniformity of the LMS technologies. This standardization shows its added-value when coordinating work and performing tests efficiently on large joint projects."

## Choreographed engineering

Hervé Ruzicska, manager of the mechanical test center, says, "For a project of this magnitude, testing must be a chronological, concurrent engineering process. In Cannes, we can run two or three tests per day and deliver results practically the moment the test is completed.

"We use a 'technical island' approach where teams converge at the test site – technicians for set up and data acquisition as well as facilities engineers, shaker specialists, and instrumentation engineers. During tests, measurements are compared with prescribed limits, and tests are automatically aborted via a control loop that triggers an end-test command that gradually scales down vibration input."

With the LMS system, it is known that fragile and expensive satellite components will be safe as the test sequence is performed exactly as intended.

"By seeing results so quickly, engineers can spot inconsistencies and make immediate corrections, even in the middle of a test," the head of the Rome-based mechanical test department IU-AIT, Daniele Tiani, explains. "This saves hours, and often days, of precious time that they would otherwise have to spend waiting for results."

Further time is saved with the LMS patch panel capability, which can avoid the time-consuming repetition of connecting and double-checking accelerometer cables as the satellite is moved from pre-test into the test area. This helps streamline the procedure of splitting up a test because not enough channels are available to run the full test.

"With patch panels pre-wired to route signals to appropriate slots of the LMS SCADAS by way of a few master cables, we can reconfigure connections in hours instead of four days or more," says Tiani.

"Clearly, there is a competitive value for Thales Alenia Space to be standardized on LMS test systems," explains Tiani. "In an industry such as satellite development, where performance and reliability are critical, the trend toward LMS as the de-facto standard across the industry makes sense. There is too much at stake to trust projects worth millions of Euros to anything less than the proven capabilities of LMS company people and technology." ∎

*Jennifer Schlegel is the corporate copywriter at LMS based in Belgium*

**The test systems are completely compatible with those at the ESA (European Space Agency). Thales can readily ensure that test procedures are done according to ESA standards. Computer buses come and go while Ethernet and internet protocol lives on**


**Technicians work on the assembly line of second-generation Globalstar satellites at the Thales Alenia Space offices in Rome. Globalstar is a low Earth orbit (LEO) satellite constellation for satellite phone and low-speed data communications**

# Blade runner

**THE LATEST MOOG AEROSPACE TEST SYSTEM IS A GREAT PARTNER FOR THE AGUSTAWESTLAND ROTOR BLADE FATIGUE TEST APPLICATION**

BY MARIE LAURE GELIN

Advanced aerospace test systems are required to create and measure force to simulate and test real-time durability and resistance of helicopter components, especially fatigue tests on the rotor, hub, and blades. Recent developments from Moog include the development of a system supplied to AgustaWestland to perform a wide range of structural and fatigue tests for helicopter rotor blades.

An important part of helicopter development is the fatigue testing of the rotor blades. During operation, helicopter rotor blades are subject to substantial flap (vertical), lag (horizontal), torsion, and centrifugal (CF) loads. Flap and lag occurs as bending of the blade, as well as shear loading. Moog's aerospace test system, in conjunction with the HBM data acquisition system, has been designed to accommodate these elements and to ensure the required relationship between the flap, lag, and torsion moments on the blade at all times.

At AgustaWestland, all test conditions are defined in terms of CF load, flap, lag, and torsion moments to be applied at a particular blade station (span-wise location). Moments and torsions are measured by strain gauges installed along the blade. As it is possible for strain gauges to be damaged during fatigue testing, these must not be used to close the control loop. The controller must control the loading actuators in force mode using six load cells to provide the individual loop feedback.

To meet these specifications, Moog supplied its aerospace test controller with six servo control channels, incorporating the latest quad core IPC processor and a real-time Ethernet platform to enable playback of the complex loading spectrum on the helicopter blade.

The system's real-time Ethernet platform increases the functionality of servo controllers and boosts the performance of aerospace testing, providing faster graphics, accurate synchronization of up to 500 control channels, reduced latency time, and complete management of many safety procedures to eliminate risk on the test specimen. It provides the test system with a high bandwidth and an unprecedented level of safety, and is particularly suited for high performance aircraft, helicopter, and spacecraft testing.


Moog has delivered a new aero test rig to the Korean Aerospace Research Institute (KARI) to perform a wide range of tests in a South Korean project to develop and build 245 utility helicopters

## Multilevel blocks

Fatigue loads vary during different maneuvers, both for ground and inflight conditions, and the aerospace test software accommodates this using multilevel instruction blocks. A fatigue spectrum for rotor blades consists of up to 200 instruction blocks containing a total of 10 million fatigue cycles.

To apply the correct bending moments on the rotor blade, a cascaded closed-loop control is used, where an inner loop controls six servo-hydraulic loading actuators in force mode and an outer loop adjusts the actuators' command set points based on current bending moment errors.

The strain gauges are measured and converted into bending moments by the HBM data-acquisition system and then transmitted to the Moog controller via a bi-directional Ethernet communication interface. In the aerospace test software, these 'actual' bending moments are compared against 'desired' bending moments using a corrective PID loop in soft real time. The output of the PID loop is translated into force commands for the individual force loops using a 66 transfer matrix. This is set up using the aerospace test software's online calculation channels, called Shared Memory.

The corrections to the inner-force loop commands are made at intervals, rather than instantaneously. This is because it is necessary to verify that the bending moment information can be relied upon to guard against damage to the strain gauges before the system responds to the outer loop. The control system provides a means of bringing the test to a controlled stop in the event of errors being detected, or an emergency stop switch being thrown.

Moog's aerospace test system proved to be a perfect match for AgustaWestland's fatigue test application, offering all the functions needed in one software suite. ∎

*Marie Laure Gelin, marketing manger, Territory (Europe), Moog*

# Korean helicopter program

Experience in helicopter testing and Korean technical support capabilities helped Moog win a project that included system development, configuration, and comprehensive training for the Korean Aerospace Research Institute (KARI).

The aerospace test system is being used by KARI to perform a wide range of structural and fatigue tests for helicopters. This system is part of a multibillion dollar procurement project by the South Korean Ministry of National Defense to develop and build 245 utility helicopters over a 16-year period.

Moog's previous experience with similar test-rig installations, knowledge of helicopter test techniques, and on-the-ground technical support from its Korean engineering team helped win and develop the project.

KARI's specifications for the customized test-rig installation included six cabinets with 16 control channels each and a 256-channel HBM data acquisition system. It incorporates new software functions that give real-time Ethernet-based data transfer between the command generator (real-time front end) and the localized control loops. A dedicated Ethernet interface is used for the transfer of the load cell, position and spectrum data from the Moog test controller to the CatMan data acquisition unit, and activation of commands (for example, taking a snapshot) from the test controller system to the Cat-Man system.

Installed in just three days in 2008, the test rig is now fully operational and running full-scale structural tests. The system has the potential to run up to 12 independent helicopter tests.

The requirements of the brief sent to Moog specified the need for a hydraulic system, actuator, and data acquisition system to carry-out static structural and fatigue tests for the helicopter rotor system. The hydraulic system was installed in the rotary wing aircraft laboratory to supply the flow used in the hydraulic actuator for repetitive loading during the fatigue test.

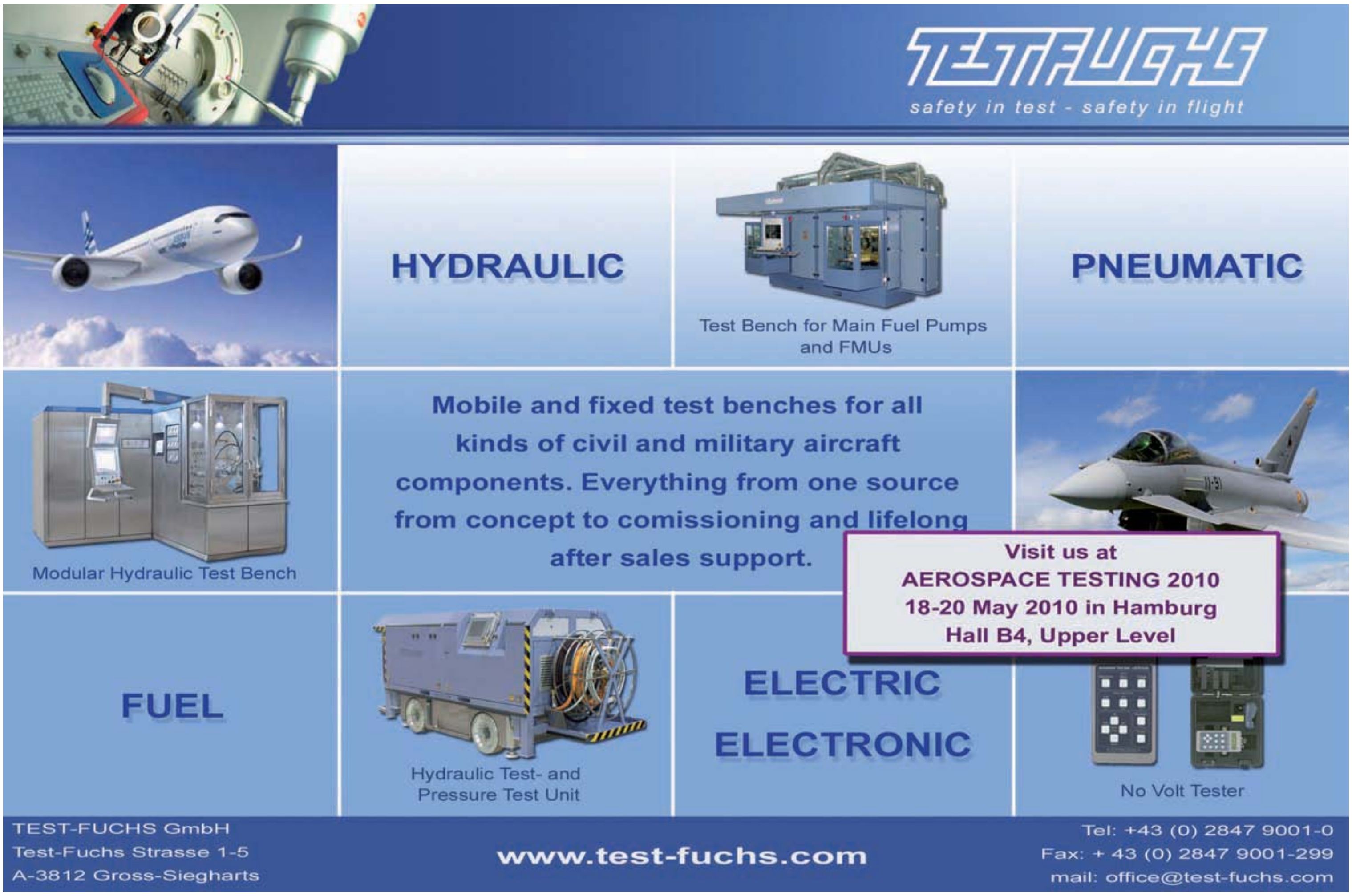
The KARI test rig needed to create and measure forces to simulate and test real-time durability and life of helicopter components, especially fatigue tests on the rotor, hub, and blades. It also needed to integrate seamlessly with KARI's existing data acquisition systems and hydraulic control equipment in the test labs.

"The KARI project was specific in its requirements and presented us with an exciting technical challenge. Our engineering team, and our depth of experience in aero test rigs and helicopter testing, were crucial to the success of this program and we are delighted with the end result," says business development director for test systems Tom Pierce.

"The new aero test system gives KARI a multitude of benefits including cost-efficient operation, almost unlimited flexibility, and total access to local Moog expertise and ongoing system support."

The KARI load-control system can perform 12 different tests independently with up to eight-channel control stations or one full-scale test. In both cases, up to 96 channels can be used. The load-control system has been set up to communicate seamlessly with two different data acquisition external systems (such as HBM and VTI), giving KARI the flexibility it requires to handle a wide range of tests.

The system also delivers fast and efficient analysis and comparison of tests. Because the two systems are connected via Ethernet, KARI can directly cross-check data from the load control system and data acquisition system through time stamps. This means all data can be stored and archived on a hard disk for post-test analyses. KARI's test program currently runs eight distinct and independent component tests simultaneously.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The company Schulze Radio Systems produces reliable and rugged telemetry and radio systems for aerospace and marine applications with extreme quality requirements. The main focus is on the usability of the products as MIL-grade commercial off-the-shelf (COTS) which is ensured by standardization and consistent quality management.

# System communication

## SPECIAL TOOLS AND SERVICES HAVE BEEN DEVELOPED FOR THE COMPLIANCE TESTING OF ARINC664 END SYSTEMS AND SWITCHES

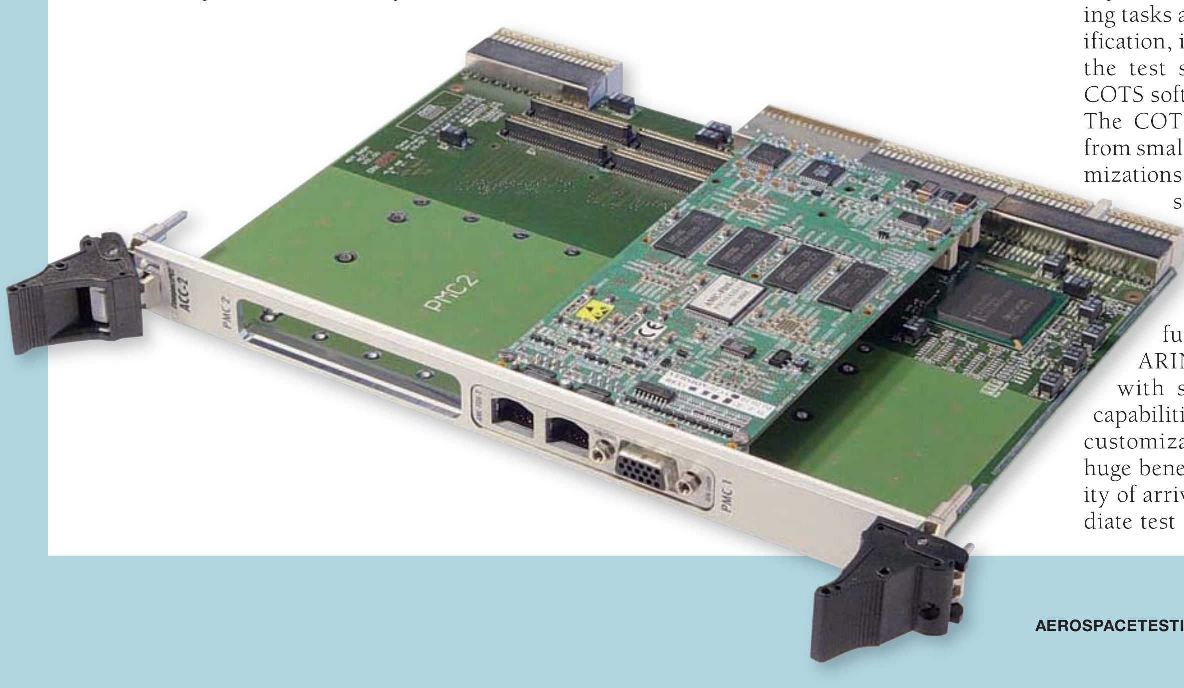
BY JOACHIM SCHULER

The use of the Ethernet-based ARINC664 technology for communication between avionics computers and systems introduced by Airbus on the A380 program, as the avionics full duplex switched Ethernet (AFDXTM), is increasing. This has lead to further developments and implementation of end systems and switches compatible to the ARINC664 specification. No standardized test plans have been released, and the definition and specification of test plans for the devices has fallen on the designers and manufacturers of these components, leading to proprietary implications.

In response to an equipment manufacturer's request, Aim GmbH, a test-tool and equipment supplier, developed a turnkey solution for compliance testing of ARINC664 end systems and switches, including the test system and the related test services. Potentially this could establish a baseline and become an ARINC664 standard product for compliance testing of end systems and switches.

The first stage was identifying the functional requirements and the related test requirements from the ARINC664 specification – mainly Part 7 and chapter 3.0 for the end system, and chapter 4.0 for the switch functionality. The end system and/or switch supplier is forced to fill in the gaps with proprietary device-specific definitions because ARINC664 does not define all requirements in detail. A comprehensive cross-referencing between test requirements and functional requirements in ARINC664 chapters provided an important baseline for the definition and specification of the detailed test procedure and the test system hardware/software structure needed. This enables the special functionality required for testing to be identified at an early stage, avoiding the risk of cost-intensive modifications or workarounds later.

Dedicated ARINC664 COTS test equipment (especially interface boards with IRIG-B synchronization, time stamping capabilities for received and transmitted frames, and hardware trigger input and output support) reduce the risk and makes test system implementation easier, with almost zero development effort on the hardware side. For switch testing, up to 24 ARINC664 ports (depending on the unit under test) had to be handled concurrently. A modular approach, based on COTS 6U compact PCI industrial standard with PMC modules, was used to implement the necessary number of ARINC664 interface ports.

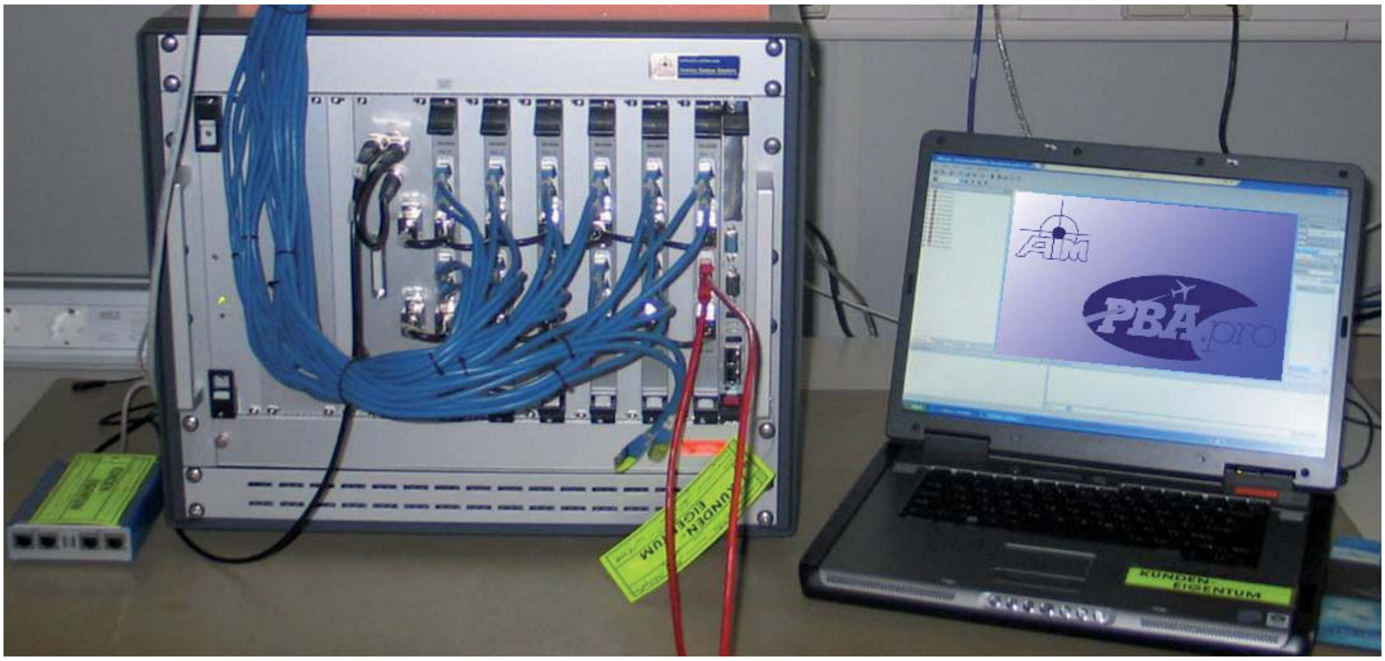



**Partially equipped 6U CompactPCI Carrier with up to two ARINC664 PMC interface modules such as AIM AMC-FDX-2y**

The test system was designed to suit both ARINC664 switch and end system testing. The hardware engineering tasks for this test system were the compilation of COTS components, (such as embedded Windows PC, cPCI back plane, power supply unit) into a chassis with appropriate cabling, and the design of an integrated hardware trigger and IRIG-B time code-signal routing panel. This test system can be operated either directly via the embedded PC with monitor, keyboard and mouse, or via a laptop, connected via standard Ethernet, to the embedded PC. A USB-based non-intrusive ARINC664 network tap, which can be installed in any network part, is also part of the test system hardware and is required for some special tests.

On the software side, specified test requirements from the initial phase justified the decision to also use a COTS software solution as a baseline, offering customization, automation (scripting), report/logging generation, and data-loading capabilities. The software engineering tasks are then related to the specification, implementation, and test of the test scripts organized via the COTS software's scripting capability. The COTS software also benefited from small modifications and/or optimizations, identified during the test-script development process.

By building the test system almost entirely with COTS hardware and software components, a fully functional multichannel ARINC664 network analyzer, with scripting and automation capabilities, is obtained without any customization up to this point – a huge benefit. This gives the possibility of arriving quickly at an intermediate test system for manual/interac-



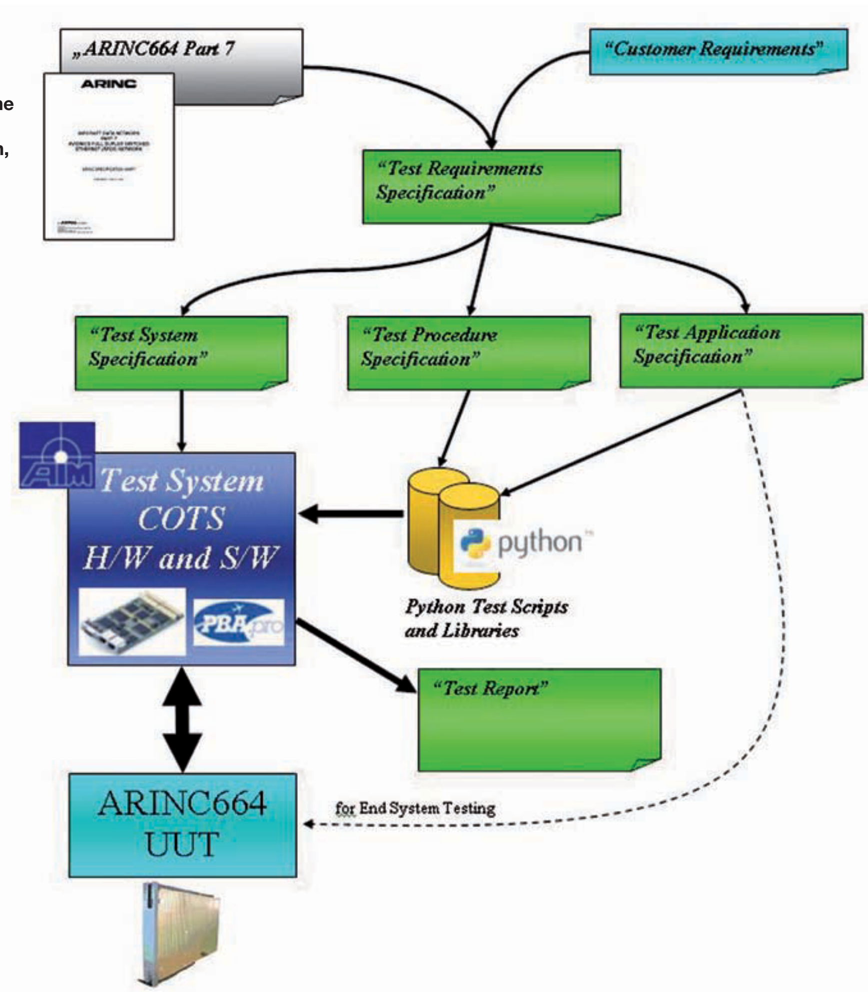
Test System with chassis, laptop and the connections to the UUT (a 24-Port ARINC664 Switch, not shown)

tive pre-testing, prior to the final, formal test.

So far, the approach for testing of ARINC664 end systems and switches is similar. In the following stage, the detailed test procedures for end systems and switches are specified, and testing for ARINC664 switches and for the end systems differs slightly.

For switch testing, a black box approach was adopted, with the device under test running operational hardware and software without any specially activated test code. The necessary configurations (VL routing table with all its parameters for proper traffic policing, forwarding, embedded E/S operation) are loaded prior to testing, then activated during the test procedure.

End system testing required the specification of a test application, executed on the end system under test, and acting as a counterpart to the test system for setup, and a control for the end system under test. This test application is a mandatory element because the test focus is on ARINC664 interoperability and not on a particular operational functionality. The end system implements the interface to an ARINC664 network inside the operational equipment. The test application runs in an end system's test environment, which can be a processor board which hosts the end system in the form of a PMC module.

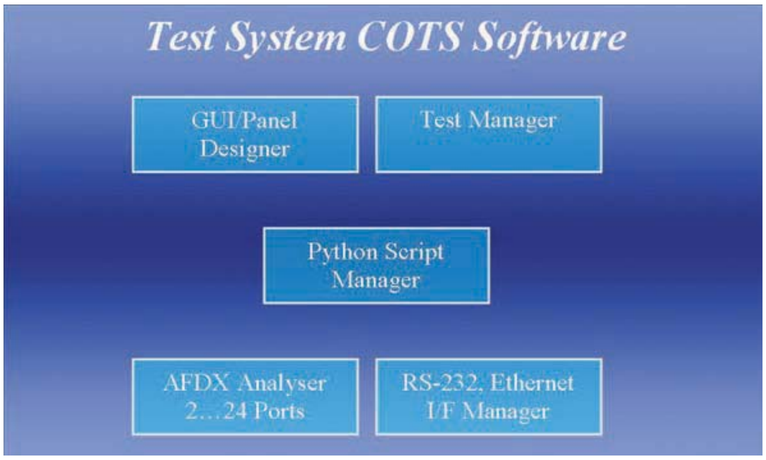



Overview of the testing approach

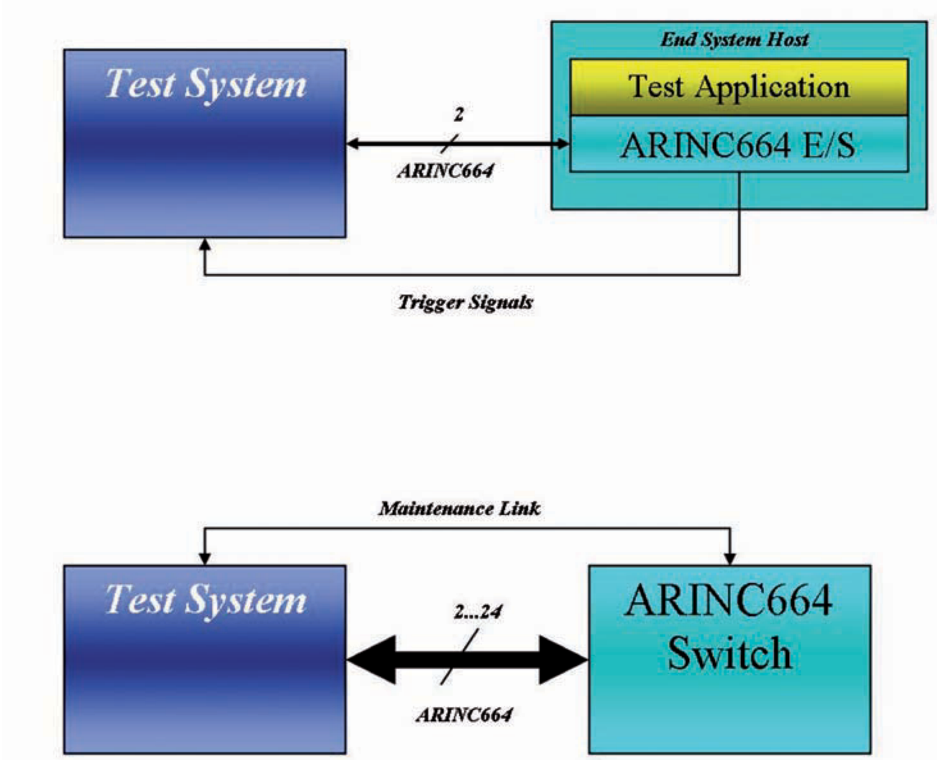
The key point is that this specification represents the interface between the test system and end system for the implementation of the test application by the manufacturer/designer. For maximum flexibility, the test application specification neither specifies the use of a particular operating system in the end system's test environment nor requires additional communication interfaces over and above the ARINC664 network. The interface to the test application is a command/acknowledge-based communication protocol over ARINC664, specially designed for end-system testing and derived from the test requirements. The end system under test's configuration is performed from the test system side over an ARINC664 link at run time, via the test scripts. This does not require the loading or compiling of fixed/static configurations prior to the testing.

As a part of the detailed test procedure definition, the structure of the object-oriented test scripts was designed using Python scripting language and a maximum of reusable code for both the ARINC664 end system and switch testing, organized into respective libraries for traffic stimulation utilities, for reception, evaluation, SNMP, ICMP and test application communication (for end system testing).

**COTS software structure such as AIM PBA.proTM**




**End system and switch-test setup schematic**




All test requirements from the first phase are reflected in corresponding test cases described in detail in the test procedure specification. Wherever possible, automatic test performance was designed to achieve maximum reproducibility and fail-safety. One of the core functionalities of the scripting libraries is the automatic evaluation of the test results. They respectively analyze the received traffic from the end system, or forwarded traffic, in case of switch testing, from the scripting level. As part of the test system software, script utility libraries have been created offering primitives for handling of RS-232, and Ethernet-based maintenance ports of the unit under test (especially for switch testing). This is done via the test system CPU's standard peripheral hardware. The libraries are used in the test scripts in order to enhance the quality of the test results by cross-checking maintenance information, in addition to the traffic results monitored on ARINC664 connections. Use of maintenance ports is necessary in some special test cases, particularly with ARINC664 switch testing.

End systems configurations and switches are designed to use an intelligent allocation and definition of virtual links, UDP ports, and their related parameters and boundaries. The project's final stage consisted of performing the ARINC664 compliance testing at the customer's site and handing over a signed report and the test scripts.

The approach is based on the customization of COTS tools and offers a fully traceable method of testing ARINC664 compliance from the ARINC specification level, with its functional requirements, down to the implemented test scripts in the test system for almost all ARINC664-compatible end systems and switches. Adaptations of this solution can be undertaken by the customer to incorporate further customer-specific requirements. Such an exercise is low risk due to the modular approach for the test-system hardware and software. Indeed, this was one of the primary design goals, in parallel with creating a system that offered reproducible, high-performance and cost-effective testing. ∎

*Joachim Schuler is a manager S/W Engineering with AIM GmbH, Germany*

# ANALOG DIGITAL ARINC PCM 1553 GPS IRIG VIDEO...

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# Put the brakes on

The development of a brake test stand has provided a challenge for the design engineers at Test-Fuchs. The customer requested some new technology to help reduce the testing times of components.

Finding a design solution in partnership with an MRO solution providers was a challenge. The design of the test equipment reflected the client's technical in-depth specifications and philosophies of this lean production organization.

The result of the company's partnership with the customer is a test stand that combines quality and engineering skills with a need to reduce the cost of test components. The dual-station automatic brake test stand (Part Number PFB3S) is designed to meet the requirements for brake assembly servicing and testing in the related component maintenance manuals. This product is designed to meet the needs of high-volume brake service shops.

Easy to operate, the test stand performs functional tests and operational testing with a pressure from 0.03 bar (0.44PSIG) up to 650 bar (9,428PSIG). It also includes functions like flushing, spilling, bleeding, and low-to-high pressure tests for single and dual circuit brake systems.

In flushing and spilling mode, old phosphate ester is spilled out of the components and collected in a waste phosphate ester drum. The process can be visually controlled through transparent return hoses and an illuminated sight glass. A special bleeding procedure is integrated for bleeding through vacuum support in the return-line circuit. Each test station has an independent pressure-supply circuit with a gear pump for low-pressure demands and a hydraulic pressure intensifier for high pressure. Pressure regulation is realized by servo solenoid-directional control valves.

An independent cooling and filtering circuit integrated in the test stand ensures the lowest possible particle class and stable temperature conditions during the tests. The transparent protection covers are moveable by operator hand for safe high-pressure tests.

The test stand is fully PLC controlled with an art graphic-user interface, and the interaction with the user is realized by 15in touch-screens for each station. The HMIs are integrated in movable panels to enable the user to move the panel into a comfortable position. The fluid supply and return ports are located on the side. The test sequences can be started by a simple click on the relevant part number and the appropriate test sequence. The values are stored in a database. All parameters (pressure, time, number of cycles, and more) can also be defined by the user in manual mode. Calibration can be done with the integrated calibration software.

For brake assembly mounting and easy manipulation, mounting trolleys with the necessary adapters for the brakes are provided. The mounting trolleys can be easily moved, and the brake assembly can be rotated over two axes by hand to support the bleeding procedure. The test stand and the mounting trolleys are complete and made of stainless steel and aluminum. The test stand can be used with all types of phosphate esters and other hydraulic media.

Staff protection is a strict requirement, with the PFB3S meeting all safety regulations during the aircraft brakes test process.

Cost reduction and minimized turn-around times, combined with reliability and quality, are success factors in the MRO business. Test-Fuchs developed this universal test system for all hydraulic aircraft brakes that are currently on the market with specialist assistance from customer engineering and workshop staff.

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Web: www.test-fuchs.com

**Go to online reader enquiry number 101**

# Tomography and measurement

Computed tomography (CT) can handle a wide range of measurement tasks. Frequently, the surveying of outer component structures is not the only point of interest. The geometry of inner structures, such as cooling channels inside turbine blades or bore holes in aluminum die-cast parts, can be a focal point. With the help of CT, the specified geometric dimensioning and tolerancing (GD&T) of inner structures can be inspected precisely where they occur in applications dealing with bore alignments or the residual wall thicknesses of hollow bodies.

The x-ray tube, the detector, and the manipulator must be attuned to the application to obtain optimum measurement results. Industrial deployment has shown that the combination of an x-ray source with a variable focal spot and a 16bit flat-panel detector is best suited to meet multifaceted challenges, and supplies the most accurate measurement results. Depending on the specification involved, Yxlon uses its microfocus tubes or its sealed variofocus tubes in this sector.

The variofocus tube has an output of 250W at an effective focal-spot size of approximately 80µm, whereby the focal spot can be adjusted variably to adapt to the inspection task. Magnifications that cover a large number of industrial applications are possible. At an output of up to 1,600W, the variofocus tube scans at the greatest possible speed using the variably adaptable focal spot mentioned above, yet without having increased image noise impair the quality of the data and thus the resulting GD&T measurement results. In contrast, microfocus tubes with multifocus technology (MFT) are predominantly employed for applications that demand a much higher resolution. The gap between the microfocus tube and conventional x-ray tubes has been closed through the evolution of microfocus technology on the one hand, and the development of variofocus technology on the other.

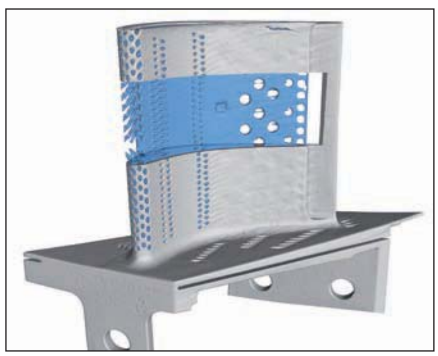
When sharp image quality is called for, the flat-panel detector plays a role in CT alongside the x-ray tube. The flat-panel detector used fulfills all the requirements necessary for obtaining exact measurements. In addition to 16bit technology as standard and large areas for gray scale or contrast, the detector has a highly dynamic radioscopic range that gives metrological precision and high-detail detectability. This is vital for measurement tasks in the field of CT because the thickest spots and the thinnest areas of a given inspection item must lie within the scope of dynamics for each projection.

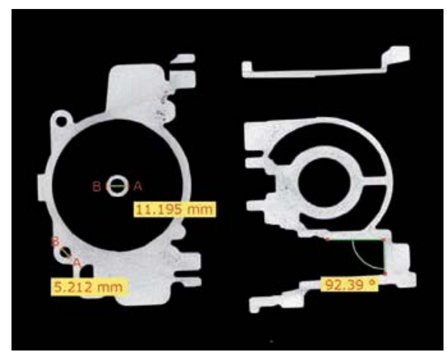
Together with CT software, computers equipped with a constantly growing output, and high-performance graphic cards enable a reconstruction of three-dimensional datasets within 3-15 minutes for all typical applications.

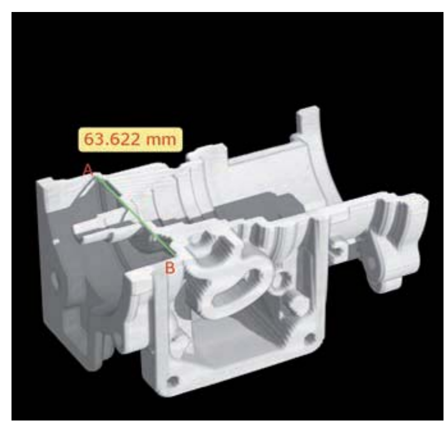
## X-ray inspection

Turbine blades are complex manufactured parts that need x-ray technology for inspection. The push for greater turbine efficiency means that turbine blades are exposed to constantly increasing turbine inflow temperatures. The result is that better cooling is required. Pores in welded-on material, foreign substances in the cooling channels, or incorrectly executed bores (such as boring into the rear wall) can be detected in turbine blades using x-ray inspection. For instance, the wide range of gray-scale dynamics displayed by digital detectors enable pores in welded-on material to be recognized with a single x-ray inspection of the turbine blade.

A measurement of turbine blade wall thickness using ultrasonic technology is nearly impossible due to the turbulators or inner walls existing inside. This is where the advantages of x-ray based CT come to bear in turbine blade inspection: CT enables a no-contact, reproducible measurement of all structures with high accuracy.



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yxlon@hbg.yxlon.com

**Go to online reader enquiry number 102**

# Avionics system for Turkey

EMC Partner has delivered the 60th avionics test system to a Turkish customer. EMC Partner supplies indirect lightning test systems, with systems already operating in most European countries, Korea, China, Japan, the USA, and Canada.

The company designs and manufactures indirect lightning test systems for avionics fitted to many platforms already in service around the world. It is especially proud to be associated with the Boeing 787 and Airbus A400M programs that recently completed successful maiden flights.

In addition to indirect lightning requirements in RTCA DO160 and EUROCAE ED14, the entire system is flexible enough to meet all airframe manufacturer's specific needs. The company's flexibility is demonstrated by the forthcoming introduction of the DO160 version G, which will include waveform 6H for the first time. Waveform 6H is a multiple-burst current impulse system used to test low impedance cables of short length. EMC Partner's indirect lightning test equipment customers are already equipped to meet this new challenge.

Further development of the system, based on customer requests, has led the company to design cable induction clamps for the injection of current and voltage impulses into cable bundles of up to 60mm diameter.

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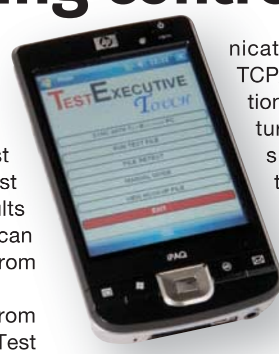
Email: sales@emc-partner.ch
www.emc-partner.com
or go to online enquiry card 103

# Handheld wiring control




DIT-MCO International's TestExecutive TouchTest is a handheld pocket computer that gives test technicians the freedom to move around, under, and inside the unit under test (UUT). TouchTest enables remote control of the DIT-MCO host PC. Operators can run tests and view results immediately to fix problems. A technician can work independently at a greater distance from the test system.

Just about anything technicians do from their desktop, they can do from the TouchTest handheld. For example, they can use its touchscreen to select test files on the host computer. TouchTest also means users can switch from automatic to manual control mode to take full control of the test system to facilitate fault locations, repairs, and other tasks. It communicates to the PC through TCP/IP over a WiFi connection. The mobile device features a 480 x 640 touchscreen. Users scroll through menus and select test system operations on its easy-to-read graphical interface.

**For further information contact**
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Email: infolink@ditmco.com
Web: www.ditmco.com
or go to online enquiry card 104

# Video and optical inspection

InterTest has provided RVI tools and NDT equipment to a wide range of customers. In the RVI market, the company specializes in video and optical inspection under white, ultraviolet, and infrared light. RVI tools enable users to see flaws in hidden and hazardous places unseen with the naked eye. InterTest manufactures an extensive line of RVI equipment, from borescopes, video probes, UV video systems, and light sources to robotic camera integrations and custom-engineered designs. The company's trained technicians are also available to perform application consulting and field service.

In the NDT area, InterTest specializes in ultrasonic, eddy current, fluorescent penetrant, and magnetic p requirements. With article inspection, penetrative and magnetic particle-inspection techniques identify surface flaws with fluorescing particles that are drawn by capillary action or magnetization to the flaws. The company provides custom-engineered solutions based on these technologies, and performs the system integration and automation required to make them viable and effective in specialized applications.

**For further information contact**
InterTest, Tel: +1 908 496 8008
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www.intertest.com
or go to online enquiry card 105

# Technology for low-speed wind tunnels

RUAG has developed, manufactured, and operated precise six-component strain gauge balances. Based on this experience, a second block-type balance family was developed with substantially higher stiffness and increased specific load capacities. The compact design can be used inside models with limited space or in dynamic applications where low deformations are required. Extensive tests during the development phase, calibration data, and applications in various wind tunnels confirm the high expectations of this new balance.

In close cooperation with other partners, RUAG plays a major role in the testing and development of the new counter-rotating technology for future aircraft. This technology, in combination with space limitations inside the nacelle, requires new measurement technology and substantially higher power than that provided by existing propulsion systems. RUAG pushed the hydraulic propulsor technology to develop compact rotary shaft balances for powered tests that provide six components with good accuracy and high repeatability. Signals from the balances and the blades are transmitted by telemetry systems.

The in-house software code for acquiring, processing, and displaying all the data on- and offline has been adapted to the new systems and the customers' needs. Close cooperation between all subsystems was necessary during the development and its integration into the test objects. Isolated testing of the propulsion system, as well as model testing, have been carried out on a timely and cost-efficient basis, providing reliable results.

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6032 Emmen, Switzerland
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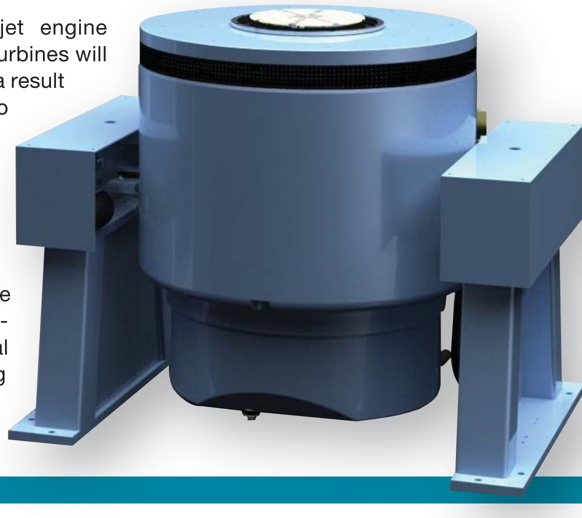
# System steps out of the envelope



In the not to distant future, jet engine compressors and high-pressure turbines will rotate at much higher speeds. As a result of this fact, vibration testing to frequencies beyond 4KHz will be system required. These high frequencies can be achieved using the Model T208 IAR-Series vibration test system from Unholtz-Dickie Corporation.

Major components include the T208 IAR shaker, featuring an ultra-rugged 9.38in (238mm) solid metal induct-a-ring armature, weighing 31 lb (14kg), a bare table resonance of 5,700Hz, and a force rating of 3,000 lbf (13.3kN). The SAI-Series power amplifier also incorporates reliable IGBT output circuitry, capable of delivering high peak currents and voltages necessary at high frequencies. Also included with the system is the Vwin II vibration controller, with an optimized sine control algorithm for sweeping and phase track-dwell control.

**For further information contact**
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E-mail: info@udco.com
**or go to online enquiry card 107**



# Comfort and flexibility for application interface

AIM, an industry supplier of advanced test and simulation modules and databus test and analysis software, has launched an Object Oriented C++ application interface with comfort and flexibility for application programmers.

The Standard API functionality has been encapsulated in C++ classes with well-defined default settings. When creating an object of any kind, only the non-standard parameters need to be explicitly set up by the user. It is still possible to access the full API features and to apply all parameters because the object members are accessible through corresponding 'set' and 'get' methods.

The AIM Class Library (ACL) is designed to work under Windows and Linux, and includes provisions to easily adapt it to other operating systems. The ACL is designed to support as many C++ compilers as possible. If the current implementation of an ACL class does not match the programmer's requirements, it is still possible to use those as a baseline to create customized subclasses.

The AIM Class Library (ACL) will become part of the future MIL-STD-1553 Board Software Packages (BSP).

**For further information contact**
AIM GmbH
Email: info@aim-online.com
**or go to online enquiry card 108**

# Precision sensors for test and measurement

Honeywell offers expert thinking, extensive technology resources, and over 50 years experience to help address the highly demanding test and measurement challenges within the aerospace arena. The company's global design, engineering, and manufacturing expertise means fast delivery for both off the shelf or custom-engineered solutions to meet specific customer requirements.

The company also offers a wide portfolio of precision, fatigue-rated sensors for many extreme environments and/or tight places and engineered for enhanced precision, repeatability, and ruggedness. Its test and measurement product line includes: pressure transducers; miniature pressure transducers; load cells; miniature load cells; torque transducers; displacement sensors; accelerometers; wireless telemetry, and test instrumentation. Potential aerospace test and measurement applications include: Force/pressure for flight and ground-testing applications; airframe/structural, hydraulics and fuel systems testing; ground-support testing; jet engine turbine stress, temperature, vibration monitoring; pressure testing in actuators and engines, and propulsion monitoring for torque, temperature, speed, power monitoring of rotating propeller shafts.

Honeywell also offers electromechanical and sensor systems, from discrete components to pilot interface and controls. Products include: RVDT, LVDT, resolver, synchro, potentiometer, and switches as the standard sensing elements. No matter if your needs are large or small, if you need a standard product or a fully custom design, look to Honeywell for solutions.

For further information contact
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Sensors for Test and Measurement,
Tel: +1 614 850 5000;
Fax: +1 614 850 1111;
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Web: www.honeywell.com/sensotec
or go to online enquiry card 109

# Give a boost to automation

The Morphee 2 system for the automation of several testbed types has been developed by D2T. The system covers the writing and the execution of simple or complex tests, and the acquisition of measurements. It is distributed on more than 2,500 testbeds throughout the world, including aerospace applications for turbine research and durability testing, maintenance routines, and other applications.

D2T always opts for the most open and dynamic standards on the market. Morphee 2 was the first automation system on the market based on Windows technology. This powerful system uses a market-standard real-time RTX kernel and evolves in step with the developments in PC (such as multicore) and Windows technology. It also uses an ultra-fast (10kHz) EtherCAT communications bus, which is currently considered to represent the future communications standard for testbeds. Its true potential is in its ability to implement simulation in the testbed, including the ability to execute MATLAB models in real time.

The user is also able to make online modifications while a test is running, which makes it possible to add a screen or an instrument, modify the value of a test safety, or make changes to future test points. The openness and flexibility of Morphee 2 permits a single control and data acquisition system for all testing applications. From component test rigs to new or refurbished testbeds, the company helps meet the high-speed/high-channel counts common to the aerospace industry.

For further information contact D2T
www.d2T.com
or go to online enquiry card 110

# Lightweight sensors

Modern lightweight materials are often used in aerospace applications and in other sectors, such as traffic and construction engineering, mechanical engineering, and the energy business. Fiber composite technology in particular is resulting in huge weight savings.

Fiber optic Bragg sensors and interrogators are also being used in the Business Jet Comp Air CA-12. The US company Comp Air commissioned Chandler Monitoring Systems Inc (CMS) for the system development, using interrogators, strain, and temperature sensors from HBM's technology partner Micron Optics Inc and optical transducers from Cleveland Electric Laboratories for the fire protection zone of the engine compartment.

The 10-person turboprop aircraft is the first aircraft to be built completely of composite materials. A prototype with installed strain and temperature sensors was tested in 2007. Once again, the company will be a trendsetter in aircraft construction – this is the first time a fiber-optic monitoring system will be used.

Due to its small dimensions, material conformity, and immunity against electromagnetic interference, fiber optic measurement technology is of particular importance in this area. The complexity of the entire measurement system can be reduced by transmitting the data for all connected measurement points at the same time through one thin waveguide, resulting in increased stability and availability. Fraunhofer Institute uses optical sensors on composite material. The illustrations show a bearing surface section for feasibility testing of a prototype test carrier (a VLA, very light aircraft.

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FROM MAY 2010, BASIC FRENCH MILITARY HELICOPTER FLIGHT TRAINING WILL BE TAKEN OVER BY A PRIVATE COMPANY. DAVID OLIVER LOOKS AT THE SPIN

BY DAVID OLIVER

HeliDax, co-owned by Défense Conseil International and Proteus Helicopters, was selected by the French Ministry of Defense (DGA) in 2007 for a PFI contract to provide all basic helicopter training for the French armed services, army, air force, navy, and the gendarmerie. The contract, which is the first French PFI, requires HeliDax to provide up to 22,000 outsourced helicopter flight hours over the next two decades on a fleet of new helicopters. The flights will be at the École d'Application de l'Aviation Légère de l'Armée de Terre (EA-ALAT) in Dax in southwest France.

The helicopter HeliDax selected to replace the ALAT's veteran Aerospatiale SA 341 Gazelle helicopters, which have been in service for over three decades and are becoming expensive to operate and maintain, is the Eurocopter EC 130B Colibri. Originally developed as a collaborative program between Eurocopter, China National Aero-Technology Import and Export Corporation (CATIC), and Singapore Technologies Aerospace (STA), the single-engine five-seat helicopter first flew in 1995. The new generation benefits from the latest helicopter technologies including a quiet Fenestron tail rotor and a vibration-free Spheriflex main rotor

# The French training revolution

head. Powered by a single fuel-efficient 500shp (376kW) Turbomeca Arrius 2F turboshaft engine, its ergonomic cockpit is equipped with a digital flat-screen Sextant Avionique/SFIM vehicle and engine multifunction display (VEMD), which provides optimal operational efficiency and safety. The EC 120B also has dual controls, a twist-grip throttle, and rotor brake. The VEMD shows the first limitation indicator for torque, engine rpm, and temperature, making it a good platform for flight training. To date, the type has been adopted in the military flight training role by China, Indonesia, Portugal, Spain, and Singapore.

For the French contract, HeliDax is responsible for the acquisition of 30 EC 120B helicopters, with an option for an additional six aircraft, and their through-life maintenance and repair. It also has the responsibility for the fitting of a glass cockpit and avionics better suited for the instruction of student pilots for future helicopter types currently entering service with the French armed forces, such as the Caracal combat search and rescue (CSAR) helicopter, the Tiger combat helicopter, and the NH90 tactical transport helicopter (TTH).

The EC 130 Nouvel Hélicoptère École (NHE) is being equipped with SAGAM integrated cockpit display system (ICDS), a PA 85 autopilot, ETC Industries Brite Saver usage monitoring system (UMS), GPS, NVG-compatible lighting, and new radios. Depending on the configuration, the ICDS can function as a multifunction display (MFD), primary flight display (PFD), engine monitoring system (EMS), navigation display (MD), or a combination of all four. ICDS displays information in alphanumeric text and graphic formats to provide enhanced situational awareness, increased flight safety and efficiency, and a reduced pilot workload. The AP 85 is a full-time autopilot with full-time stability augmentation (SAS). The pilot turns it on before take-off and turns it off after landing. Standard upper modes are altitude hold, airspeed hold, and heading select, with GPS couple as an optional mode.

**"For the French contract, HeliDax is responsible for the acquisition of 30 EC 120B helicopters"**

When the new helicopters are delivered from Eurocopter, the cockpits are stripped out by HeliDax's certified engineers. Two EC 120s are modified every five weeks, including the fitting of formation lights and cowlings, all under a supplemental type-certificate (STC) procedure. They are then test flown by HeliDax's chief pilot, Louis Fauquembergue, a very experienced former EA-ALAT instructor.

Some 50 maintenance staff have been undergoing training with Eurocopter at Mari-

After the ferry flight from the factory, the EC 120B cockpit is stripped out (below)

Newly delivered EC 120Bs about to undergo modification in the HeliDax hangar (opposite page)

HeliDax engineers fitting a new glass cockpit to the Colibri and glass cockpit (far right)

(All photos courtesy David Oliver)

gnane, initially to man one of two parallel maintenance lines at Dax – one for the reducing numbers of Gazelles and the other for the rising number of Colibris. Under the supervision of technical director Joel Baudon, the HeliDax staff will work alongside ALAT technicians until the Gazelle is phased out in January 2011.

HeliDax is also a maintenance and offshore operator with Part FR145 EASA maintenance organization approval and is contracted to maintain emergency medical service (EMS) AgustaWestland AW109 helicopters operated by Proteus Helicopters, a subsidiary of the Spanish INAER Group based at Dreux.

Overseeing operations at Dax is HeliDax's deputy general manager Jacques Vian, a former ALAT colonel who worked with Eurocopter on the French Army's NH90 TTH acquisition program.

A year after the first EC 120B Colibri was delivered to HeliDax in October 2008, the first army and air force EA-ALAT instructors commenced a conversion course to the modified NHE helicopters, which comprised two hours ground school and 6.5 flying hours. By May 2010, half the HeliDax fleet is scheduled to be available for the first EC 120B student pilot course, and the rundown of the fleet of 50 AS 341 Gazelles being replaced should have begun. HeliDax is an EASA flight training organization (FTO) staffed, equipped, and operated in a suitable environment, offering approved flying training and theoretical knowledge instruction for specific helicopter flight training programs.

**"One hundred students per year will enter flying training at EA-ALAT on a new Colibri syllabus"**

One hundred students per year will enter flying training at EA-ALAT on a new Colibri syllabus devised by the school's QHIs. The training comprises 100 flying hours plus 35 simulator hours. Initially, the latter will take place on legacy Gazelle simulators, although Lt Col Eric Merck, the head of simulation for the French army, has begun the acquisition process for EC 120B simulators, the first of which will be delivered in 2011. Under the EU common military training program, implemented in 2008, the EA-ALAT at Dax will also begin to receive a number of rotary wing trainees in the near future from Germany and the Netherlands in addition to those from France and Belgium.

Wearing their distinctive high-visibility red and white color scheme, the EC 120Bs will retain their civil registrations and civilian callsigns while flying in a designated military training zone that stretches from Dax airfield to the French coast north of Biarritz. ∎


# Hans von Ohain's gas turbine-driven centrifugal flow jet propulsion engine

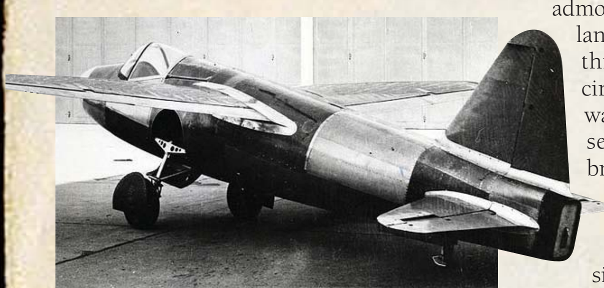
BY FRANK MILLARD

Hans Joachim Pabst von Ohain, born in Dessau, Germany on December 14, 1911, is recognized as one of the joint inventors of the aircraft jet engine. Although his engine design was penned later than Sir Frank Whittle's patent, he got his design into the air earlier. In 1935 Von Ohain was awarded a PhD in physics and aerodynamics from the University of Göttingen, where he created a plan for a propeller-less engine.

After receiving his doctorate, von Ohain chose to remain at the university's Physical Institute assisting its director Robert Pohl and in 1936 he patented his own jet engine design. Von Ohain's engine employed a centrifugal compressor and turbine placed back-to-back. A model of the engine was produced by auto-engineer Max Hahn and tested at the university. Combustion was the main problem encountered. The fuel had a tendency to burn outside of the flame cans, blowing through the turbine and overheating the electric motor that powered the compressor.

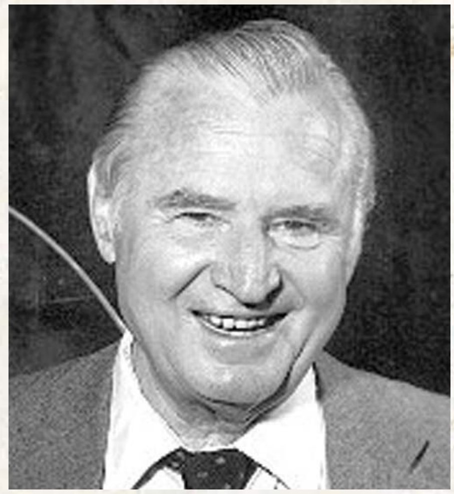
In February 1936, Ernst Heinkel arranged for his engineers to meet with von Ohain to discuss his work. Convinced of the potential of the invention, Heinkel gave von Ohain workshop space at the Marienhe airfield, Rostock. With improvements to the airflow, von Ohain's engine started to take shape as a workable model, and provided the basis for a new engine incorporating all of the changes that von Ohain had made, but was now fuelled by hydrogen gas. Gasoline was also experimented with because combustion problems had continued to plague the engine, but the fuel clogged the combustors. In 1937, a new engine was designed to accommodate the new fuel, which provided the basis of a flight-quality design – the HeS 3. The upgraded design featured a rearrangement of the engine that reduced its width and used machined compressor and turbine stages with the flame cans positioned between the compressor and the turbine. This was later amended by moving the cans to the compressor's outer rim and guiding compressed air toward the combustion chambers, the heated air flowing back into the turbine inlet. This became the HeS 3b. This engine, the first fully operational centrifugal-flow turbojet engine, first ran in the early summer of 1939 and was tested in the air shortly afterward. On August 27, 1939 the He 178 became the first jet-powered aircraft to fly.

The single-engine experimental aircraft was designed as a shoulder-winged monoplane of light metal construction, with a jet intake through the nose and 1,100 lb of thrust. Test pilot Erich Warsitz, who had recently piloted the first rocket-powered aircraft, reflected that when the He 178 first flew, it was recognized that by virtue of its longer flight endurance and greater operational reliability "it was the jet, and not the rocket aircraft, which belonged to the future". Warsitz later described the flight itself: "The first flight with pure jet drive was made on August 27, 1939. The aircraft began to roll straight and level and then quickly picked up a very fast speed. I took her up, banked left, noticed that the surface pressures were not quite normal, the machine was hanging a little to the left but I kept her trimmed with stick and rudder, she was yawing a little. I had flown a large circuit of the airfield, and though admonished to fly one circuit only and then land, naturally after getting the feel of the thing I flew faster and made a second circuit. Below me I could see everybody waving. I told myself as I completed the second circuit, 'OK, finish off!' and brought her in, bringing the machine to a stop a meter before where Heinkel and his staff were standing."



The He 178 and, above right, Hans von Ohain

After improvements, a new version, the He S.8A, was flight tested on April 2, 1941. However, the first operational jet fighter aircraft was not a Heinkel with an



engine built by von Ohain, but the more efficient Me 262 designed by Anselm Franz. Indeed, by mid-1937, von Ohain was not the only German engineer working on jet propulsion. Herbert Wagner and Max Adolph Muller of Junkers, and Helmut Schelp of the air ministry, started working on their own designs, but came to the conclusion that for ease of flow through the engine and lower drag, an axial-flow compressor was preferable to a centrifugal-flow unit. Commentators have pointed out that unlike in the UK where Whittle's design gathered dust for years, the German military committed funds toward the development of jet-propelled combat aircraft prior even to the first successful jet-powered flight.

British test pilot Eric (Winkle) Brown recalls that, although German axial-flow engines were superior to the British turbo-jet engines, "their complexity caused production problems and a lack of strategic metals to withstand the inherent heat stresses meant that their early operational turbojets had a scrap life of only 25 hours". However, Brown continues: "In 1944, two jet aircraft became operational – the twin-axial-flow-engined Ar 234B photo-reconnaissance bomber and the twin-axial-flow-engined Me 262 fighter-bomber. They were the most formidable aircraft of World War II – at least 100mph faster than any contemporary aircraft." The jet-powered combat aircraft had come of age. ∎

MAGNIFICENT MEN

and their flying machines